Research Square

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Effects of Spinal Versus General Anesthesia on QTc Interval and QTc Variability During Elective Cesarean Section: A Prospective Randomized Study

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Abstract

Background

QTc prolongation is associated with increased risk of ventricular arrhythmias. Both pregnancy and anesthesia may modulate ventricular repolarization; however, comparative data between spinal and general anesthesia during cesarean section are limited.

Objective

To compare the effects of spinal and general anesthesia on QTc interval dynamics and QTc variability in parturients undergoing elective cesarean section.

Methods

In this prospective randomized study, 50 ASA II parturients were allocated to spinal anesthesia (Group S, n = 25) or general anesthesia (Group G, n = 25). QTc intervals were recorded at predefined time points. QTc variability (ΔQTc) was defined as the difference between maximum and minimum QTc values recorded during the procedure.

Results

QTc intervals increased significantly over time in both groups ($p < 0.05$), with no significant differences between groups at individual time points. In Group G, QTc prolongation occurred at 5 minutes and postoperatively, whereas in Group S, prolongation was observed at 15 minutes and postoperatively. QTc variability (ΔQTc) was significantly greater in the general anesthesia group (64 [58–126] ms for general anesthesia and 43 [31.5–57.5] ms for spinal anesthesia; median [IQR]) ($p < 0.001$). No arrhythmic events were observed.

Conclusion

Both anesthetic techniques were associated with transient QTc prolongation; however, general anesthesia resulted in greater QTc variability, suggesting increased instability in ventricular repolarization. These findings suggest increased repolarization instability with general anesthesia, which may warrant closer ECG monitoring in high-risk patients.

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1. Introduction

The time interval between the onset of the QRS complex and the end of the T wave on an electrocardiogram (ECG) is defined as the QT interval, representing the time required for ventricular

depolarization and repolarization [1]. The heart rate-corrected QT interval (QTc) may become prolonged in conditions associated with ventricular electrical instability and is closely related to an increased risk of life-threatening arrhythmias such as torsades de pointes (TdP), ventricular fibrillation, and sudden cardiac death [2, 3].

During pregnancy significant physiologic changes occur in the cardiovascular system, including increase in heart rate, stroke volume, and cardiac output, along with a decrease in systemic vascular resistance. Moreover, increased blood volume, hormonal alterations, and enhanced sympathetic activity are also observed [4]. These physiological adaptations may alter myocardial repolarization and contribute to dynamic changes in the QTc interval [4, 5]. In addition to the physiological changes of pregnancy, cesarean section delivery also introduces further stress responses due to surgery and anesthesia, leading to alterations in may modulate ventricular repolarization dynamics [6].

Due to its rapid onset of action, favorable maternal safety profile, and avoidance of airway intervention, spinal anesthesia (SA) has become the preferred method for elective cesarean section today [7]. However, SA induces sympathetic blockade, leading to hypotension and autonomic imbalance which can affect the duration of QTc interval [8].

General anesthesia (GA), although less commonly used for elective cesarean delivery, remains necessary in selected cases [7, 9]. Laryngoscopy and tracheal intubation (LTI) trigger a marked sympathoadrenal response, which has been shown to affect QTc interval duration [10]. Moreover, several anesthetic agents commonly used during GA—including volatile anesthetics and certain neuromuscular blockers—have been reported to prolong the QTc interval [11, 12]. Oxytocin, routinely administered after delivery, has also been implicated in QTc prolongation [13].

Although previous studies have evaluated the electrophysiological effects of individual anesthetic agents, comparative data regarding the impact of spinal versus general anesthesia on QTc interval dynamics during cesarean section are limited and inconsistent. Therefore, in the present study we aimed to compare the effects of spinal and general anesthesia on QTc intervals in parturients undergoing elective cesarean section and to determine whether either anesthetic technique is associated with fewer alterations in ventricular repolarization.

2. Materials and methods

2.1. Study design and setting

This prospective randomized study was designed to compare the effects of spinal anesthesia and general anesthesia on the QTc interval in patients undergoing elective cesarean section. The study was approved by the local Institutional Review Board (Ethics Committee of Health Science University Haseki Training and Research Hospital, Istanbul, Türkiye; approval date: 04 October 2023; approval number: 169–2023) and registered at ClinicalTrials.gov https://register.clinicaltrials.gov/prs/beta/studies/S000GUHR00000053/recordSummary, NCT07524296

– April 6, 2026). The study adheres to CONSORT guidelines. The research was performed according to the Declaration of Helsinki, and written informed consent was obtained from all participants The study was carried out at the Haseki Training and Research Hospital, a university-affiliated hospital with 800-bed in Istanbul, Türkiye between October 4, 2023 and December 4, 2023.

