Research Square

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Effect of Mixed Reality-Assisted Preoperative Anesthesia Visits on Anxiety in Patients Undergoing Laparoscopic Surgery: A Randomized Controlled Trial

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Abstract

Background

Preoperative anxiety is common among surgical patients and may adversely affect perioperative outcomes. Mixed reality (MR) offers an immersive approach to preoperative education and may improve patients' perioperative experience. This randomized controlled trial aimed to evaluate whether an MR-assisted preoperative anesthesia visit could reduce preoperative anxiety in patients undergoing elective laparoscopic surgery.

Methods

This prospective, single-center, randomized controlled trial was conducted at Xinhua Hospital Affiliated to Shanghai Jiao Tong University School of Medicine. Participants were randomly assigned to an MR-assisted preoperative anesthesia visit delivered through an MR headset or to a standard preoperative anesthesia visit. The primary outcome was the total Amsterdam Preoperative Anxiety and Information Scale (APAIS) score immediately after the intervention (T1). Secondary outcomes included perioperative pain and postoperative quality of recovery. In a subset of participants in the MR group, single-channel electroencephalography (EEG) was recorded during the intervention for exploratory, descriptive analysis.

Results

Of 76 patients assessed for eligibility, 56 were randomized and 55 were included in the analysis (MR group, n = 27; control group, n = 28). At T1, the mean total APAIS score was lower in the MR group than in the control group (12.04 ± 3.63 vs. 15.07 ± 2.99), with an estimated between-group difference of − 3.03 points (95% CI, − 4.84 to − 1.23; *P* = 0.001). The difference remained at arrival in the operating room (T2: 12.33 ± 3.82 vs. 15.43 ± 2.92; *P* = 0.002). The distributions of preoperative Numerical Rating Scale (NRS) pain scores differed between groups at T1 and T2. The Quality of Recovery-15 (QoR-15) score was higher in the MR group at 24 h after surgery, whereas no between-group difference was observed at 48 h. Exploratory EEG recordings from the MR subgroup showed descriptive changes in the α/β and β/θ power ratios across intervention modules.

Conclusion

MR-assisted preoperative anesthesia visits reduced preoperative anxiety in adults undergoing elective laparoscopic surgery. Differences in preoperative pain-score distributions and early postoperative quality of recovery also favored the MR group, although these secondary findings require confirmation. The EEG findings were descriptive and should be interpreted as hypothesis-generating.

Introduction

Preoperative anxiety may arise from concerns about illness, hospitalization, anesthesia, surgery, and uncertain perioperative outcomes [1]. Reported prevalence among adults undergoing surgery ranges from 11% to 80%, reflecting differences in patient populations, clinical settings, and assessment methods [2]. Greater preoperative anxiety has been associated with perioperative complications [3–5], lower patient satisfaction [6], and greater postoperative pain [7]. It may also intensify physiological stress responses and contribute to perioperative instability. Practical strategies to reduce preoperative anxiety are therefore an important component of perioperative care.

The preoperative anesthesia visit provides an opportunity for patient education, psychological support, and clinician-patient communication [8, 9]. Its effect on anxiety, however, may vary with the timing and duration of the consultation, communication strategies, and the way information is presented. Pharmacological anxiolysis, audiovisual education, music, and relaxation-based interventions have therefore been studied as adjuncts to routine care [10]. Pharmacological interventions can cause adverse effects and sedation [11], whereas some non-pharmacological approaches may provide limited immersion or engagement.

Immersive technologies are increasingly used as non-pharmacological interventions for perioperative anxiety. Virtual reality (VR) can redirect attention and facilitate relaxation, and previous studies have reported reductions in anxiety and pain [12–14]. Our group previously developed a VR intervention incorporating guided imagery and breathing exercises and observed lower pain and anxiety in pilot studies [15]. However, fully immersive VR can restrict awareness of the physical environment and real-time interaction with clinicians. These limitations may be relevant during preoperative anesthesia care, when education, relaxation, and communication occur together.

Mixed reality (MR) overlays virtual content on the physical environment, allowing patients to engage with digital material while remaining aware of their surroundings and able to communicate with healthcare professionals [16, 17]. This format may support standardized education, breathing exercises, relaxation training, and attention-focused tasks during preoperative anesthesia visits. Portable MR devices may also facilitate use in perioperative settings [17–19]. Evidence for MR-assisted preoperative anesthesia care remains limited, however, and physiological responses during MR-based relaxation and attention exercises have not been well characterized.

