Trials

STUDY PROTOCOL

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Intraoperative virtual reality for older patients undergoing total knee arthroplasty: study protocol for a randomized clinical trial

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Abstract

Background In an aging surgical patient population, preventing complications such as oversedation has taken increasing priority in perioperative care. Intraoperative use of virtual reality (VR) may decrease sedative requirements. We hypothesize that the use of immersive VR during total knee arthroplasty (TKA) will lead to decreased propofol requirements, improved patient-reported satisfaction, and reduced postoperative opioid requirements compared to active and usual care controls.

Methods This is a single-center, randomized clinical trial of older (age > 60) patients undergoing TKA. Participants will be randomized into three groups (2:2:1): VR immersion, music, and sham VR plus usual care. All patients will receive a regional block and spinal anesthesia. Patients in the immersive VR and music groups will use patient-controlled sedation (PCS) with propofol, while those in the sham VR group will act as the standard of care control group and will receive monitored anesthesia care (MAC) with propofol infusion.

Statistical analysis Analyses will be conducted using IBM SPSS Statistics Version 25, considering a two-sided *p*-value < 0.05 to be statistically significant. The primary outcome is the intraoperative dose of propofol (mg kg^{-1} min^{-1}). Secondary outcomes include patient satisfaction, post-anesthesia care unit (PACU) length of stay, postoperative pain scores and analgesic requirements, functional outcomes, postoperative delirium, and postoperative neurocognition.

Discussion VR used as a non-pharmacological adjunct to regional and spinal anesthesia during TKA may reduce sedative requirements while maintaining patient satisfaction. If true, this approach to minimizing sedation may impact clinical outcomes including perioperative complications and length of stay for older patients, while maintaining a high degree of patient satisfaction.

Trial registration This trial was registered on ClinicalTrials.gov on January 29, 2021. The registration number is NCT04748549.

Keywords Patient-controlled sedation, Perioperative complications, Sedation, Total knee arthroplasty, Virtual reality

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Introduction

Background and rationale {6a}

Over 700,000 total knee arthroplasties (TKA) are performed annually in the United States, with a projected increase in the number of older patients undergoing surgery in the coming years [1, 2]. With an increasing number of older and potentially more medically complex patients and a prioritization of same day surgery, optimizing perioperative care during TKA in older individuals is essential. One such area in which care can improve is via reducing oversedation.

Oversedation during monitored anesthesia care (MAC) can lead to serious complications, including death, making prevention a priority for physicians and healthcare organizations [3–5]. Likewise, a recent area of focus for anesthesiologists is the prevention of perioperative neurocognitive disorders including delirium and delayed neurocognitive recovery, both possibly related to anesthetic dosage [6–8]. Lastly, delayed recovery of consciousness is a major contributor to extended postanesthesia care unit (PACU) length of stay.

Spinal anesthesia combined with MAC is a standard approach for TKA, but intravenous sedation, given to decrease anxiety or discomfort, carries the risk of oversedation. However, eliminating it without an effective alternative could negatively impact patient experience. Therefore, an intervention that balances the goals of intraoperative patient comfort and safety is needed.

Objectives {7}

The objective of this superiority trial is to investigate the effect of immersive VR during TKA, in comparison to an active control and a sham VR plus usual care, on intraoperative propofol administration and other secondary outcomes such as patient satisfaction, perioperative efficiency, neurocognitive disorders, and functional recovery. We hypothesize that the use of immersive VR during TKA will lead to a decrease in propofol requirements, will improve patient-reported satisfaction, and will reduce postoperative opioid requirements compared to an active control and usual care.

Trial design {8}

This is a single-center, randomized clinical trial of older adult patients (≥60 years old) undergoing TKA. There was a run-in phase with six enrolled participants to gain experience with the VR intervention and identify areas that need improvement before the trial began. Following informed consent, participants will be allocated into one of three groups (2:2:1 allocation): immersive VR, music, and sham VR plus usual care (Fig. 1). The study adheres to the SPIRIT guidelines.

