

Original Research Article

DIGITAL DISTRACTION AS AN ADJUNCT TO STANDARD ANALGESIA IN PEDIATRIC SURGERY: A RANDOMIZED CONTROLLED TRIAL OF PAIN, ANXIETY, AND RECOVERY OUTCOMES

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ABSTRACT

Background: Perioperative pain and anxiety are common in children undergoing surgery and may adversely affect recovery. Digital distraction is a practical nonpharmacological strategy that may complement standard analgesic care.

Materials and Methods: This prospective randomized controlled trial included 100 children aged 3–10 years undergoing elective major or minor surgery. Participants were randomized 1:1 to structured digital distraction plus standard analgesia (n=50) or standard care alone (n=50). Outcomes included postoperative pain, perioperative anxiety, rescue analgesic use, recovery and discharge-readiness times, adverse events, parent satisfaction, and 2-month follow-up outcomes.

Results: Pain scores were significantly lower with digital distraction at 30 minutes, 1 hour, 2 hours, and before discharge. Perioperative anxiety was also lower (group-by-time $P < 0.001$). Rescue analgesia was required in 30.0% of the digital-distraction group versus 54.0% of controls ($P = 0.025$). Recovery and discharge-readiness times were shorter, and parent satisfaction was higher in the intervention group. Adverse events and most 2-month clinical outcomes did not differ significantly between groups.

Conclusion: Digital distraction used as an adjunct to standard analgesia improved short-term pain and anxiety outcomes, reduced rescue analgesic requirements, shortened early recovery, and increased parent satisfaction. Its clearest benefits occurred during the immediate perioperative period.

Keywords: Pediatric surgery; digital distraction; postoperative pain; perioperative anxiety; analgesia; recovery; randomized controlled trial.

INTRODUCTION

Surgery can be distressing for children, particularly during the preschool and early school years, when unfamiliar surroundings, separation from caregivers, invasive procedures, and limited understanding of perioperative events may intensify fear. Postoperative pain remains a major concern in pediatric surgical care and, when inadequately controlled, may impair sleep, mobilization, oral intake, emotional well-being, and recovery.

Contemporary pediatric pain management therefore emphasizes age-appropriate assessment and individualized multimodal strategies rather than reliance on a single analgesic approach.^[1]

Pharmacological treatment remains central to postoperative pain control. Depending on the procedure and expected pain intensity, commonly used approaches include acetaminophen, non-steroidal anti-inflammatory drugs, regional analgesia, and opioids when clinically indicated. Pediatric analgesia nevertheless requires careful dosing and monitoring because developmental

differences influence pharmacokinetics and adverse-effect profiles. Modern enhanced-recovery pathways increasingly favor opioid-sparing regimens combined with nonpharmacological measures.^[1]

This approach is particularly relevant because pain in children is closely linked to anxiety, fear, behavioral distress, and previous healthcare experiences.

Perioperative anxiety can heighten pain perception and reduce cooperation during induction, procedures, and postoperative care. Interventions that address psychological distress alongside nociceptive pain may therefore improve the overall perioperative experience. Distraction is among the most practical nonpharmacological approaches and redirects attention from threatening or painful stimuli toward an engaging competing activity. It may be delivered through music, cartoons, interactive games, tablets, or immersive virtual-reality platforms. A recent systematic review and meta-analysis of randomized trials found that distraction techniques reduced preoperative anxiety in pediatric patients and, in some comparisons, performed favorably against pharmacological anxiolysis.^[2]

Digital technology has expanded the use of distraction by providing portable, standardized, and developmentally adaptable interventions. In a randomized trial, Turgut et al. reported that immersive virtual-reality preparation reduced perioperative anxiety and improved parental satisfaction; postoperative pain scores were also lower in the intervention group, although the between-group pain difference was not statistically significant.^[3] These findings suggest that digital distraction may influence both symptom intensity and the broader emotional experience of surgery.