We therefore developed an MR-assisted preoperative anesthesia intervention for adults undergoing elective laparoscopic surgery. In this prospective, single-center, randomized controlled trial, the primary objective was to determine whether MR-assisted visits reduced preoperative anxiety, measured with the Amsterdam Preoperative Anxiety and Information Scale (APAIS) [20], compared with standard visits. Secondary outcomes included perioperative pain and postoperative quality of recovery. In addition, EEG-derived indices recorded in an MR subgroup were explored descriptively across the intervention modules.

Methods

Study design and ethical approval

This prospective, single-center, parallel-group randomized controlled trial was conducted at Xinhua Hospital Affiliated to Shanghai Jiao Tong University School of Medicine, Shanghai, China, from August 2025 to January 2026. The Ethics Committee of Xinhua Hospital approved the protocol in July 2025 (XHEC-C-2025-145-2). The trial was prospectively registered with the Chinese Clinical Trial Registry on 1 August 2025, before participant enrollment (ChiCTR2500106996). The study was conducted in accordance with the Declaration of Helsinki and reported in accordance with the Consolidated Standards of Reporting Trials (CONSORT) guidelines. All participants provided written informed consent before enrollment.

Participants

Patients aged 25–75 years who were scheduled for elective laparoscopic surgery at Xinhua Hospital were screened for eligibility. Exclusion criteria were ocular, facial, or cervical conditions that could interfere with safe or comfortable use of the MR headset; neurological or other disorders considered incompatible with MR exposure, including epilepsy, dementia, migraine, or clinically relevant sleep disorders; severe visual or hearing impairment; a history of severe motion sickness or photosensitivity; participation in another clinical trial within the preceding 3 months; pregnancy; or use of hypnotic or psychotropic medication within the preceding 6 months. Prespecified reasons for discontinuation after enrollment were an intraoperative change in the surgical procedure, postoperative admission to the intensive care unit, or inability or unwillingness to complete scheduled follow-up. Reasons for discontinuation and the availability of outcome data were documented for all participants.

Sample size calculation

The sample size was based on the APAIS score immediately after the preoperative intervention (T1), the prespecified primary outcome. Preliminary data indicated mean T1 APAIS scores of 17.63 in the control group and 13.06 in the MR group. With a two-sided α of 0.05 and 90% power, PASS 2021 estimated that 25 participants were required per group. Allowing for approximately 10% attrition, the target sample was 56 participants (28 per group).

Randomization, allocation concealment, and blinding

Participants were randomly assigned in a 1:1 ratio to the MR or control group using block randomization. A researcher who was not involved in recruitment, intervention delivery, or outcome assessment generated the allocation sequence in SPSS.

Allocation was concealed in sequentially numbered, opaque, sealed envelopes prepared by an independent research assistant. After eligibility was confirmed and written informed consent was obtained, the next envelope was opened to reveal the allocation. Participants and clinicians delivering the intervention could not be blinded because of the nature of the intervention; outcome assessors remained blinded to group allocation.

Interventions

Control group

Participants in the control group received a standard preoperative anesthesia visit on the day before surgery. In accordance with institutional practice, an anesthesiologist provided verbal information about the planned anesthesia, perioperative procedures, and relevant precautions.

Mixed reality group

Participants in the MR group received the same standard preoperative anesthesia visit as the control group on the day before surgery. Immediately afterward, they completed an MR intervention delivered through a headset and comprising four sequential modules: anesthesia education, breathing and relaxation training, cognitive focus training, and relaxation training (Supplementary Material). Single-channel EEG was recorded synchronously during the MR session in a subset of participants. EEG-derived measures were analyzed descriptively to characterize changes in relaxation and attentional engagement across modules.

Outcomes and assessment time points

The primary outcome was the APAIS total score immediately after the intervention (T1). The six-item APAIS assesses anxiety related to anesthesia and surgery and the need for information. Total scores range from 6 to 30, with higher scores indicating greater anxiety and/or information needs. APAIS was also assessed before the preoperative anesthesia visit (T0) and upon arrival in the operating room (T2).