Methods: participants, interventions, and outcomes

Study setting {9}

This study is being conducted at BIDMC, Boston, United States. The Committee on Clinical Investigations at Beth Israel Deaconess Medical Center (BIDMC, IRB Protocol No. 2020P001176) approved this study on January 4, 2021. Enrollment began in April 2022, and as of the submission of this manuscript, recruitment is still ongoing. The authors delayed submitting the protocol for publication until the 50% enrollment milestone was reached to

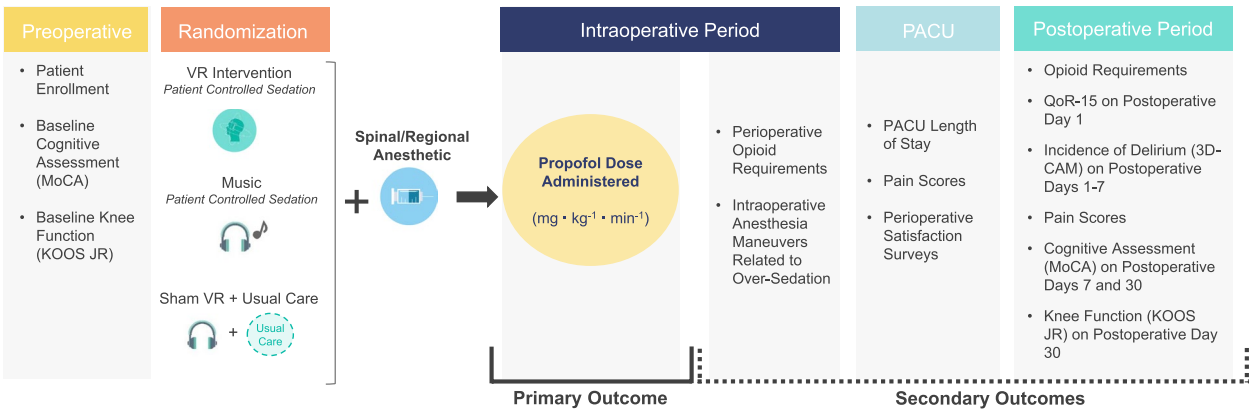

Fig. 1 Study schema. Participants will be enrolled preoperatively and assessed with baseline surveys. They will then be randomized into one of three groups (2:2:1 allocation): immersive VR, music, or sham VR plus usual care. Every patient will receive a spinal anesthetic and regional nerve block. The VR and music groups will self-administer propofol via a patient-controlled sedation (PCS) pump, while the usual care group will receive monitored anesthesia care (MAC) with propofol. Postoperative assessments will be administered at PACU discharge and up until postoperative day 30. KOOS JR, Knee Osteoarthritis Outcome Score; MoCA, Montreal Cognitive Assessment; PACU, post-anesthesia care unit; QoR-15, Quality of Recovery 15; VR, virtual reality; 3D-CAM, 3-Minute Diagnostic Assessment for Delirium using the Confusion Assessment Method

ensure all amendments were finalized and to publish the most accurate and complete version of the protocol.

Eligibility criteria {10}

Eligible patients must be aged 60 or older and scheduled for primary TKA at BIDMC under spinal/regional anesthesia. Exclusion criteria include complex or revision surgeries, "same day" TKA, open wounds or facial infection, history of seizures or epilepsy, patients unable to tolerate the VR headset while wearing hearing aids or due to complete or partial blindness, patients with a pacemaker or other implanted device, are on droplet or airborne precautions, are non-English or non-Spanish speaking, and those with a diagnosis of moderate to severe dementia. Patients with severe cognitive impairment, as defined by a baseline Montreal Cognitive Assessment (MoCA) score of < 10 out of 30 points, will be dropped from the study.

Who will take informed consent? {26a}

Written informed consent will be obtained from all participants by the principal investigator or members of the research team who completed consent training. An explanation of the study's purpose, methods, benefits, and risks will be provided. All potential participants may refuse to participate or withdraw consent at any time during the study.

Additional consent provisions for collection and use of participant data and biological specimens {26b}

This item does not apply as there will be no collection of biological specimens.

Interventions

Explanation for the choice of comparators {6b}

Virtual reality (VR) offers a potential alternative by creating an immersive experience that distracts the mind from noxious stimuli. It has been found safe and effective in reducing pain and anxiety for inpatients and those with chronic pain, during minor procedures, as well as the first stage of labor [9–14]. Its effects are less well-established during surgery. In a preliminary study, we demonstrated that VR immersion during upper extremity surgery with regional anesthesia reduced intraoperative propofol dose while maintaining a high degree of patient satisfaction [15]. Given these results, we believe that using immersive VR in other surgeries performed under spinal/regional anesthesia and MAC might provide similar benefit.

