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ORIGINAL ARTICLE

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The effect of virtual reality on postoperative anxiety and pain in patients following cardiac surgery: a randomized controlled trial

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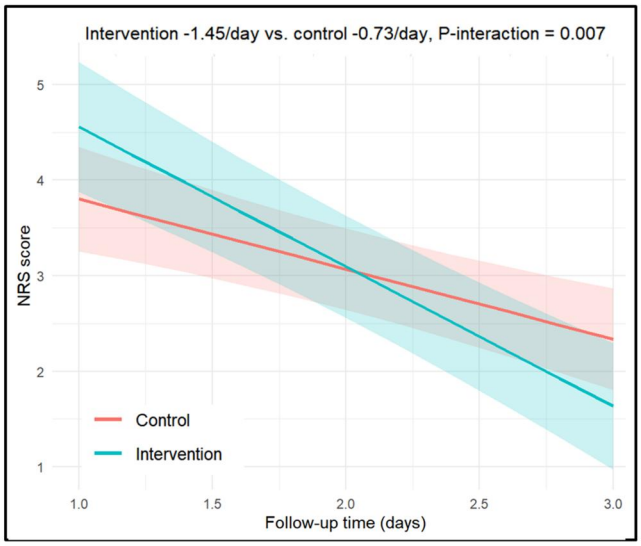
The effect of virtual reality distraction therapy on postoperative pain and anxiety in patients following cardiac surgery: a randomized controlled trial.

Summary

The VRECOVERY trial is an RCT that investigated the effect of virtual reality (VR) distraction therapy on postoperative pain and anxiety in patients that underwent coronary artery bypass surgery.

Among 192 participants, **VR significantly reduced postoperative pain (NRS scores: -1.45/day vs. -0.73/day, *p*=0.007).** The effect on anxiety was not significant (STAI-6 scores -0.60/day vs. +0.09/day, *p*=0.06).



Legend: NRS; Numeric Rating Scale, RCT; Randomized controlled trial, STAI; State Trait Anxiety Inventory 6, VR; virtual reality.

Abstract

OBJECTIVES: The VRECOVERY investigated the impact of virtual reality (VR) distraction therapy on postoperative pain, anxiety and quality of recovery in patients undergoing coronary artery bypass grafting surgery.

METHODS: A single-centre randomized controlled trial was conducted involving 192 participants, allocated to either the intervention or control group. Participants in the intervention group received VR distraction therapy on postoperative days 1, 2 and 3, while the control

group received standard postoperative care. Primary outcomes were measured in both groups directly following the VR sessions of the intervention group. Outcomes included (i) postoperative pain [Numeric Rating Scale (NRS)], (ii) postoperative anxiety [State Trait Anxiety Inventory 6 questionnaire (STAI-6)] and (iii) quality of postoperative recovery [Quality of Recovery 15 questionnaire (QoR-15)].

RESULTS: A total of 100 participants completed the study, including 39 patients (mean age 69.1 ± 7.7 years) in the intervention group and 61 patients (mean age 66.8 ± 8.2 years) in the control group. Eighty-nine percent of participants was male. VR-distraction therapy demonstrated a significant difference in postoperative pain decrease between groups (NRS score; intervention group −1.45/day vs control group −0.73/day, $P = 0.007$), and an important overall difference in postoperative anxiety slopes (STAI-6 score; intervention group −0.60/day vs control group +0.09/day, $P = 0.06$). There was no effect observed on postoperative quality of recovery ($P = 0.11$).

CONCLUSIONS: The VRECOVERY trial suggests a beneficial impact of VR distraction therapy in reducing postoperative pain. There was no significant effect on postoperative anxiety and quality of recovery.

Keywords: Virtual reality • Cardiac surgery • Postoperative pain • Postoperative anxiety • Coronary artery bypass grafting

ABBREVIATIONS

CABG	Coronary artery bypass grafting
VR	Virtual reality
3D	Three dimensional
RCT	Randomized controlled trial
QoR-15	Quality of Recovery 15
ICU	Intensive care unit
HMD	Head-mounted display
LMM	Linear mixed model
NRS	Numeric Rating Scale
STAI	State-Trait Anxiety Inventory
STAI-6	State Trait Anxiety Inventory 6

INTRODUCTION

Postoperative pain and anxiety are common side effects of cardiac surgery [1]. These phenomena arise from both the tissue damage incurred during surgery [2] and the psychological impact of undergoing surgery. Both postoperative pain and anxiety have been linked to adverse events, including delayed wound healing, extended hospitalization, risk of chronic pain and long-term psychological consequences [3]. Therefore, proper management of postoperative pain and anxiety is essential to optimize postoperative recovery.