Evidence for postoperative application is also increasing. Mathias et al. observed lower postoperative pain, anxiety, and physiological indicators of distress when age-appropriate distraction was added to standard care.^[4] Chen et al. reported lower postoperative FLACC pain scores and a reduced incidence of emergence delirium with immersive virtual-reality distraction.^[5] Gerards et al. also observed lower average pain and anxiety during painful pediatric surgical procedures, although several between-group comparisons were not statistically significant.^[6]

A 2022 systematic review and meta-analysis further showed that virtual-reality interventions can reduce pain and anxiety across a range of pediatric medical procedures.^[7] However, existing studies vary substantially in age, digital modality, timing, procedure, outcome measure, and comparator. Many focus on preoperative anxiety or brief procedural pain, while fewer evaluate postoperative pain, anxiety, analgesic requirements, and recovery together. The present randomized controlled trial therefore compared structured digital distraction used alongside standard analgesic care with standard care alone in children aged 3–10 years undergoing major or minor surgery, with pain and anxiety as primary

outcomes and analgesic use and recovery as secondary outcomes.

MATERIALS AND METHODS

Study design and setting

This prospective, parallel-group randomized controlled trial enrolled 100 children aged 3–10 years undergoing elective major or minor surgical procedures at the participating pediatric surgical center. Recruitment occurred over approximately 4–5 months, and each participant was followed for a minimum of 2 months. The trial was prepared and reported in accordance with CONSORT 2025 recommendations.^[8]

Ethics

Ethics Committee (EC) approval was obtained before initiation of the study. Written informed consent was obtained from parents or legal guardians, with age-appropriate assent from children whenever feasible. Participant confidentiality and standard clinical care were maintained throughout the study.

Participants

Children aged 3–10 years scheduled for elective surgery were screened for eligibility. Written informed consent was obtained from a parent or legal guardian, with age-appropriate assent obtained from the child when feasible. Exclusion criteria were emergency surgery, critical illness, major neurodevelopmental impairment that precluded reliable outcome assessment, significant visual or hearing impairment that prevented use of the digital intervention, previous enrollment, and inability to complete follow-up.

Randomization and intervention

Eligible participants were allocated 1:1 to the digital-distraction group (n=50) or standard-care group (n=50) using a computer-generated random sequence with concealed allocation. Participant blinding was not feasible because of the nature of the intervention; outcome assessors and the statistician were kept unaware of group allocation whenever operationally possible. The intervention comprised age-appropriate structured digital distraction delivered on a tablet or comparable digital device during the predefined perioperative period. Both groups received the institution's routine anesthetic and postoperative analgesic protocol, whereas the control group received no structured digital-distraction intervention. Comparable digital approaches have been evaluated in recent pediatric randomized trials.^[9]

Intervention protocol: Children allocated to digital distraction received age-appropriate animated videos or simple interactive games on a tablet device selected from a prespecified content library according to age and child preference. The session began approximately 10–15 minutes before anesthetic induction and continued during transfer and pre-induction preparation. Once the child was awake and responsive in the recovery area, the intervention was

resumed for approximately 15–20 minutes as tolerated. Headphones were used when tolerated. Adherence was recorded by the study team, and the intervention was stopped if the child became distressed, requested removal, or uninterrupted clinical communication was required. Both groups received the same institutional weight-based multimodal analgesic regimen appropriate to the surgical procedure. Rescue analgesia was administered for clinically significant breakthrough pain, including an age-appropriate pain score of 4 or greater, in accordance with the institutional protocol.