2.2. Patient selection and group allocation

The patients enrolled in the study were selected from 64 consecutive pregnant women who scheduled for an elective cesarean section delivery (Fig. 1). Exclusion criteria were baseline QTc > 440 ms, use of medications that affect the QTc interval, family history of long QT syndrome, electrocardiographic evidence of arrhythmia and/or conduction abnormalities, or the presence of a permanent pacemaker, contraindications to spinal anesthesia (high intracranial pressure, injection site infection, coagulation disorders, severe hypovolemia, aortic and/or mitral stenosis), history of spinal surgery, congenital spinal deformity or neuromuscular disease, anemia, electrolyte imbalance, significant cardiopulmonary/hepatic/renal disesase, obesity (Body Mass Index > 30 kg/m2), an American Society of Anesthesiologists (ASA) physical classification ≥ III or refusal to participate.

In the preoperative ward an intravenous (IV) line was established and all patients received 10 mL/kg isotonic saline within 20 minutes. Patients were randomly allocated to either the spinal anesthesia group (Group S) or the general anesthesia group (Group G) using a sealed envelope method by an independent investigator who blinded to group allocation and were subsequently transferred to the operating room.

2.3. Anesthesia procedure

In the operating room, patients received isotonic saline at a rate of 8 mL/kg/h for IV hydration. Prexoxgenation was administered via face mask for 3 minutes (8 L/min).

In Group G anesthesia was induced using 1 μg/kg fentanyl and 2-2.5 mg/kg propofol. Muscle relaxation was achieved with 0.6 mg/kg rocuronium and endotracheal intubation was performed with an experienced anesthesiologist on the first attempt. Following intubation, mechanical ventilation was provided in volume-controlled mode using an anesthesia machine (Dräger Primus, Dräger Medical Systems, Inc., Danvers, MA, USA), with a tidal volume set at 6–8 mL/kg based on ideal body weight and a positive end-expiratory pressure of 5 cmH_2O. The respiratory rate was adjusted to maintain end-tidal carbon dioxide ($EtCO_2$) levels between 32 and 36 mmHg. Anesthesia was maintained with sevoflurane at 0.8-1.0 minimum alveolar concentration (MAC) in an oxygen–air mixture (fraction of inspired oxygen [FiO_2] = 0.4) until the delivery of neonate. After delivery, 1.2 MAC of sevoflurane, additional doses of rocuronium (0.15 mg/kg) and fentanyl (1 μg/kg) were used for the maintenance of anesthesia. At the end of the procedure, residual neuromuscular blockade was reversed with IV sugammadex (4 mg/kg). Tracheal extubation was carried out once the patient was fully awake and breathing spontaneously with adequate tidal volume.

In Group S, patients were placed in the sitting position, and spinal anesthesia was achieved at the L4-L5 interspace using a 25-gauge Whitacre pencil-point spinal needle under strict sterile conditions after

intradermal injection of 1 mL 2% lidocaine hydrochloride. Once free flow of cerebrospinal fluid was observed, 12.5 mg (2.5 mL) of hyperbaric bupivacaine (Marcaine Spinal 0.5% Heavy; AstraZeneca, Türkiye) was injected into the subarachnoid compartment for 30 seconds. Following patients were immediately placed in the supine position with a 15-degree left lateral tilt until delivery of the neonate. Oxygen was delivered to patients via a face mask at a rate of 5 L/min. Pinprick test was used to evaluate the level of sensory blockade and T6 dermatome level was considered adequate for surgery.

2.4. Monitoring

Non-invasive blood pressure (NIBP), heart rate (HR), peripheral oxygen saturation (SpO_2), and continuous electrocardiographic (ECG) monitoring were performed throughout the procedure using a standard anesthesia monitor (BeneView T8 Patient Monitor, Shenzhen Mindray Bio-Medical Electronics Co., Ltd., Shenzhen, China). QT interval measurements were automatically obtained from lead II, and corrected QT (QTc) values were automatically derived by applying Bazett's formula ($QTc = QT/\sqrt{RR\ [s]}$) via the ECG monitoring system.