Intervention description {11a}

Study staff will be present intraoperatively to monitor the intervention. All patients will wear a VR PICO G2 4K headset and noise-canceling headphones for the duration of the surgery. At the end of the surgery, the equipment will be removed, and standard postoperative care will commence.

Immersive virtual reality group

The VR headset will display preselected content from XRHealth (Boston, MA) in an immersive 360-degree environment with paired audio. Participants will be able to choose from multiple immersive experiences including canoeing in a river, swimming underwater with dolphins, and guided meditation, among other options. Study staff will monitor and manage the VR content via an external control software on a tablet and are able to change content and send text messages to the patient throughout the intervention. The VR programming will run for the duration of the surgery.

Music group

Study staff will play music from a playlist based on the patient's preferences, while the VR headset will be turned off. The purpose of this group is to act as an active control with another established form of intraoperative distraction, while blinding the anesthesiologist from the intervention.

Sham VR plus usual care group

Patients will wear headsets and headphones, but only the noise-canceling feature of the headphones will be enabled. Neither visual nor audio content will be played for participants in this group. To maintain blinding, staff will be present in the room along with all equipment, as for the other study groups.

Anesthesia protocols

All participants will receive the standard preoperative care for TKA at BIDMC including a preoperative adductor canal or femoral nerve block and spinal anesthesia. To reduce the influence of anesthesia providers on the determination of patients' sedative requirements, patients in the VR and music groups will use a patient-controlled sedation (PCS) system. Similar to published protocols, the PCS system will administer a bolus of 20 mg of propofol on demand with a lock-out time of two minutes between doses [16].

Patients in the VR sham group will act as the standard of care control group and will undergo MAC as per BIDMC standard of care with a continuous propofol infusion to achieve "minimal" or "moderate" sedation as defined by the American Society of Anesthesiologists (ASA) [17]. The propofol infusion will be started at an initial dose of 50 mcg kg^{-1} min^{-1}, then titrated to the appropriate level of sedation by the anesthesia provider. Patients will be monitored according to ASA standards.

Postoperative care will be conducted following current BIDMC standards.

Criteria for discontinuing or modifying allocated interventions {11b}

The anesthesia provider may consider using a continuous propofol infusion if the patient reports severe discomfort or activates the pump every two minutes for 10 min. Thus, while in the VR and music groups the PCS system will be the intended primary mode of sedation, the anesthesia provider is empowered to provide additional sedation according to their clinical judgment.

Strategies to improve adherence to interventions {11c}

To improve adherence to interventions, participants undergo a thorough enrollment process, including trying the VR headset and selecting their content and music. During the intervention, team members monitor participants and communicate via headset messages to ensure comfort and safety.

Relevant concomitant care permitted or prohibited during the trial {11d}

Sedatives other than propofol will be discouraged in all groups; however, midazolam administration to facilitate the preoperative regional/spinal anesthetic will be permitted. Providers will avoid using analgesics for sedation purposes and only administer them if the patient reports a pain score of seven or higher on a 10-point scale.

Provisions for post-trial care {30}

Provision for post-trial care is addressed in the informed consent form.

Outcomes {12}

Primary and secondary outcomes will be assessed through data collection from the patient's electronic medical records and perioperative assessments as defined in Table 1. The primary outcome will be the intraoperative propofol dose (mg kg^{-1} min^{-1}). This information will be taken from the intraoperative anesthetic record and