The conventional approach to postoperative pain and anxiety management relies on medical therapy and pain education. However, given the documented side effects associated with medical therapy [4], integrating non-pharmacologic strategies into the treatment arsenal would offer a valuable complement to existing options. Virtual reality (VR) is a modern emerging technique that offers possibilities in the management of pain and anxiety by distraction therapy. This approach employs immersive 3-dimensional (3D) videos accompanied by soothing sounds, and guided breathing exercises [5]. By integrating immersive visual and auditory stimuli, VR constructs a captivating and tranquil environment, redirecting patients' focus away from the pain and anxiety-provoking aspects of the clinical reality [6].

The literature indicates that the impact of VR distraction therapy on postoperative pain and anxiety remains unclear, with several studies reporting both positive outcomes and non-significant results [1, 7]. Therefore, we performed the VRECOVERY trial to investigate the effect of VR distraction therapy on postoperative pain and anxiety patients following cardiac surgery, specifically in patients undergoing elective coronary artery bypass grafting (CABG) surgery via median sternotomy, as this procedure is the most commonly performed cardiac surgery worldwide annually [8].

Specifically, this study seeks to address 3 key questions: (i) Does VR distraction therapy effectively manage postoperative pain following CABG? (ii) Is VR distraction therapy effective in alleviating postoperative anxiety following CABG? and (iii) Does VR distraction therapy facilitate accelerated postoperative recovery?

Methods

The VRECOVERY trial is a single-centre randomized controlled trial (RCT) at the Department of Cardiothoracic Surgery of the Amsterdam University Medical Center (AmsterdamUMC). The study included 192 participants that underwent CABG surgery between December 2022 and January 2024.

Ethics approval

This study adhered to the principles of the Declaration of Helsinki (2013 version, Fortaleza, Brazil) and complied with the regulations of the Medical Research Involving Human Subjects Act. Study approval was obtained from the Medical Ethics Committee of the AmsterdamUMC under reference number 2022.005-NL79616.018.21. The study was registered on ClinicalTrials.gov (identity number NCT06001502).

Inclusion and exclusion criteria

Patients were required to meet specific inclusion criteria including undergoing CABG surgery via median sternotomy, being at least 18 years old, and providing signed informed consent (Supplementary Material, A1). Exclusion criteria encompassed major comorbidities, hearing/visual impairment, psychiatric disorders, vomiting/nausea, epilepsy, claustrophobia, facial wounds, clinical isolation, prolonged stay at the intensive care unit (ICU) and postoperative ICU readmission.

Randomization and blinding

Randomization to either the intervention or control group was conducted using Castor EDC (https://data.castoredc.com/), employing a 1:1 allocation ratio with blocks of 4 participants. This allocation was done by the researchers after patients were admitted to the preoperative ward. By randomizing patients before surgery, we allowed participants in the intervention group

to become familiar with the VR device beforehand, reducing the likelihood of VR-induced delirium in the perioperative setting. Due to the nature of using a physical device, blinding of either patients or researchers was not feasible.

Intervention

The intervention entailed VR distraction therapy, provided by Healthy Mind™ (https://healthymind.fr/). This setup comprises a head-mounted display (HMD) for immersive visuals, headphones for audio, and a tablet for controlling VR sessions. Participants in the intervention group underwent one 20-min sessions of VR-distraction therapy per day with this setup, at a set time point in the afternoon. Additionally, patients in the intervention group also followed the standard postoperative pain and anxiety management protocols.

Participants were presented with a choice of 6 different digital environments for each VR session (Fig. 1A). All environments featured serene natural scenery accompanied by calming music and guided meditation. Furthermore, deep breathing exercises were integrated into the virtual environments (Fig. 1B), starting halfway through the 20-min VR session. These exercises were tailored in duration and frequency based on cardiac surgery specific postoperative guidelines [9].

All intervention group patients underwent a VR distraction therapy session on postoperative days 1, 2 and 3. Subsequent to each session, participants rated their postoperative pain on the numeric rating scale (NRS), postoperative anxiety by the Spielberger's State Trait Anxiety Inventory 6 (STAI-6) questionnaire and complete the quality of recovery 15 (QoR-15) to assess the quality of postoperative recovery. The control group received conventional management for pain and anxiety and also completed the same questionnaires at corresponding time points during the same day as the intervention group. An overview of the study design is shown in Fig. 2.