QTc intervals were measured and recorded at predefined time points: prior to anesthesia induction in the general anesthesia group (QTc-pre) or before intrathecal injection in the spinal anesthesia group (QTc-pre); at 1, 5, 10 and 15 minutes following endotracheal intubation or intrathecal injection, and immediately after the surgery (following surgical closure or tracheal extubation in group G, QTc-post). The difference between the longest and shortest QTc values (ΔQTc) obtained from QTc measurements taken at five-minute intervals was also recorded.

2.5. Data collection

Demographic and clinical variables, including age, sex, height, weight, body mass index (BMI), comorbidities, and American Society of Anesthesiologists (ASA) physical status were documented. In Group S, the maximum sensory block level was assessed. Cardiopulmonary adverse events such as hypotension (mean arterial pressure ≤ 70 mmHg), hypertension (systolic ≥ 160 mmHg and/or diastolic ≥ 90 mmHg), bradycardia (heart rate ≤ 50 beats/min), tachycardia (heart rate ≥ 100 beats/min), hypoxemia (SpO_2 < 90%) and arrhythmia were also recorded. Cases where spinal anesthesia was converted to general anesthesia for any reason or cases with missing data were excluded from the evaluation.

2.6. Statistical analysis

Statistical Package for Social Sciences software for Windows (SPSS, version 27.0; IBM, Chicago, IL, USA) was used to analyse of study data. Quantitative variables were expressed as mean ± standard deviation (SD), while categorical variables were represented as patient numbers and percentages. Normality of quantitative variables was assessed using the Kolmogorov–Smirnov/Shapiro–Wilk test. Normally distributed data were compared between the groups using independent Student's t-test, while the Mann–Whitney U test was applied for non-normally distributed variables. Categorical variables were compared using chi-squared or Fisher's exact tests. Duration of QTc within each group were evaluated using repeated measures analysis of variance with Greenhouse-Geisser correction; Bonferroni test was

used for post-hoc comparisons. Based on a previous study, the duration of QTc was 428 ± 26 ms after C/S performed with spinal anesthesia. Power analysis with α = 0.05 and β = 0.2 revealed that a minimum 25 patients per group was required to detect at least a 20 ms difference in QTc duration in pregnant patients undergoing general anesthesia [14]. A p-value < 0.05 was considered statistically significant.

3. Results

A total of 64 consecutive parturients scheduled for elective cesarean section were initially assessed for eligibility in this prospective randomized study. Eight patients were excluded due to not meeting the inclusion criteria, and six declined to participate. Consequently, 50 patients were included in the final analysis, with 25 patients allocated to the spinal anesthesia group (Group S) and 25 patients to the general anesthesia group (Group G) (Fig. 1). Data recording was carried out by the study researchers.

Baseline demographic characteristics were comparable between the two groups. There were no statistically significant differences in age, gender, weight, height, or body mass index (BMI) (Table 1). All participants were classified as ASA physical status II. Gestational diabetes mellitus was present in 3 (12%) patients in Group S and 1 (4%) patient in Group G, with no significant difference between the groups (p = 0.609).

Table 1
Patient characteristics.

Variables	**Group S (N = 25)**	**Group G (N = 25)**	**P value**
Age (yr)	29 ± 6	28 ± 6	0.705[a]
Weight (kg)	75 ± 13	74 ± 11	0.906[a]
Height (cm)	160 ± 5	162 ± 5	0.196[a]
BMI (kg/m2)	28.95 ± 4.33	28.21 ± 3.61	0.512[a]
GDM n (%)	3 (%12)	1 (%4)	0.609[b]
Hypotension n (%)	8 (32%)	6 (24%)	0.529[b]

Values are expressed as mean ± SD or percentage and number of patients. [a] Student's t-test, [b] Chi-square test. BMI: body mass index, GDM: gestational diabetes mellitus.

Table 2
Comparisons of QTc values of the groups.