Secondary outcomes were perioperative pain intensity, postoperative quality of recovery, sleep quality, patient satisfaction, and agitation-sedation status in the post-anesthesia care unit (PACU). Pain was assessed with an 11-point Numerical Rating Scale (NRS; 0 = no pain, 10 = worst imaginable pain) at T0, T1, T2, 24 h after surgery (T3), and 48 h after surgery (T4). The 15-item Quality of Recovery questionnaire (QoR-15) [21] and sleep quality were assessed at T0, T3, and T4. Participants rated sleep during the preceding night on an 11-point numerical rating scale from 0 (best possible sleep) to 10 (worst possible sleep). Satisfaction with perioperative care was assessed at T4 on an 11-point numerical rating scale from 0 (completely dissatisfied) to 10 (completely satisfied). Agitation-sedation status in the PACU was assessed with the Richmond Agitation-Sedation Scale (RASS).

EEG acquisition and processing

Single-channel EEG signals were recorded synchronously during the MR intervention and processed in MATLAB R2022b (MathWorks, Natick, MA, USA). Preprocessing included noise suppression and band-pass filtering at 0.5–35 Hz to reduce low-frequency drift and high-frequency noise. EEG-derived relaxation (α/β power ratio), attention (β/θ power ratio), and composite ([α + θ]/β power ratio) indices were calculated for descriptive comparisons across the predefined intervention modules.

Statistical analysis

Statistical analyses were conducted using IBM SPSS Statistics version 27.0 (IBM Corp., Armonk, NY, USA) and R version 4.2.1. MATLAB R2022b (MathWorks, Natick, MA, USA) and Python version 3.9 were used for EEG signal processing and related computational analyses.

Continuous-variable distributions were assessed with the Shapiro-Wilk test. Normally distributed variables are reported as mean ± standard deviation and were compared between groups with independent-samples t tests. Non-normally distributed variables are reported as median (interquartile range) and were compared with the Mann-Whitney U test. Categorical variables are reported as number (percentage) and were compared with the chi-squared test or Fisher's exact test, as appropriate.

Repeatedly measured outcomes were analyzed with linear mixed-effects models. Group, time (categorical), and the group-by-time interaction were included as fixed effects, and participant was included as a random effect. Prespecified between-group comparisons at individual time points were conducted after the longitudinal analysis. The between-group effect estimate and 95% confidence interval were reported for the primary outcome. All tests were two-sided, and $P < 0.05$ was considered statistically significant. EEG analyses were exploratory and descriptive.

Results

Participant flow and baseline characteristics

Of 76 patients assessed for eligibility, 56 provided written informed consent and were randomized. One participant in the MR group discontinued the intervention because of transient dizziness. The remaining 55 participants completed the study and were included in the analysis (MR group, n = 27; control group, n = 28; Fig. 1). Baseline demographic, clinical, and outcome measures are summarized in Tables 1 and 2. No serious adverse events occurred.

Table 1
Personal characteristics

Characteristic	Control group (n = 28)	MR group (n = 27)
Age, mean (M, IQR)	62(48,67)	66(53,72)
Sex		
Male	14(51.9%)	17(60.7%)
Female	13(48.1%)	11(39.3%)
Marital status		
Not married (single, widowed, or divorced)	1(3.7)	0(0%)
Married	26(96.3%)	28(100%)
Comorbidities		
Yes	16(59.3%)	14(50%)
No	11(40.7%)	14(50%)
Surgical History		
Yes	9(33.3%)	10(35.7%)
No	18(66.7%)	18(64.3%)

Data are presented as median (interquartile range) or number (percentage), as appropriate. MR mixed reality.

Table 2
Comparison of APAIS total and subscale scores between the two groups at different time points

APAIS total score	Control group (n = 28)	MR group (n = 27)	*P* value
T0	20.89 ± 4.28	22.22 ± 4.40	0.261
T1	15.07 ± 2.99	12.04 ± 3.63	0.001*
T2	15.43 ± 2.92	12.33 ± 3.82	0.002*
Need-for-information subscale			
T0	6.82 ± 1.56	7.11 ± 1.55	0.494
T1	5.93 ± 1.51	4.41 ± 1.37	< 0.001*
T2	6.04 ± 1.48	4.44 ± 1.53	< 0.001*
Anxiety subscale			
T0	14.07 ± 3.51	15.11 ± 3.18	0.255
T1	9.14 ± 2.14	7.63 ± 2.63	0.023*
T2	9.39 ± 1.95	7.89 ± 2.79	0.025*