Outcome assessment and follow-up

The primary outcomes were postoperative pain intensity and perioperative anxiety. Pain was assessed using age-appropriate validated measures; the Face, Legs, Activity, Cry and Consolability (FLACC) scale was used when observational assessment was required.^[10] Assessments were performed at baseline, immediately after surgery, 30 minutes, 1 hour, 2 hours, and before discharge. Secondary outcomes included rescue analgesic requirement, recovery and discharge-readiness times, emergence-related behavioral disturbance, postoperative nausea or vomiting, other adverse events, and parent-reported satisfaction. Follow-up continued for 2 months to document persistent or recurrent pain, additional analgesic use, healthcare utilization, readmission, and overall recovery. Pediatric recovery domains were informed by contemporary patient-centered recovery measures.^[11] Anxiety assessment and co-primary endpoints: Perioperative anxiety was assessed using the modified Yale Preoperative Anxiety Scale (mYPAS), an observer-rated instrument with scores ranging from 23.33 to 100, with higher scores indicating greater anxiety. Assessments were performed by a trained outcome assessor at baseline, immediately before anesthetic induction or the procedure, and during the immediate postoperative assessment. The co-primary endpoints were postoperative pain score at 30 minutes and pre-induction mYPAS score. Pain was assessed with the FLACC scale when observational assessment was required and with an age-appropriate self-report scale when the child was able to provide a reliable response.

Sample size and statistical analysis

Sample-size justification: A pragmatic target of 100 participants (50 per group) was prespecified on the basis of the expected recruitment volume during the 4–5-month enrollment period and the planned 1:1 allocation. With 50 participants per group, a two-sided alpha of 0.05 provides approximately 80% power to detect a standardized between-group mean difference of 0.57 for a continuous primary outcome. The target also allowed for modest loss to follow-up during the 2-month observation period.

Analyses were conducted according to the prespecified analysis plan. Continuous data were summarized as mean $\pm$ standard deviation or median (interquartile range), as appropriate, and categorical data as number (percentage). Between-group

comparisons used the statistical tests appropriate to data distribution and cell counts. Repeated pain and anxiety measurements were evaluated for group, time, and group-by-time effects. A two-sided $P < 0.05$ was considered statistically significant. Two-month outcomes were analyzed among participants with available follow-up data; therefore, these follow-up analyses represent available-case rather than strict intention-to-treat analyses.

Statistical methods: Analyses were performed using IBM SPSS Statistics, version 29.0 (IBM Corp., Armonk, NY, USA). Continuous variables were assessed for distributional assumptions and summarized as mean $\pm$ standard deviation or median with interquartile range, as appropriate; categorical variables were summarized as number and percentage. Between-group continuous outcomes at individual time points were compared using independent-samples *t* tests, with Mann–Whitney *U* tests used when distributional assumptions were not met. Categorical outcomes were compared using the chi-square test or Fisher exact test when expected cell counts were small. Repeated pain and anxiety scores were analyzed using a linear mixed-effects model with fixed effects for group, time, and the group-by-time interaction and a participant-level random intercept. All tests were two-sided, and $P < 0.05$ was considered statistically significant. Two-month outcomes were analyzed using available cases; missing follow-up values were not imputed.

RESULTS

Participant flow and baseline characteristics

A total of 124 children undergoing major or minor surgical procedures were assessed for eligibility. Twenty-four were excluded because they did not meet eligibility criteria, declined participation, or fulfilled other predefined exclusion criteria. The remaining 100 children were randomized equally to digital distraction plus standard analgesia ($n=50$) or standard care ($n=50$). At the 2-month follow-up, 48 children (96.0%) in the digital-distraction group and 47 children (94.0%) in the standard-care group completed all scheduled assessments. [Figure 1]