Time point	Group S (N = 25)	Group G (N = 25)	P_1	P_2	P_3
QTc-pre	427 ± 13	424 ± 15	0.386 [a]	-	-
QTc-1	435 ± 27	432 ± 27	0.726 [a]	1.000	1.000
QTc-5	437 ± 16	444 ± 29	0.294 [a]	0.173	**0.029**
QTc-10	438 ± 25	433 ± 36	0.646 [a]	0.640	1.000
QTc-15	440 ± 17	434 ± 42	0.508 [a]	**0.023**	1.000
QTc-post	448 ± 24	456 ± 30	0.292 [a]	**0.008**	**< 0.001**

Values were expressed as mean ± SD and ms. P_1 value: comparison between groups; P_2 value: compared to QTc-pre in group S; P_3 value: compared to QTc-pre group G. [a] Student's t test

Analysis of QTc interval measurements demonstrated no significant differences between the spinal and general anesthesia groups at any measurement time point ($p > 0.05$). However, within-group comparisons revealed significant changes over time. In Group S, QTc values measured at 15 minutes (QTc-15) and immediately after surgery (QTc-post) were significantly prolonged compared with baseline values (QTc-pre) ($p = 0.023$ and $p = 0.008$, respectively). In Group G, QTc values at 5 minutes (QTc-5) and postoperatively (QTc-post) were significantly prolonged compared with baseline measurements (QTc-pre) ($p = 0.029$ and $p < 0.001$, respectively). Furthermore, the variability in QTc interval, expressed as ΔQTc (the difference between the maximum and minimum QTc values recorded during the procedure), was significantly greater in the general anesthesia group (64 [58–126]; median [IQR]) compared with the spinal anesthesia group (43 [31.5–57.5]; median [IQR]) ($p < 0.001$) (Fig. 2).

The number of patients with QTc ≥ 450 ms and ≥ 470 ms during the procedure was similar between groups ($p = 0.333$ and $p = 0.136$ respectively). However, ΔQTc ≥ 60 ms was significantly more frequent in the general anesthesia group (5 vs 18 $p < 0.001$) (Fig. 3).

Mean blood pressure was significantly lower in the spinal anesthesia group at the 5 and 10 minutes following spinal anesthesia or endotracheal intubation (Fig. 4). Regarding intraoperative hemodynamic events, mild hypotension occurred in 8 patients (32%) in the spinal anesthesia and 6 patients (24%) in the general anesthesia group, and this was successfully managed with intravenous fluid administration and/or adjustment of inhalational anesthetic concentration (Table 1). No cases of hypertension, tachycardia, arrhythmia, or hypoxemia were observed during the study period. In the spinal anesthesia group, the maximum sensory block level was T4 in 9 patients (36%) and T6 in 16 patients (64%).

4. Discussion

The aim of the present study was to investigate changes in the QTc interval during C/S and to compare the effects spinal anesthesia and general anesthesia on ventricular repolarization. The main findings of the study can be summarized follows. First, spinal and general anesthesia demonstrated a similar overall effect on QTc interval duration. Second, in patients who received general anesthesia, QTc duration was significantly prolonged 5 minutes after laryngoscopy and tracheal intubation compared with baseline values (from 424 ± 15 ms to 444 ± 29 ms, p = 0.029). In contrast, in patients who received spinal anesthesia, QTc duration was significantly prolonged 15 minutes after intrathecal administration of bupivacaine compared with baseline values (from 427 ± 13 ms to 440 ± 17 ms, p = 0.023). Third, after surgical skin closure or tracheal extubation, QTc intervals were significantly prolonged in both groups compared with baseline measurements (spinal anesthesia group: from 427 ± 13 ms to 448 ± 24 ms, p = 0.008; general anesthesia group: from 424 ± 15 ms to 456 ± 30 ms, p < 0.001). Finally, the magnitude of QTc variability (ΔQTc) was significantly greater in patients receiving general anesthesia than in those receiving spinal anesthesia (p < 0.001).

Pregnancy is associated with significant cardiovascular adaptive and hormonal changes such as eccentric hypertrophy, persistent sympathetic activation and pronounced elevation in estrogen and progesterone concentrations which may lead to changes in expression and function of cardiac ion channels. These alterations influence ventricular repolarization dynamics and contribute to QTc interval prolongation [15–17]. In a recent meta-analysis to investigate the magnitude of QTc interval alteration, it has been reported that the QTc progressively prolongs throughout pregnancy, with an average prolongation of approximately 23 ms (95% CI: 12.3 to 33.3; p < 0.001) in the third trimester compared to non-pregnant women. Moreover similar to our results (426 ± 14 ms, in whole patients), in this study the QTc value calculated using only the Bazzett method was found to be 416 (404–425) ms in the third trimester [18].