Data are expressed as means ± standard deviation. *APAIS* Amsterdam Preoperative Anxiety and Information Scale.T0: before the preoperative anesthesia visit, T1: after the intervention, T2: upon arrival in the operating room. *$P < 0.05$

Primary outcome

The mean total APAIS score was lower in the MR group than in the control group after the intervention (Table 2). At T1, the mean scores were 12.04 ± 3.63 and 15.07 ± 2.99, respectively, corresponding to an estimated between-group difference of -3.03 points (95% CI, -4.84 to -1.23; $P = 0.001$). The difference remained at T2 (12.33 ± 3.82 vs. 15.43 ± 2.92; $P = 0.002$). Anxiety and need-for-information subscale scores were also lower in the MR group at these time points (all $P < 0.05$; Table 2).

Secondary outcomes

QoR-15 trajectories differed between groups, with a significant group-by-time interaction ($P < 0.001$; Table 3). At 24 h after surgery, the mean QoR-15 score was higher in the MR group than in the control group (99.96 ± 4.46 vs. 97.21 ± 3.40; $P = 0.013$). No significant between-group difference was observed at 48 h.

Table 3
Comparison of secondary clinical outcomes

NRS	Control group (n = 28)	MR group (n = 27)	*P* value
T0	3 (3, 5)	3 (3, 5)	0.814
T1	3 (2, 4)	3 (2, 3)	0.024*
T2	3 (2, 4)	3 (2, 3)	0.022*
T4	3 (2, 4)	3 (2, 3)	0.213
T5	3 (2, 3)	2 (2, 3)	0.313
QoR-15			
T0	90.07 ± 3.89	87.70 ± 5.88	0.086
T3	97.21 ± 3.40	99.96 ± 4.46	0.013*
T4	100.04 ± 2.90	100.59 ± 4.13	0.564
Sleep quality			
T0	5.64 ± 1.64	5.30 ± 1.84	0.463
T2	5.14 ± 1.27	6.04 ± 1.06	0.006*
T3	4.57 ± 1.29	4.93 ± 1.30	0.314
T4	5.71 ± 0.98	6.07 ± 1.21	0.229
RASS	0.0 (− 1.0, 0.0)	0.0 (− 1.0, 0.0)	0.703
Patient Satisfaction	7.0 (7.0, 8.0)	7.0 (7.0, 8.0)	0.451

Data are presented as mean ± standard deviation or median (interquartile range), as appropriate. Between-group comparisons were performed using the independent-samples t test, or Mann-Whitney *U* test, as appropriate. *NRS* Numerical Rating Scale, *QoR-15* 15-item Quality of Recovery questionnaire, *RASS* Richmond Agitation-Sedation Scale. T0: before the preoperative anesthesia visit; T1: immediately after the intervention; T2: upon arrival in the operating room; T3: 24 h after surgery; T4: 48 h after surgery. *$P < 0.05$.

NRS pain-score distributions differed between groups at T1 and T2, although the median was 3 in both groups (Table 3). At T1, the median was 3 (IQR, 2–3) in the MR group and 3 (IQR, 2–4) in the control group ($P = 0.024$). The corresponding values at T2 were 3 (IQR, 2–3) and 3 (IQR, 2–4), respectively ($P = 0.022$). No significant between-group differences were observed at subsequent assessments.

Patient satisfaction and RASS scores in the PACU did not differ significantly between groups (Table 3). Heart rate and mean arterial pressure also showed no significant between-group differences at baseline or subsequent assessments (all $P > 0.05$; Fig. 2). The descriptive trajectories appeared to fluctuate less in the MR group, but this pattern was not statistically significant.

Exploratory EEG findings

EEG-derived indices were evaluated in the subset of MR-group participants who underwent EEG monitoring (Fig. 3). The α/β power ratio increased during the breathing and relaxation modules. The β/θ power ratio increased transiently during the cognitive-focus module and decreased during the subsequent relaxation module. The composite ([α + θ]/β) power ratio also varied across modules. Because these analyses were descriptive and lacked a concurrent control condition, the observed temporal patterns should be considered hypothesis-generating.