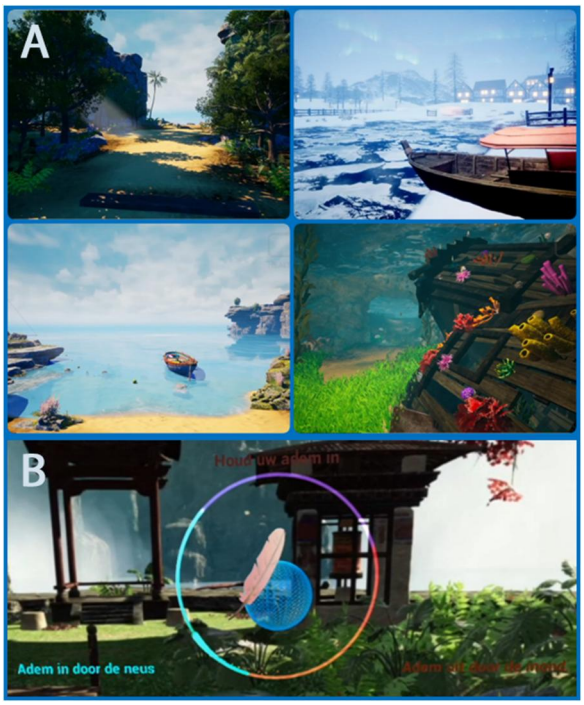


Figure 1: (**A**) Screenshots from different virtual environments used in the virtual reality distraction therapy system. (**B**) The guided breathing exercise.

Study outcomes

Primary outcomes were (i) postoperative pain assessed by the NRS, (ii) postoperative anxiety measured by the STAI-6 and (iii) postoperative quality of recovery evaluated through the QoR-15. These outcomes were assessed on postoperative days 1, 2 and 3, during the afternoon, following the daily session of VR distraction therapy.

Numeric rating scale. The NRS (Supplementary Material, B) is a validated tool for quantifying postoperative pain [10]. This scale prompts patients to assess the intensity of their pain with a score from 0 to 10. A rating of 0 signifies the absence of pain, while a score of 10 represents the utmost level of pain.

State trait anxiety inventory-6. Spielberger's STAI questionnaire is an instrument to assess clinical anxiety [11]. Its original version comprises an extensive length (40 questions) and inclusion of some irrelevant aspects for the postoperative context. Therefore, our study adopted the STAI-6 (Supplementary Material, C), a condensed validated version, comprising only 6 items, distilled from the original 40-item questionnaire [11]. Participants rate each item on a scale from 'Not at All' to 'Very Much', assigning scores ranging from 1 to 4 to their responses. The summation of these scores across all 6 items yields the total score, with a maximum achievable score of 24.

Quality of recovery-15. The QoR-15 (Supplementary Material, D) is a validated questionnaire comprising 15 items designed to evaluate the quality of recovery following surgery [12]. Its design encompasses the evaluation of pain, physical comfort, physical independence, psychological support and emotional state. Each item encapsulates a unique facet of the recovery process, enabling respondents to provide ratings on a scale ranging from 0 to 10. In this scale, a score of 0 signifies 'No' or 'Never', while a score of 10 denotes 'Yes' or 'Always'. The total score is determined by summing all responses. Notably, higher total scores correspond to heightened levels of quality of recovery. In this study, we used a modified version of the QoR-15 by leaving out 3 questions which were overlapping with the STAI-6 items, therefore the maximum achievable score on our scale was 120 instead of the original 150.

Statistical analysis

Sample size calculation was conducted based solely on the NRS pain score, as there was a lack of literature to inform calculations using the STAI-6 and QoR-15 questionnaires. With a significance level set at 0.05, a power of 0.80, and assuming a correlation of 0.6 between repeated measures within 2 groups, each comprising 50 patients, the study can detect an effect size of 0.42. As the primary outcome was a questionnaire, which is missing after dropout, only per-protocol analyses were performed. Descriptive statistics were used to present categorical data, by use of frequency tables. Normally distributed continuous data are presented as a mean with standard deviation and non-normally distributed continuous data are presented as a median with interquartile range. Data were

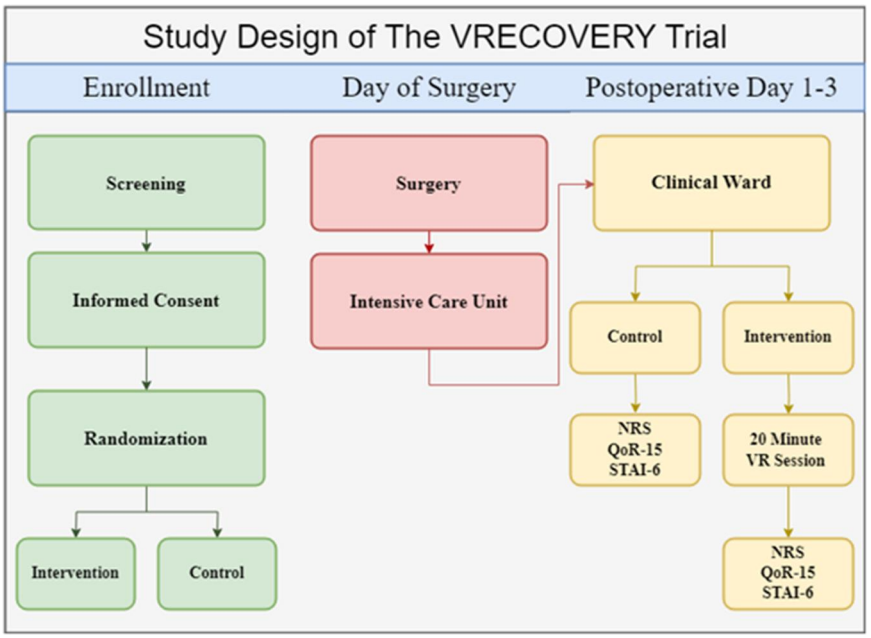


Figure 2: Study design of the VRECOVERY trial. Abbreviations: NRS: numeric rating scale; VR: virtual reality; QoR-15: quality-of-recovery-15 questionnaire; STAI-6: state trait anxiety inventory 6.