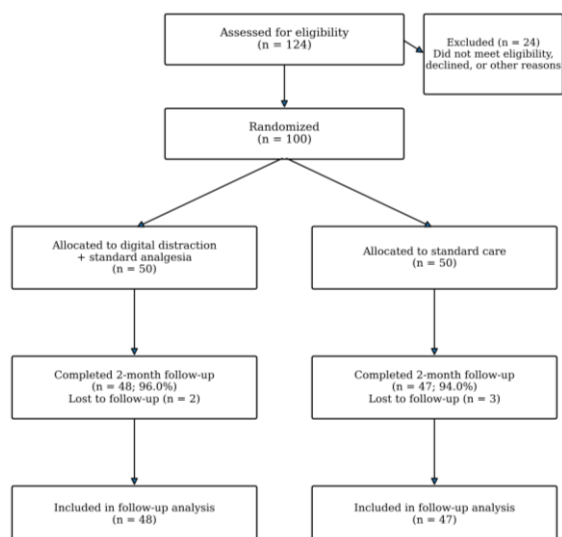


Figure 1: CONSORT flow diagram of study participants

Table 1: Baseline demographic and clinical characteristics

Characteristic	Digital distraction (n=50)	Standard care (n=50)	P value
Age, years	6.5 ± 2.2	6.6 ± 2.1	0.817
Age 3–5 years, n (%)	22 (44.0)	23 (46.0)	1.000
Age 6–10 years, n (%)	28 (56.0)	27 (54.0)	1.000
Male, n (%)	29 (58.0)	27 (54.0)	0.840
Major surgery, n (%)	24 (48.0)	26 (52.0)	0.842
Surgery duration, min	64 ± 23	66 ± 25	0.678
Baseline pain score	0.4 ± 0.7	0.5 ± 0.8	0.508
Baseline anxiety score	31.8 ± 7.4	32.5 ± 7.7	0.644

Data are presented as mean ± standard deviation or number (percentage), as appropriate.

Postoperative pain outcomes

Immediately after surgery, pain scores were similar between the digital-distraction and standard-care groups (4.8 ± 1.7 vs 5.0 ± 1.8 ; $P=0.569$). Statistically significant between-group differences emerged at later assessments. At 30 minutes, mean pain was 3.4 ± 1.5 versus 4.4 ± 1.7 (MD, -1.0 ; $P=0.002$); at 1 hour, 2.5 ± 1.3 versus 3.4 ± 1.5 (MD, -0.9 ; $P=0.002$); and at 2 hours, 1.6 ± 1.1 versus 2.4 ± 1.3 (MD, -0.8 ; $P=0.001$). Before discharge, scores remained lower with digital distraction (0.8 ± 0.8 vs 1.2 ± 1.0 ; $P=0.030$). The overall group-by-time effect was significant ($P<0.001$) (Table 2; Figure 2).

Baseline demographic and clinical characteristics were comparable between groups. Mean age was 6.5 ± 2.2 years in the digital-distraction group and 6.6 ± 2.1 years in the standard-care group ($P=0.817$). No statistically significant between-group differences were observed in sex distribution, type of surgery, duration of surgery, baseline pain, or baseline anxiety. [Table 1]

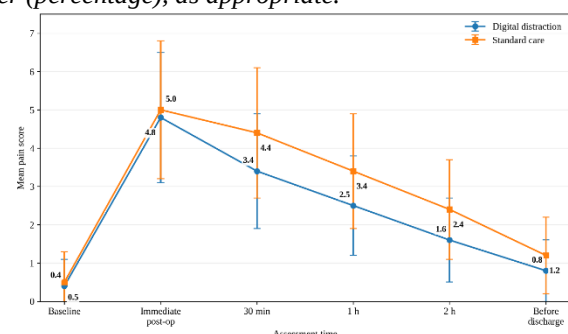


Figure 2: Postoperative pain-score trajectory in the digital-distraction and standard-care groups. Points represent mean values; error bars represent ±SD

Table 2: Postoperative pain and perioperative anxiety scores

Assessment	Digital distraction	Standard care	Mean difference	P value
Pain score — Baseline	0.4 ± 0.7	0.5 ± 0.8	−0.1	0.508
Immediate postoperative	4.8 ± 1.7	5.0 ± 1.8	−0.2	0.569
30 minutes	3.4 ± 1.5	4.4 ± 1.7	−1.0	0.002
1 hour	2.5 ± 1.3	3.4 ± 1.5	−0.9	0.002
2 hours	1.6 ± 1.1	2.4 ± 1.3	−0.8	0.001
Before discharge	0.8 ± 0.8	1.2 ± 1.0	−0.4	0.030
Anxiety — Baseline	31.8 ± 7.4	32.5 ± 7.7	−0.7	0.644
Pre-induction/procedure	36.9 ± 8.8	49.6 ± 11.5	−12.7	<0.001
Immediate postoperative	34.2 ± 8.0	41.7 ± 9.9	−7.5	<0.001