Discussion

In this randomized controlled trial, MR-assisted preoperative anesthesia visits reduced preoperative anxiety in adults undergoing elective laparoscopic surgery compared with standard visits. The distributions of preoperative pain scores also differed between groups, and quality of recovery was higher in the MR group at 24 h after surgery, but not at 48 h. Patient satisfaction, PACU sedation, and perioperative hemodynamic measures did not differ between groups. EEG data from an MR subgroup showed descriptive variation across intervention modules. Together, these findings support further evaluation of MR as an adjunct to conventional preoperative anesthesia care.

The reduction in anxiety is consistent with reports that immersive technologies can reduce procedural and perioperative anxiety [13, 17, 22–24]. Conventional preoperative visits may vary in the content and timing of information delivery and in patients' ability to understand and retain that information [8]. The MR intervention combined standardized education with interactive psychological support. It also allowed participants to remain aware of the clinical environment and communicate with healthcare professionals, features that may be useful in preoperative care.

Several intervention components may have contributed to the observed effect. Immersive content may have redirected attention from surgery-related concerns, while structured anesthesia education may have reduced uncertainty about perioperative procedures [25]. The lower need-for-information scores in the MR group are consistent with this explanation. Breathing and relaxation exercises may have reduced emotional arousal, and cognitive focus training may have redirected attention from threatening thoughts [26]. Because the intervention combined these components, their individual contributions cannot be determined from this trial.

The between-group difference in APAIS scores was present immediately after the intervention and upon arrival in the operating room. Anxiety may increase as patients move from the ward to the preoperative holding area and operating room [27], making this interval a relevant target for intervention. The findings

suggest that a single MR session may have an effect across this short preoperative period [17]. The study did not assess whether the effect persisted beyond the immediate perioperative period.

The pain-score distributions also differed between groups at the two preoperative assessments, despite identical medians. Anxiety can increase attention to bodily sensations and reinforce negative expectations about pain [28–30], and immersive interventions may influence cognitive and affective aspects of pain perception through attentional redirection [31, 32]. Pain was a secondary outcome, however, and no mediation analysis was performed. The trial therefore cannot determine whether reduced anxiety caused the observed differences in pain-score distributions.

The QoR-15 score was higher in the MR group at 24 h after surgery, but the difference was no longer evident at 48 h. Previous studies have linked preoperative psychological distress and patients' perioperative experience with patient-reported recovery [33–35]. The transient difference in this trial may indicate that any benefit from a single preoperative MR session is concentrated in the early postoperative period. Standardized perioperative management and postoperative analgesia in both groups may also have reduced later between-group differences.

Heart rate and mean arterial pressure did not differ significantly between groups at the prespecified time points. The apparently smaller fluctuations in the MR group were descriptive and were not supported by statistical testing. This trial therefore provides no evidence that MR-assisted visits improve perioperative hemodynamic stability. Studies using prespecified measures of hemodynamic variability or autonomic activity are needed to assess whether psychological effects are accompanied by measurable physiological changes.

The exploratory EEG data described responses during different MR modules. The α/β power ratio increased during the breathing and relaxation modules, whereas the β/θ power ratio rose transiently during cognitive-focus training and then declined. These patterns were consistent with the intended functions of the modules [36, 37], but frequency-band ratios are indirect, context-dependent measures [38]. Moreover, EEG was recorded with a single-channel device in an MR subgroup without a concurrent control condition. The findings cannot establish specific neural mechanisms of anxiety reduction and should be used only to inform future confirmatory studies.

MR may have practical value as a non-pharmacological adjunct because it combines standardized perioperative education with breathing, relaxation, and attentional exercises in one session. Continued awareness of the clinical environment may also preserve communication with anesthesia professionals during the intervention. MR should complement, rather than replace, individualized preoperative assessment and clinician-patient communication.

This study has several limitations. Its single-center design and small sample limit the precision and generalizability of the estimates beyond the study population and setting. The MR group also received an additional intervention after the standard visit, so the effects of MR could not be separated from those of additional time and attention. Finally, EEG was recorded with a single-channel device in only a subset of

the MR group and without a concurrent control condition. Selection, physiological, and movement artifacts may therefore have influenced the EEG findings, which cannot be interpreted as specific biomarkers of anxiety, attention, or relaxation.