tested for normality by use of Q–Q plots. If inconclusive, a Shapiro–Wilk test was performed. Wilcoxon-rank sum tests were performed to investigate point-estimates of scores at different timepoints.

Linear mixed effect models. A linear mixed model (LMM) regression model with fixed effect time, intervention group and their interaction term was developed to investigate differences in score decrease/increase over time between groups. Random intercepts for patients and random slope for time were incorporated to account for possible clustering of data within subjects. The fit with and without random slope over time was assessed using AIC and BIC. Final model specification is shown in Supplementary Material, E. Normality of the residuals was visualized using Q–Q plots and shown in Supplementary Material, F. In case of considerable deviation of normality, the outcome was transformed. All statistical analyses were performed using IBM SPSS Statistics 28 (SPSS, Inc., Chicago, IL, USA) and R (Version, 4.4.0, Vienna, Austria). Results were considered statistically significant when $P < 0.05$.

RESULTS

A total of 245 individuals were eligible for participation in the VRECOVERY trial, of which 53 participants declined participation. Subsequently, 192 patients were randomly assigned to either the intervention or control group, with each group comprising 96 patients. In the intervention arm, 57 out of 96 participants discontinued their involvement, leaving 39 individuals to complete the study. The reasons for dropout in this group were refusal to continue participation in VR distraction therapy sessions ($n = 24$), prolonged ICU stay ($n = 19$), reoperation at day 1 after surgery ($n = 3$), postoperative delirium ($n = 4$), missing measurements due to logistic issues ($n = 6$) and 1 patient did not undergo surgery after inclusion (Fig. 3). The specific reasons for refusing further participation in the intervention group included the following: 15 patients felt that they did not have the capacity for a VR session during the focus on their clinical recovery after surgery, 6 participants experienced nausea from the VR sessions and 3 patients found the VR device uncomfortable to wear. In the control arm, 35 patients withdrew from the study, resulting in 61 controls completing the study. The primary reasons for dropout in the control group were prolonged ICU stay ($n = 15$), refusal of further participation ($n = 5$), reoperation at day 1 after surgery ($n = 5$), postoperative delirium ($n = 2$), replacement of thoracic drains due to pleural effusion ($n = 2$) and 6 missing measurements due to logistical challenges.

Eventually, a total of 100 patients completed the study, with 61 individuals randomized into the control group (mean age 66.8 ± 8.2 years) and 39 into the intervention group (mean age 69.1 ± 7.7 years). The majority of participants was male, accounting for 89% of the total sample. There were no considerable differences in baseline characteristics between the groups (Table 1).

Postoperative pain

On postoperative day 1, the intervention group exhibited median NRS pain scores 5.0 (3.5; 7.0) versus 4.0 (2.0; 5.0) in the control group ($P = 0.06$) (Fig. 4A). By day 2, the intervention group demonstrated a relatively greater reduction in pain scores, resulting in equivalent median scores for both groups [3.0 (2.0; 3.5) vs 3.0 (2.0; 5.0), $P = 0.64$]. On postoperative day 3, the intervention group maintained a more pronounced decrease in pain, compared to the control group [1.0 (0; 3.0) vs 2.0 (1.0; 4.0), $P = 0.23$]. LMM analyses revealed a statistically significant difference in the rate of pain score reduction over time between the groups (Fig. 4B). The postoperative pain scores declined by 1.45 points per day in the intervention group, compared to a decrease of 0.72 points per day in the control group ($P = 0.007$). These findings indicate a substantial impact of VR distraction therapy on postoperative pain reduction compared to conventional treatment.