Table 1 Definition of primary and secondary outcomes

Domain	*Measure*	*Metric*	*Method of aggregation*	*Timepoint*
Primary outcome				
Intraoperative propofol dose	*Intraoperative propofol dose (mg kg^{-1} min^{-1})*	*Comparison at specific timepoint*	*Median (interquartile range)*	*Intervention*
Secondary outcomes				
Intraoperative opioid dose	*Intraoperative opioid dose (mg kg^{-1})*	*Comparison at specific timepoint*	*Median (interquartile range)*	*Intervention*
Oversedation	*Intraoperative maneuvers related to oversedation (airway interventions including jaw thrust or insertion of airway devices)*	*Comparison at specific timepoint*	*Proportions*	*Intervention*
Post anesthesia care unit length of stay	*PACU length of stay (minutes)*	*Comparison at specific timepoint*	*Median (interquartile range)*	*PACU stay*
PACU analgesic dose requirements	*Analgesic dose requirements (mg kg^{-1})*	*Comparison at specific timepoint*	*Median (interquartile range)*	*PACU stay*
Postoperative pain	*Pain scores (score: 0–10)*	*Comparison at specific timepoint*	*Median (interquartile range)*	*From PACU stay to POD-7/discharge (whichever comes first)*
Patient satisfaction with anesthesia	*ISAS (score: – 33 to 33)*	*Comparison at specific timepoint*	*Median (interquartile range)*	*PACU stay*
Quality of recovery from anesthesia	*QoR-15 (score: 0 to 150)*	*Comparison at specific timepoint*	*Median (interquartile range)*	*PACU stay, POD-1*
Opioid-related adverse events	*Questionnaire including the most common opioid related adverse events*	*Comparison at specific timepoint*	*Proportions*	*PACU stay*
Delirium	*3D-CAM (presence or absence of delirium)*	*Comparison at specific timepoint*	*Proportions*	*POD-1 to POD-7/discharge (whichever comes first)*
Postoperative neurocognitive disorder	*MoCA-22 (score: 0–22)*	*Change from baseline*	*Median (interquartile range)*	*Enrolment, POD-7 and POD-30*
Functional knee recovery	*KOOS JR (score: 0–100)*	*Change from baseline*	*Median (interquartile range)*	*Enrolment and POD-30*

3D-CAM 3 Minute Diagnostic Confusion Assessment Method, *ISAS* Iowa Satisfaction with Anesthesia Scale, *KOOS-JR* Knee Osteoarthritis Outcome Score, *MoCA-22* Montreal Cognitive Assessment-22, *PACU* Postoperative anesthesia care unit, *POD* Postoperative day, *QoR-15* Quality of Recover 15

from the PCS software reports for patients in the VR and music groups.

Secondary outcomes include intraoperative airway interventions, vital signs (blood pressure, heart rate, respiratory rate, blood oxygen saturation), and opioid dose requirements. Postoperative outcomes include PACU length of stay, analgesic dose requirements, and hourly pain scores. Once the patient is clinically ready for PACU discharge, a blinded team member will assess patient satisfaction using the Iowa Satisfaction with Anesthesia Scale (ISAS), an 11-item questionnaire. Answers range from −3 (disagree very much) to +3 (agree very much), with higher scores indicating greater satisfaction [18]. Additionally, quality of recovery from anesthesia will be assessed using the Quality of Recovery-15 (QoR-15), a 15-item questionnaire addressing five dimensions (pain, physical comfort, physical independence, psychological support, and emotional state), with higher scores correlating with greater satisfaction [19]. Opioid-related adverse events (ORAEs) such as nausea or ileus will also be evaluated.

On postoperative day 1 (POD 1), hospitalized patients will be re-assessed by a blinded team member with the QoR-15. Patients will also be assessed with the 3-Minute Diagnostic Assessment for Delirium using the Confusion Assessment Method (3D-CAM) once daily to assess for postoperative delirium beginning on postoperative day 1 until day 7 or discharge, whichever comes first. This tool assesses the four features of delirium: (1) acute change and fluctuating course, (2) inattention, (3) disorganized thinking, and (4) altered level of consciousness) [20]. Presence of delirium is considered if the patient has items 1 and 2 and either 3 or 4.

On POD 7 and POD 30, blinded study staff will assess neurocognitive function using the MoCA-22. Finally, the orthopedic surgeon will evaluate knee health around postoperative day 30 using the KOOS JR, a seven-item patient-centered outcome tool scoring from 0 (absolute knee disability) to 100 (perfect knee health) [21]. A blinded team member will extract this assessment from the patient's medical records.

Participant timeline {13}

The participant timeline is shown in Fig. 2.