Perioperative anxiety

Baseline anxiety levels were similar between groups (31.8 ± 7.4 vs 32.5 ± 7.7 ; $P=0.644$). During the pre-induction/procedural period, anxiety increased in both groups but was significantly lower with digital distraction (36.9 ± 8.8 vs 49.6 ± 11.5 ; MD, -12.7 ;

$P<0.001$). Immediately after surgery, anxiety also remained lower in the intervention group (34.2 ± 8.0 vs 41.7 ± 9.9 ; MD, -7.5 ; $P<0.001$). The overall group-by-time effect was significant ($P<0.001$) (Table 2; Figure 3).

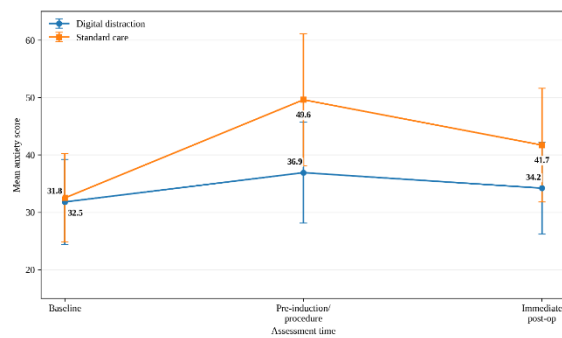


Figure 3: Perioperative anxiety-score trajectory in the digital-distraction and standard-care groups. Points represent mean values; error bars represent $\pm$ SD

Analgesic requirements and early recovery

Rescue analgesia was administered to 15 of 50 children (30.0%) in the digital-distraction group and 27 of 50 (54.0%) in the standard-care group ($P=0.025$). The mean number of rescue doses was lower with digital distraction (0.5 ± 0.8 vs 0.9 ± 1.0 ; $P=0.030$), as was total postoperative analgesic consumption (1.3 ± 0.7 vs 1.7 ± 0.8 standardized units; $P=0.009$). Mean recovery time was 72 ± 18 versus 83 ± 21 minutes ($P=0.006$), and discharge readiness was achieved at 118 ± 26 versus 132 ± 31 minutes ($P=0.016$). Emergence-related behavioral disturbance, postoperative nausea/vomiting, and other adverse events did not differ significantly. [Table 3]

Table 3: Analgesic use and early recovery outcomes

Outcome	Digital distraction (n=50)	Standard care (n=50)	P value
Rescue analgesia, n (%)	15 (30.0)	27 (54.0)	0.025
Number of rescue doses	0.5 ± 0.8	0.9 ± 1.0	0.030
Total analgesic consumption	1.3 ± 0.7	1.7 ± 0.8	0.009
Recovery time, min	72 ± 18	83 ± 21	0.006
Discharge readiness, min	118 ± 26	132 ± 31	0.016
Emergence disturbance, n (%)	5 (10.0)	11 (22.0)	0.171
Nausea/vomiting, n (%)	6 (12.0)	10 (20.0)	0.414
Other adverse events, n (%)	2 (4.0)	3 (6.0)	1.000

Two-month follow-up outcomes

At 2 months, persistent or recurrent pain was reported in 4 of 48 children (8.3%) in the digital-distraction group and 9 of 47 (19.1%) in the standard-care group ($P=0.146$). Additional analgesic use, unscheduled healthcare visits, readmission, and complete recovery numerically favored digital distraction but did not

reach statistical significance. Parent satisfaction was higher in the digital-distraction group: mean satisfaction score was 4.5 ± 0.6 versus 4.1 ± 0.8 ($P=0.007$), and high or very high satisfaction was reported by 87.5% versus 70.2% of parents ($P=0.047$). [Table 4]