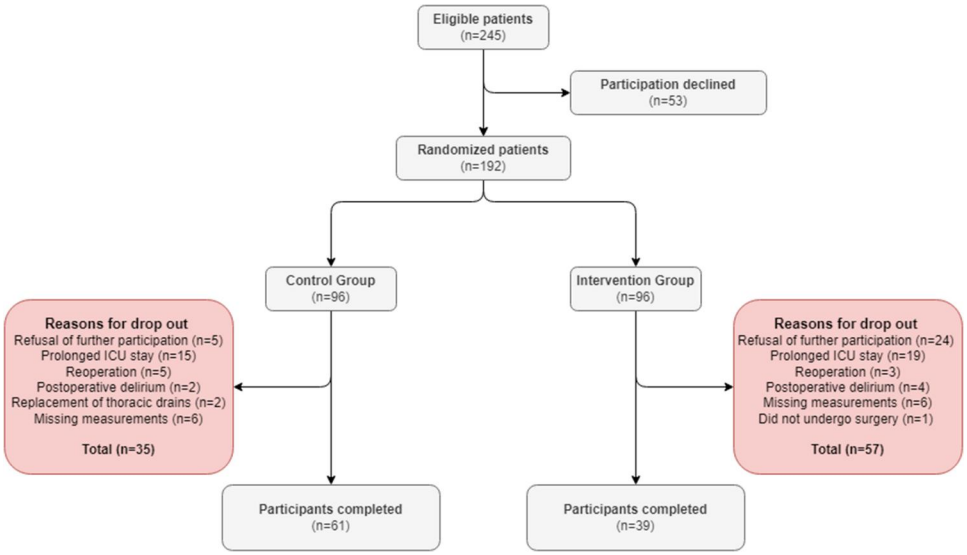


Figure 3: Participants flowchart. Abbreviation: ICU, intensive care unit.

Table 1: Baseline characteristics

Characteristics	Total	Intervention	Control
Participants, *n*	100	39	61
Sex: male, *n*	89	35 (90)	54 (88)
Age, mean (SD)	67.65 ± 8.02	69.05 ± 7.66	66.75 ± 8.18
BMI, mean (SD)	27.13 ± 3.05	27.16 ± 3.13	27.12 ± 0.03
Active smokers, *n*	15	5 (13)	10 (16)
Alcohol use, *n*	64	26 (67)	38 (62)
Hypertension, *n*	50	21 (54)	29 (48)
Diabetes mellitus, *n*	26	11 (28)	15 (25)
COPD, *n*	4	1 (3)	3 (5)
Asthma, *n*	8	1 (3)	7 (11)
Atrial fibrillation, *n*	12	2 (5)	10 (16)

Abbreviations: BMI: body mass index; COPD: chronic obstructive pulmonary disease; SD: standard deviation.

Postoperative anxiety

STAI-6 scores at the first postoperative day were comparable between the intervention and control groups, awarding median scores of 7.0 (6.0; 10.0) and 8.0 (7.0; 10.0) ($P = 0.26$), respectively. On day 2, the intervention group showed slightly lower anxiety scores compared to the controls [7.0 (6.0; 8.0) vs 8.0 (6.0; 10.0), $P = 0.04$] (Fig. 2). By day 3, the intervention group continued to show a reduction in anxiety levels, while the control group's anxiety levels remained stable [6.0 (6.0; 8.0) vs 8.0 (6.0; 11.0), $P = 0.01$]. Overall, LMM analyses (Fig. 5B) revealed that patients in the intervention group demonstrated a decrease in log-transformed anxiety levels over time (−0.6 points per day), while patients in the control group showed a slight increase in postoperative anxiety (+0.09 points per day, $P = 0.06$).

Quality of postoperative recovery

On day 1 after surgery, QoR-15 scores between the intervention and control groups were comparable; reporting a median score of 90.0 (79.5; 107.5) in the intervention group and 94.0 (79.0; 102.0) in the control group ($P = 0.94$) (Fig. 6A). However, on day 2, scores between the groups began to diverge, with in the intervention group a median score of 107.0 (102.5; 115.0) vs 104.0 (95.0; 113.0) in the control group ($P = 0.14$). This trend continued on day 3, with the intervention group showing a median QoR-15 score of 116.0 (105.0; 125.0) and the control group demonstrating a median score of 109.0 (99.0; 120.0) ($P = 0.06$). Regardless of the specific postoperative day, LMM analyses (Fig. 6B) revealed that over all 3 measurements combined, patients in the intervention group had a slope of +11.5 points per day versus control group +8.3 points per day, this difference was non-significant ($P = 0.13$).

DISCUSSION

In this RCT, we investigated the impact of VR distraction therapy on postoperative pain and anxiety in patients undergoing CABG surgery. The key findings of our study can be outlined as follows: (i) VR distraction therapy demonstrated a significant higher decrease in postoperative pain levels, (ii) patients receiving VR distraction therapy exhibited a higher decrease in anxiety levels, with significantly lower point estimates at the last 2 days and (iii) lastly, VR distraction therapy did not demonstrate an effect on postoperative quality of recovery both on point estimates and level of increase over time.