Conclusions

MR-assisted preoperative anesthesia visits were associated with lower total APAIS scores immediately after the intervention and upon arrival in the operating room among patients undergoing elective laparoscopic surgery. Secondary analyses showed differences in preoperative pain-score distributions and a higher QoR-15 score at 24 h, but not at 48 h. EEG recordings obtained from a subset of participants in the MR group showed descriptive variation in power ratios across the intervention modules. These findings support MR as a potential non-pharmacological adjunct to conventional preoperative anesthesia care, although larger multicenter studies are needed to confirm its clinical effectiveness and durability.

Declarations

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Authors' contributions

SXW and QX have made substantial contributions to the conception of the work; SXW, YLP and LYZ made significant contribution to the acquisition of the data; SXW, LYZ, YFM, and QX made substantial contributions to the analysis and interpretation of data; SXW and YLP wrote the initial draft of the manuscript and YFM, KM, and QX revised it.

Approval of final version of the manuscript: all authors

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Availability of data and materials

The datasets generated and analyzed during the current study are not publicly available because of patient privacy but are available from the corresponding author upon reasonable request.

Ethics statement and consent to participate

This study was approved by the ethics committee of Xinhua Hospital Affiliated to Shanghai Jiao Tong University School of Medicine, Shanghai, China on July 2025 (XHEC-C-2025-145-2). Written informed consent was obtained from all participants before enrollment.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Figures