Table 4: Changes in perceived PHC and community engagement

Outcome	Digital distraction (n=48)	Standard care (n=47)	P value
Persistent/recurrent pain, n (%)	4 (8.3)	9 (19.1)	0.146
Additional analgesic use, n (%)	3 (6.3)	8 (17.0)	0.120
Unscheduled hospital/clinic visit, n (%)	2 (4.2)	6 (12.8)	0.159
Readmission, n (%)	1 (2.1)	2 (4.3)	0.617
Complete recovery, n (%)	43 (89.6)	37 (78.7)	0.170
Parent satisfaction score	4.5 ± 0.6	4.1 ± 0.8	0.007
High/very high satisfaction, n (%)	42 (87.5)	33 (70.2)	0.047

DISCUSSION

This randomized trial found that adding structured digital distraction to standard analgesic care improved several short-term perioperative outcomes in children aged 3–10 years. Pain scores were lower from 30 minutes after surgery through discharge, perioperative anxiety was reduced, fewer children required rescue analgesia, and recovery and discharge-readiness times were shorter. Parent satisfaction was also higher. In contrast, adverse events and most clinical outcomes assessed at 2 months did not differ significantly between groups. The reduction in anxiety is consistent with recent evidence supporting digital interventions in pediatric perioperative care. Taylan et al. reported significant reductions in preoperative and intraoperative anxiety with virtual-reality interventions,^[13] while Lee et al. demonstrated lower anxiety, improved induction

behavior, and shorter anesthesia-induction time after immersive virtual preparation.^[14] Systematic reviews and meta-analyses likewise support reductions in preoperative anxiety among children exposed to virtual-reality interventions.^[17,18] Together, these findings suggest that engaging digital content can reduce attention to unfamiliar surroundings and threatening perioperative stimuli.

The postoperative pain findings are also broadly consistent with recent randomized evidence. Mersin et al. observed lower postoperative pain and anxiety after preoperative virtual-reality cartoon viewing in children undergoing tonsillectomy and adenoidectomy,^[16] and Kelly et al. reported less pain during Kirschner-wire removal when virtual-reality distraction was added to standard care.^[19] However, the evidence is not uniform. Zhao et al. found statistically lower postoperative pain scores in pooled analyses but judged the magnitude of benefit to be

small, while Taylan et al. found no significant pooled effect on postoperative pain.^[13,15] Differences in procedure type, intervention timing, age, pain measurement, and background analgesia may explain these variations.

The lower rescue-analgesia requirement and shorter recovery observed here suggest potential benefits beyond subjective pain reporting. Reduced anxiety and behavioral distress may facilitate cooperation and contribute to a smoother perioperative course. These secondary findings nevertheless require cautious interpretation because current evidence is more consistent for anxiety and procedural pain than for analgesic-sparing or recovery effects. Broader evidence supports virtual reality as a nonpharmacological pain-management adjunct across perioperative and procedural settings,^[20] rather than as a substitute for clinically indicated analgesia.

At 2 months, persistent pain, additional analgesic use, healthcare visits, and complete recovery numerically favored digital distraction but were not statistically significant. This pattern suggests that the principal benefit may be concentrated in the immediate perioperative period. The study is limited by its modest sample size, single-center design, inclusion of both major and minor procedures, inability to blind participants, and developmental variation across the 3–10-year age range. Nonetheless, randomization, repeated outcome assessment, and extended follow-up strengthen the findings and support further multicenter evaluation.

CONCLUSION

Digital distraction used as an adjunct to standard analgesic care improved short-term perioperative outcomes in children aged 3–10 years undergoing surgery. The intervention was associated with lower postoperative pain and perioperative anxiety, reduced rescue analgesic use, shorter recovery and discharge-readiness times, and higher parent satisfaction. Most 2-month clinical outcomes did not differ significantly, indicating that the clearest benefits were concentrated in the immediate perioperative and early postoperative periods. Structured, age-appropriate digital distraction may therefore be a useful nonpharmacological adjunct to conventional pediatric pain management. Larger multicenter trials with standardized interventions and prespecified clinically meaningful endpoints are warranted.

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