Postoperative pain

This study demonstrated significant differences in postoperative pain over time between the intervention group and the control group in the first 3 days after surgery. Patients using VR distraction therapy experienced a 50% greater decrease (−1.45 vs 0.72) in postoperative pain compared to the control group. Established literature suggests that an NRS score change of 1.39 ± 1.05 (95% CI: 1.27–1.51) represents a clinically meaningful reduction in pain [13], underscoring the clinical relevance of our findings. The observation that the intervention group had higher pain scores on postoperative day 1, may be due to patients in

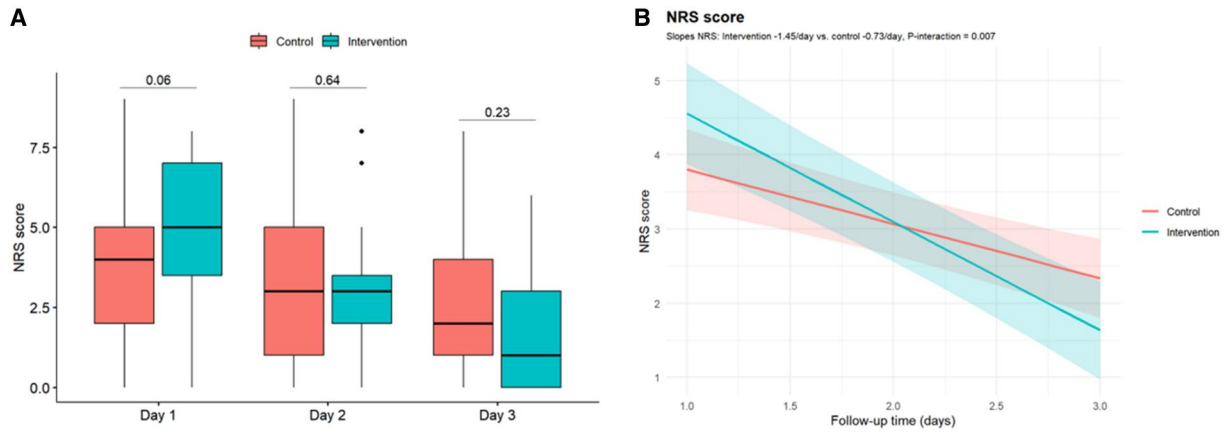


Figure 4: (**A**) Progression of postoperative pain as measured by the numeric rating scale (NRS) over postoperative days 1, 2 and 3. (**B**) The results of the linear mixed model analysis over all 3 measurements combined comparing the intervention and control group.

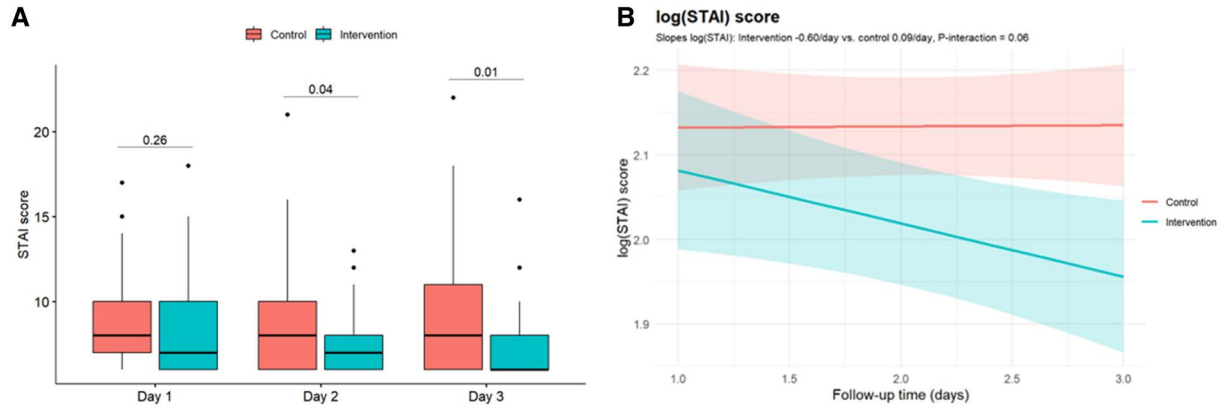


Figure 5: (**A**) Progression of postoperative anxiety as measured by state trait anxiety inventory 6 (STAI-6) scores over postoperative days 1, 2, and 3. (**B**) The results of the linear mixed model analysis over all 3 measurements combined comparing the intervention and control group.