Sample size {14}

The analysis involves two simultaneous comparisons: (1) comparing the VR group to the control group and (2) comparing the VR group to the music group. Data will be analyzed using the Bonferroni correction procedure for multiple comparisons. This is the first trial in the United States to use virtual reality for joint replacement, so no prior data exists to allow us to estimate the anticipated effect size. Therefore, we based our assumptions on clinical judgment. We believe a 33% reduction in propofol dose is clinically significant when comparing the VR to the control group. We will use G*Power 3.1.9.7. to calculate sample size, with a two-sided *t*-test with a significance level of 0.025, 90% power, and an estimated mean propofol dose of 155 (±45) mg h^{-1} in the control group for a sample size of 42 patients in the intervention group and 14 in the control group. Comparing the VR and music groups, a two-sided *t*-test with a significance level of 0.025, 42 participants per group, with an anticipated 12% decrease of propofol dose in the VR group, we will have 67% power to reject the null hypothesis. To compensate for anticipated dropout and to better estimate infrequent but important secondary outcomes including delirium, we will plan to enroll additional patients to bring the total planned enrollment in each group to 50:50:25, for a total of 125 patients. Accordingly, the power of our last hypothesis test will increase to 76%. Finally, during the pilot phase, six patients will be enrolled. Their data will not contribute to the primary outcome analysis. Thus, this study plans to enroll a total sample of 131 patients.

Recruitment {15}

Eligible patients will be identified by study staff before their pre-admission testing (PAT) clinic date and approached during their appointment to obtain informed consent. Before their surgery, participants will be notified of their randomization group, and a baseline MoCA-22 assessment will be obtained either in person or remotely. This score will be converted into a score reflective of the full-length, MoCA-30 via an established crosswalk [22].

Assignment of interventions: allocation

Sequence generation {16a}

Participants will be randomly assigned to immersive VR, music, or usual care groups (2:2:1) by block randomization schemas with constant block sizes using the plan seed procedure in SAS software version 9.4.

Concealment mechanism {16b}

A study team member will be designated to access the Research Electronic Data Capture (REDCap) database to generate a unique patient research identification number which allocates them into one of the three groups. An unblinded team member will inform the patient of their group at least 2 days before surgery.

Implementation {16c}

The biostatistician will generate the allocation sequence and communicate it to the unblinded team member, who will then perform the intervention.

	Study Period							
	Enrolment	Allocation	Intervention	Follow-up				
TIMEPOINT**	$-t_2$	$-t_1$	t_0	t_1 (PACU)	t_2 (POD-1)	t_3 (POD-2 to POD-7/ discharge)	t_4 (POD-7)	t_4 (POD-30)
ENROLMENT:								
Eligibility screen	X							
Informed consent	X							
Allocation		X						
INTERVENTIONS:								
Immersive VR, Music or Sham VR			X					
ASSESSMENTS:								
Baseline MoCA	X							
Baseline KOOS JR	X							
Primary outcome								
Intraoperative propofol dose			X					
Secondary outcomes								
Intraoperative opioid requirements			X					
Intraoperative maneuvers related to oversedation			X					
PACU length of stay				X				
Analgesic dose requirements				X				
Pain scores				♦	♦	♦		
IOWA				X				
QoR-15				X	X			
Opioid related adverse events				X				
3D-CAM					♦	♦		
MOCA-22							X	X
KOOS JR								X

Fig. 2 SPIRIT figure

Assignment of interventions: blinding

Who will be blinded {17a}

The study staff responsible for randomization will be unblinded to all participants' study group allocations. An unblinded member will perform the intervention, inform participants of group allocation, and obtain a baseline MoCA-22 score before surgery. The anesthesiologist in the operating room will be notified of the plan for PCS or MAC but will otherwise be blinded to the intervention for the duration of the procedure. Anesthesia team members are not notified of how many groups are in the study design or which interventions are being tested, only that their patient will be sedated with PCS or MAC.

All postoperative assessments will be conducted by a blinded assessor. If this assessor becomes inadvertently unblinded or unavailable, another member of the blinded team will replace them. To prevent unblinding,

any data that could potentially reveal the patient's allocation is securely stored in labeled digital and physical folders.

Procedure for unblinding if needed {17b}

The patient and the unblinded team members are prohibited from discussing the content of their assigned intervention during the operation. However, if it becomes medically necessary to disclose the patient's group assignment to protect their safety or health, the patient's group assignment will be revealed.

Data collection and management

Plans for assessment and collection of outcomes {18a}

Outcomes will be collected using the PCS software, intraoperative anesthetic records, standardized questionnaires, and nursing reports.

Plans to promote participant retention and complete follow-up {18b}

To decrease loss to follow-up, the team ensures that updated primary and secondary contact information is on file during enrolment. Inpatients are visited regularly to ensure follow-up assessments are completed. Finally, after discharge, a flexible time window is provided for the participant's convenience to ensure telephonic assessment completion: ± 24 h on POD 7 and the 7 days following POD 30.