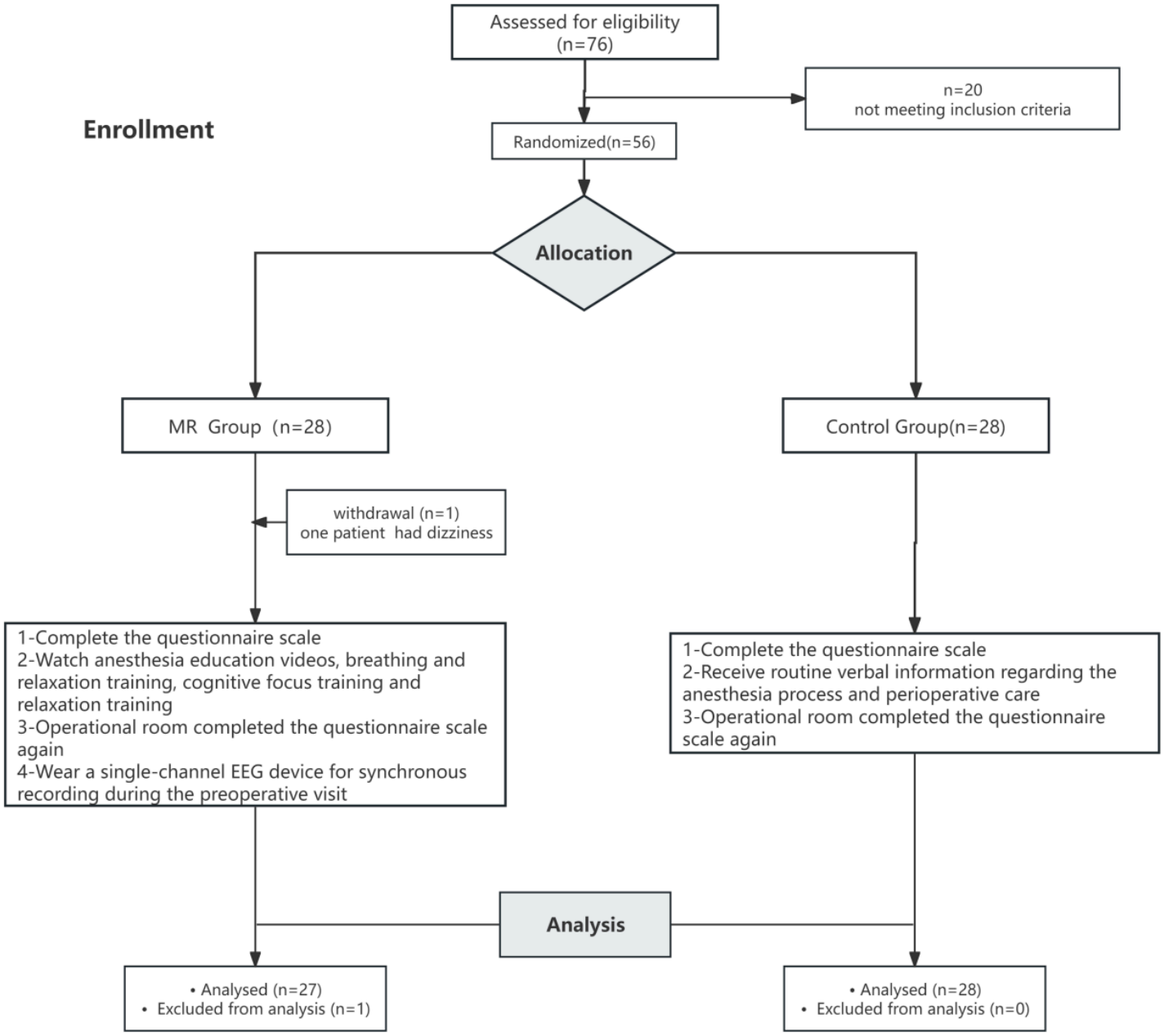


Figure 1

Study flow diagram

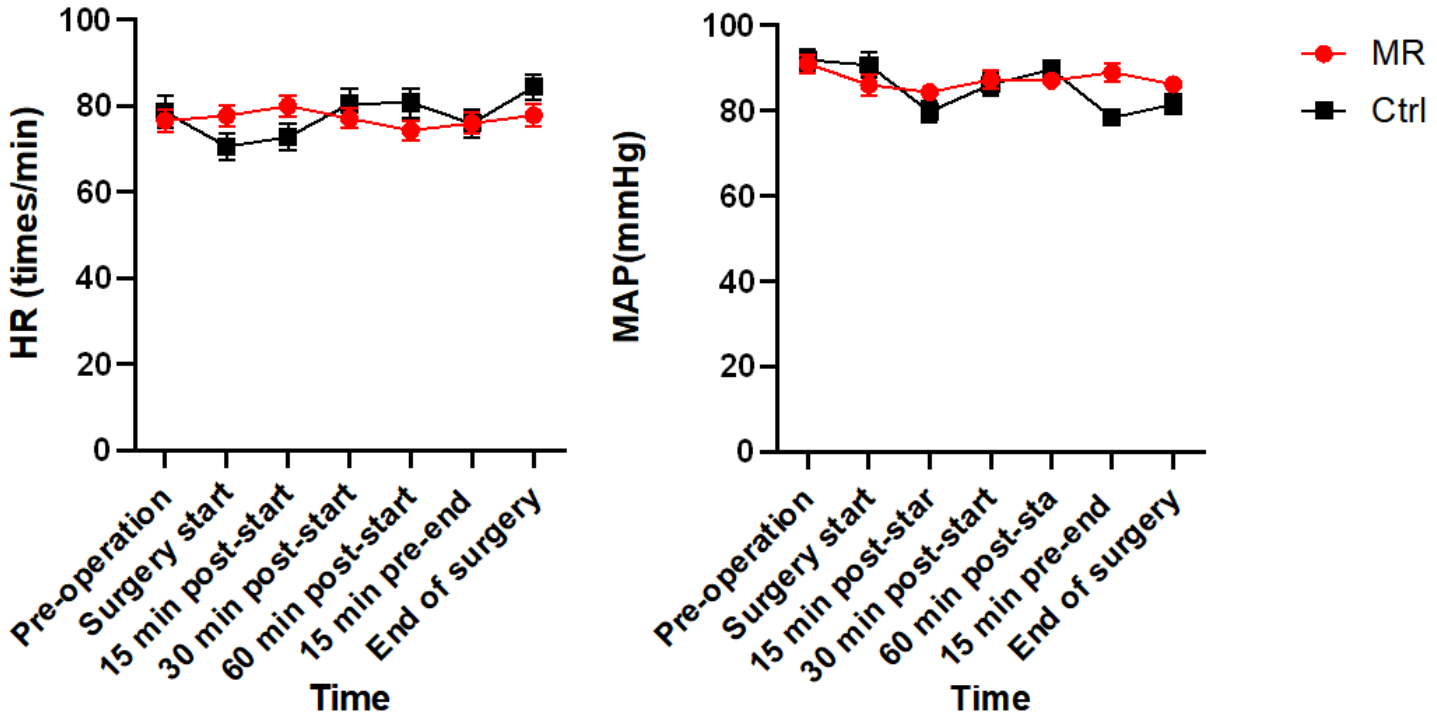


Figure 2

Heart rate and mean arterial pressure of the patients in both groups

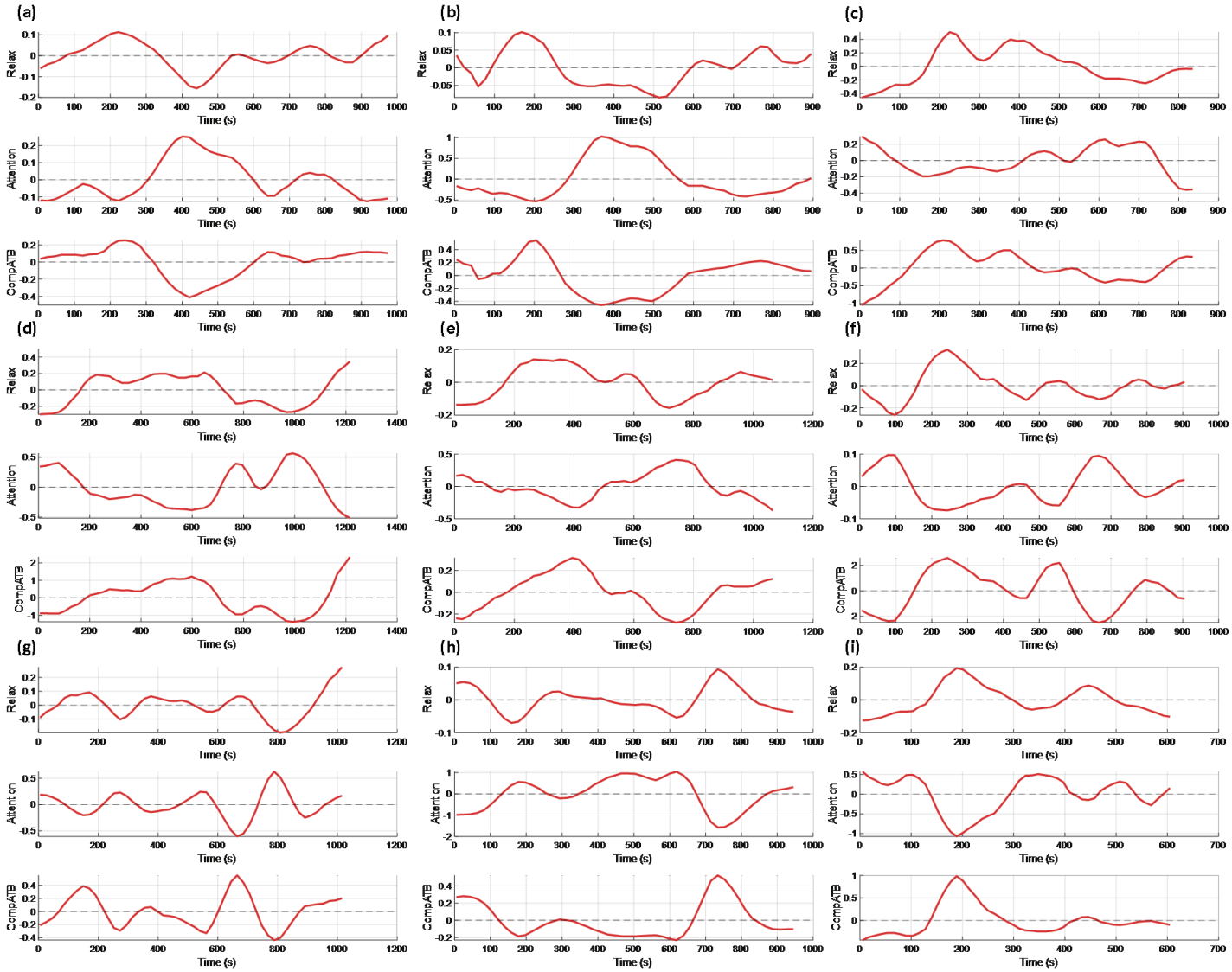


Figure 3

Representative EEG-derived indices of selected participants during MR Intervention

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table1.docx
- Table2.docx
- Table3.docx
- Video1.mp4
- Video2.mp4
- Video3.mp4

- Video4.mp4