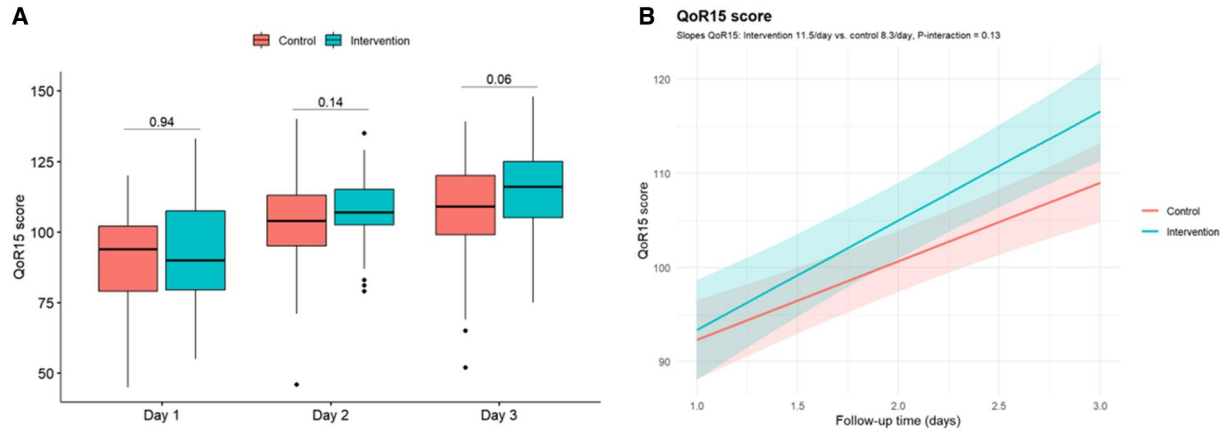


Figure 6: (**A**) Progression of postoperative quality of recovery 15 (QoR-15) scores over postoperative days 1, 2 and 3. (**B**) The results of the linear mixed model analysis over all 3 measurements combined comparing the intervention and control group.

the intervention group asking less for pain medication. However, since we did not collect data on analgesic administration, we cannot draw definitive conclusions regarding this observation.

Comparable results have been demonstrated by several previous studies [14–16], reporting a notable decrease in pain among the majority of participants using VR distraction therapy. Nonetheless, there are some methodological differences between these earlier studies and our trial; (i) most of these studies employed observational designs rather than RCTs, (ii) pain assessment in these studies relied on custom-made questionnaires instead of validated pain-specific measurement instruments like the NRS and (iii) their sample sizes were relatively modest

($n = 67$, $n = 22$ and $n = 60$, respectively). Therefore, to our best knowledge, the VRECOVERY trial is the largest and only prospective RCT performed so far comparing VR distraction therapy to conventional treatment after cardiac surgery.

Postoperative anxiety

VR distraction therapy was found to reduce postoperative anxiety, while patients undergoing conventional treatment exhibited slightly increasing anxiety scores in the first 3 days after surgery. This effect was non-significant, yet considerable in terms of magnitude. The trend of the results suggest that a larger sample size would yield a statistically significant difference. This finding underscores the potential of VR in effectively mitigating postoperative anxiety. Prior research in this area is limited, with only one study evaluating the effects of VR distraction therapy on postoperative anxiety after cardiac surgery [17]. However, it is essential to acknowledge a crucial distinction here again: this previous study compared VR distraction therapy to another form of distraction therapy (specifically, audio hypnosis) and it was lacking a control group. In contrast, our study design included a control arm receiving conventional postoperative treatment, allowing for a direct comparison with standard of care. This aspect strengthens the validity of our results to evaluate the efficacy of VR distraction therapy in the context of cardiac surgery.

Postoperative quality of recovery

LMM analyses investigating the relationship between group randomization and time on the experienced quality of postoperative recovery did not yield any statistically significant differences. Notably, apart from an ongoing study on the impact of VR distraction in the postoperative phase of general surgery [18], the VRECOVERY trial marks the first exploration of the QoR-15 questionnaire following VR distraction therapy.

Future perspective

Our findings emphasize the need for further investigation into the effects of VR distraction therapy on postoperative pain, anxiety and potentially on the enhancement of postoperative quality of recovery, particularly in larger sample sizes. An important insight from this study is that 25% of participants in the intervention group (24 out of 96) refused further participation mainly due to not feeling the capacity and energy to undergo a VR session amidst the focus on postoperative clinical recovery. This highlights the notion that VR may not be suitable for all patients as a therapeutic tool, underscoring the need for further research to characterize and specify patient profiles for whom VR could be effective.

In our study, we chose to implement VR distraction therapy during the first 3 days after surgery, as our patients are discharged to the referral hospital after this period. However, it is plausible that VR distraction therapy might be more effective if patients could self-select when to use it. It is possible that VR sessions might be more convenient and beneficial for patients at a later stage rather than immediately within the first 3 days after surgery. Also, VR distraction therapy was standardized to one session per day in this study, based on patient feedback gathered during the preliminary testing phase prior to study initiation. However, as evidence-based guidelines for the optimal daily frequency of VR distraction therapy in this context are currently lacking, we recognize that allowing patients to self-regulate VR use based on their pain or discomfort levels may offer a valuable alternative approach. Additionally, future studies should consider assessing the cost-effectiveness of utilizing VR distraction therapy. While cost-effectiveness evaluations have already been conducted in other medical fields showing reduced average costs per quality-adjusted life year [19, 20], such analyses have not yet been undertaken in the context of cardiac surgery. Conducting cost-effectiveness analyses following cardiac surgery would offer insights into the economic implications of VR distraction therapy, which would help healthcare policymakers make informed decisions regarding the adoption and integration of VR technology into routine cardiac care.