Data management {19}

Collected data will be stored securely, physically, and digitally, anonymized using a unique participant research ID, and accessed only by the team members trained in data management.

Confidentiality {27}

Data will be stored on password-protected computers behind the BIDMC firewall and entered into a computer database (REDCap). Computers and data collected on paper will be stored in locked study offices. For all analyses, subjects will be identified by their unique study ID. Limited information will be retained on patients who are pre-screened and do not qualify, or who are approached and decline participation, to generate a CONSORT flow diagram. At the completion of the study, final, aggregated, and non-identifiable data may be shared with XRHealth.

Plans for collection, laboratory evaluation, and storage of biological specimens for genetic or molecular analysis in this trial/future use {33}

This item does not apply as no biological specimens will be collected.

Statistical methods

Statistical methods for primary and secondary outcomes {20a}

Analyses will be conducted using IBM SPSS Statistics Version 25. Continuous data will be represented using mean (± standard deviation) or median (interquartile range) for variables with skewed distributions. We will first use one-way ANOVA test or Kruskal–Wallis test for non-normally distributed variables and then use the pairwise *t*-tests or Wilcoxon rank-sum tests with Bonferroni correction as post-hoc analysis if necessary. Categorical data will be presented using proportions and compared using a chi-square or Fisher's exact test.

Primary outcome

The primary outcome of this study is intraoperative propofol dose. This data will be normalized for the duration of the procedure and the patient's weight and analyzed as a continuous variable. A *t*-test or Wilcoxon rank-sum test will be used to assess differences in dose between groups. We will first compare the VR and control groups, followed by VR and music. If necessary, univariate and multiple linear regression modeling will be used to adjust for differences in baseline characteristics among the three groups that remain after randomization.

Secondary outcomes

Secondary outcomes include the comparison in propofol dose between the music and control group, intraoperative airway interventions, vital signs, and opioid dose requirements. Postoperative outcomes include length of PACU stay, analgesic dose requirements, pain scores (numeric scale), patient satisfaction (ISAS, QOR-15), opioid adverse events, postoperative delirium (3D-CAM), and neurocognitive function (MoCA-22) and knee function (KOOS-JR). Time, medication administration, and pain scores will be expressed as continuous variables. Patient satisfaction will provide quantifiable estimates of satisfaction in multiple areas, including but not limited to pain, anxiety, nausea, and overall experience. In addition to evaluating postoperative neurocognition with raw MoCA scores, we will also assess the incidence of delayed neurocognitive recovery and postoperative neurocognitive disorder. Delayed neurocognitive recovery and postoperative neurocognitive disorder will be defined as a decrease in at least one standard deviation from baseline MoCA score on POD 7 and POD 30, respectively [23]. A secondary analysis will be performed to analyze the incidence of delirium and postoperative neurocognitive disorder according to total propofol dose, regardless of group assignment. For

all secondary analyses, parametric or non-parametric tests will be employed analogously to our baseline characteristics between groups.

The unblinded biostatistician is responsible for data extraction, statistical analysis, and result reporting, ensuring analytical rigor and adherence to study objectives while maintaining the confidentiality of treatment allocations, thus outweighing any potential biases.

Interim analyses {21b}

This item does not apply as there will be no interim analyses.

Methods for additional analyses (e.g., subgroup analyses) {20b}

This item does not apply as no additional analyses are planned.

Methods in analysis to handle protocol non-adherence and any statistical methods to handle missing data {20c}

Our primary analysis will be conducted using intention-to-treat principles. The intention-to-treat (ITT) population will include all randomized participants, provided they meet the baseline eligibility criteria. Participants will be analyzed based on the treatment group they were originally assigned, regardless of whether they completed the assigned intervention or deviated from the protocol (e.g., in cases where spinal anesthesia fails and general anesthesia is administered, preventing them from experiencing the VR intervention). Additionally, the ITT analysis will still include participants who discontinue the intervention early or are lost to follow-up after randomization. However, participants will be excluded from the ITT analysis under specific conditions: if they do not undergo surgery at our medical center or if they are deemed ineligible based on pre-specified exclusion criteria discovered post-randomization (e.g., significant medical contraindications identified after enrollment but before surgery). This approach ensures that the ITT analysis preserves the integrity of randomization while minimizing biases due to post-randomization exclusions.