Limitations

Our study is subject to several limitations. Firstly, the sample size calculation was predicated solely on the NRS, potentially resulting in underpowered analyses for the STAI-6 and QoR-15 questionnaires. This limitation arose from the absence of existing literature guiding the measurement of STAI-6 and QoR-15 scores in the context of postoperative care following cardiac surgery. Furthermore, while we calculated sufficient power with 50 participants per group, the intervention group included only 39 patients compared to 61 controls. Despite this, the NRS score was the only primary outcome to show significant differences, suggesting that the study may still have had adequate power to detect meaningful changes in NRS. However, the smaller sample size may limit the generalizability of findings related to the STAI-6 and QoR-15, which were not powered for the earlier mentioned reason. Another notable limitation is the high dropout-rate (48%), primarily from intervention group participants refusing further participation, which introduced attrition bias. Unfortunately, data collection was not feasible in the drop-out patients due to various reasons. For the majority, this was due to 29 patients declining participation immediately postoperatively, 34 patients encountered prolonged ICU stay (>24 h), 8 patients required a reoperation on the first postoperative day, and lastly data collection was unsuccessful in 12 patients due to logistical challenges. In these cases of drop-outs, the effect of VR remains undetermined. Interestingly, refusal of participation occurred predominantly in the intervention group. Given the novelty of utilizing VR in this postoperative therapeutic context, identifying suitable patients for this intervention remains challenging, and these data are valuable for guiding further studies in this field as it suggests that VR distraction therapy may not be feasible or desirable for all cardiac surgery patients in the postoperative setting.

Additionally, our study design was non-blinded, and primary outcomes relied on self-reported measures, which may have introduced subjective bias, particularly as patients were aware of their treatment allocation. Despite efforts to minimize bias here, inherent limitations persist due to the nature of utilizing a physical VR device and the necessity of self-reported assessments through validated questionnaires. While we implemented validated questionnaires to enhance reliability, inherent limitations remain due to the physical nature of the VR device and the need for self-reported assessments. We recognize the potential value of including objective endpoints, such as data on postoperative analgesic administration to further distinguish between the intervention and control groups. Unfortunately, in this study, we did not collect data on postoperative administration of analgesics. This is another limitation of the current study, and we

recommend its consideration in future research on VR interventions in postoperative care.

Furthermore, we were unable to obtain baseline scores for the primary outcomes, as they depended on patients' postoperative experiences. This limitation restricted our ability to assess the absolute impact of VR distraction therapy, making the slope over time the most relevant indicator of treatment effect. Finally, this study was conducted at a single-centre, which may limit the generalizability of the findings.

CONCLUSION

In conclusion, the VRECOVERY trial suggests that VR distraction therapy may have -potential benefits in reducing postoperative pain among cardiac surgery patients. While this study demonstrates a significant impact on this critical postoperative outcome, we also recognize the limitations mainly due to participant dropout rate, which may affect the robustness of our findings. Nevertheless, our results suggest the necessity for further research with larger cohorts to confirm these results and to explore the implications for postoperative anxiety and quality of recovery. Additionally, the high dropout rate in this study itself is noteworthy, indicating that VR distraction therapy may not be suitable for all cardiac surgery patients in the postoperative period. Therefore, future studies should focus on identifying the characteristics of patients most likely to benefit from VR intervention. Finally, research should also assess the cost-effectiveness of integrating VR distraction therapy into routine cardiac care, considering both its clinical efficacy and financial implications.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *EJCTS* online.

FUNDING

None declared.

Conflict of interest: none declared.

DATA AVAILABILITY

Data are available on request to the corresponding author.

Author contributions

Sulayman el Mathari: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Resources; Software; Visualization; Writing—original draft; Writing—review & editing. **Saadullah Shehadeh:** Data curation; Investigation; Methodology; Project administration; Visualization. **W. Patrick Zwaan:** Data curation; Investigation; Methodology; Project administration. **Noor Boulidam:** Data curation; Formal analysis; Investigation; Methodology; Visualization; Writing—original draft. **Lieke Kuitert:** Data curation; Investigation; Methodology; Project administration. **Jos W.R. Twisk:** Conceptualization; Data curation; Formal analysis; Methodology; Validation. **Robert J.M. Klautz:** Data curation; Methodology; Resources. **Rob de Lind van Wijngaarden:** Conceptualization; Data curation; Methodology; Resources; Writing—review & editing. **Kevin Veen:** Conceptualization; Methodology; Project administration; Resources; Validation; Visualization; Writing—original draft; Writing—review & editing. **Jolanda Kluin:** Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Resources; Supervision; Validation; Visualization; Writing—original draft; Writing—review & editing.

Reviewer information

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