Missing data for secondary assessments from participants lost to follow-up or early drop-out will not be imputed.

Plans to give access to the full protocol, participant-level data, and statistical code {31c}

Any changes to eligibility criteria, outcomes, or analyses during the study will be reported to the IRB, ClinicalTrials.gov, and participants as needed.

Oversight and monitoring

Composition of the coordinating center and trial steering committee {5d}

The trial is overseen by a team with distinct responsibilities: an unblinded research coordinator collects adverse events during the intervention, while two blinded research coordinators assess events during the follow-up period using standardized questionnaires. A biostatistician logs these adverse events into REDCap, and a project manager and senior program manager oversee the data. Additionally, an unblinded research fellow (MD) and the principal investigator monitor adverse events from the intervention through PACU discharge and determine the degree of severity and relatedness to the intervention. This team ensures day-to-day participant safety, study conduct, and overall trial progress. An independent data safety monitoring committee was not required by the BIDMC IRB.

Composition of the data monitoring committee, its role and reporting structure {21a}

The reviewing IRB determined that an external data monitoring committee was not required for this study.

Adverse event reporting and harms {22}

We will use standardized language to classify events by seriousness (serious, not serious), expectedness (expected, unexpected), and relatedness (unrelated, unlikely, or if related: possible, probable, definite) [24, 25]. Harms will be reported in trial publications and, when appropriate, to the ethics committee. The scope of adverse event monitoring and reporting will be limited to events related to the study procedures, such as equipment malfunction leading to ineffective patient sedation, nausea, or seizures related to VR use. Participants will be followed for adverse events until the time of PACU discharge.

Frequency and plans for auditing trial conduct {23}

Auditing will be performed by the Beth Israel Deaconess Medical Center's Human Subject Protection Office and the Center for Anesthesia Research Excellence.

Plans for communicating important protocol amendments to relevant parties (e.g., trial participants, ethical committees) {25}

Once the trial is complete and the manuscript has been published, data will be shared with the scientific community and the public upon reasonable request. The study team will be responsible for creating the

manuscript, which will be submitted for publication in a peer-reviewed scientific journal.

Discussion

ChatGPT (version Default 3.5) was used solely to improve the readability of this manuscript. The authors reviewed and edited all content after using the tool and take full responsibility for the final version. The protocol itself was developed without ChatGPT and approved by the BIDMC IRB in January 2021.

Trial status

The latest protocol version approval date is February 2024. Recruitment began in April 2022, with an expected completion date in December 2026.

Abbreviations

3D-CAM	3-Minute Diagnostic Assessment for Delirium using the Confusion Assessment Method
ANOVA	Analysis of variance
ASA	American Society of Anesthesiologists
ISAS	Iowa Satisfaction with Anesthesia Scale
KOOS JR	Knee Injury and Osteoarthritis Outcome Score for Joint Replacement
MAC	Monitored anesthesia care
MoCA	Montreal Cognitive Assessment
ORAEs	Opioid related adverse events
PACU	Post-anesthesia care unit
PAT	Pre-admission testing
PCS	Patient-controlled sedation
POD	Post-operative day
QoR-15	Quality of Recovery 15
REDCap	Research Electronic Data Capture
TKA	Total knee arthroplasty
VR	Virtual reality

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13063-024-08551-6.

Supplementary Material 1. Supplemental Table 1. Trial registration data.

Supplementary Material 2. SPIRIT Checklist for *Trials*.

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Authors' contributions

Study protocol design: JPEL, RM, MJ, TS, LJK, VG, BPOG. Drafting of paper: JPEL, RM, ERH, TR, LJK, VG, BPOG. Subsequent revising and approval of paper: all authors. Authorship for future trial publications will adhere to the CJME criteria, requiring substantial contributions to the study design, data acquisition, analysis, or interpretation, active involvement in drafting or revising the manuscript, final approval of the version to be published, and accountability for the work, as determined by the principal investigator. No professional writers or large language models like ChatGPT will be used in future trial publications.

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Data availability

Not applicable.

Declarations

Ethics approval and consent to participate

The Committee on Clinical Investigations at Beth Israel Deaconess Medical Center approved this study on January 4, 2021 (Protocol No. 2020P001176).

Consent for publication

Not applicable.

Competing interests

Dr. Brian O'Gara is part of the scientific advisory board for Sedana Medical. All other authors declare that they have no competing interests.

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