Sympathoadrenal stimulation related to LTI causes significant increase in the plasma catecholamine levels that remained over 5 minutes and elevated catecholamine levels has been associated with prolongation of QTc interval [19, 20]. Yoo KY et al. [21] has been reported that plasma norepineprine concentration increase from 562 ± 260 pg/mL (baseline) to 758 ± 287 pg/mL (1 min after endotracheal intubation) and 860 ± 361 pg/mL (after delivery) in patients undergoing cesarean section under general anesthesia. In the present study we observed the QTc prolongation 5 min after LTI and tracheal extubation that can be attributed to transient sympathetic stimulation associated with airway manipulation.

It is well known that preeclampsia has a significant impact on ventricular repolarization and QTc interval is significantly prolonged in preeclamptic women compared to healthy pregnant women related to magnesium sulfate medication, higher potassium level, sympathetic hyperactivity and increased hemodynamic stress [18, 22]. Although it has been shown that spinal anesthesia normalize the prolonged QTc interval in preeclampsia, in a recent study Karahan MA et al. [24] found that QTc interval

prolongs 44, 34 and 23 ms 1, 5 and 10 min after spinal anesthesia respectively in healthy partruents undergoing C/S delivery [23]. In another studies Dogan Z et al. [25] and Tör IH et al. [26] also found that QTc interval was prolonged significantly after spinal anesthesia in C/S. These results were consistent with our findings. Similarly, it has been reported that spinal anesthesia also leads to significant QTc interval prolongation in healthy non-obstetric patients [27–29].

QTc prolongation after spinal anesthesia can be explained by a compensatory increase in sympathetic activity in the unblocked segments, including cardiac sympathetic fibers originating from T1–T4. Additionally, the decrease in arterial blood pressure induced by spinal anesthesia can enhance sympathetic outflow via baroreceptor activation, thereby prolongs the QTc interval [29–31]. Moreover, some studies suggest that the effect of spinal anesthesia on the QTc interval may depend on the amount of the local anesthetic [14, 32]. In these studies, researchers did not observe QTc prolongation after spinal anesthesia with 10 mg bupivacaine or levobupivacaine.

QTc variability reflects dynamic changes in ventricular repolarization and indicates arrhythmogenic risk rather than absolute QTc duration [33]. In this study, ΔQTc was significantly greater in the general anesthesia group, suggesting more pronounced repolarization instability, possibly due to sympathetic stimulation related to LTI and effects of inhalational agents. In contrast, spinal anesthesia may provide a more stable autonomic profile.

It should be noted that the study has several limitations. First, the study was conducted at a single center and had a small sample size. Second, only healthy parturients with ASA II physical status were included, which limits the general applicability of the findings to high-risk pregnancies such as preeclampsia or those with cardiovascular disease. Third, potential confounders that could influence the QTc interval were not consider as independent variables, such as oxytocin dosage, plasma elecrolyte and catecholamine concentrations, and hormonal fluctuations. Finally, the study focused on short-term intraoperative QTc changes and did not include continuous postoperative ECG monitoring to detect possible arrhythmic events.

Conclusion

The present study demonstrated that both spinal and general anesthesia may lead to transient changes in QTc interval duration in parturients undergoing elective cesarean section. Although absolute QTc values were comparable, general anesthesia was associated with greater QTc variability, suggesting a more pronounced effect on ventricular repolarization dynamics. These results suggest that the type of anesthesia used can have an effect on repolarization dynamics; thus, may indicate a potential electrophysiological vulnerability rather than clinically overt arrhythmia. Therefore close QTc monitoring may be beneficial, especially in patients with known susceptibility to cardiac arrhythmias such as preeclampsia, diabetes mellitus or hypertension.

Declarations

Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Ethics approval and consent to participate

The study was approved by the local Institutional Review Board (Ethics Committee of Health Science University Haseki Training and Research Hospital, Istanbul, Türkiye; approval date: 04 October 2023; approval number: 169–2023). The research was performed according to the Declaration of Helsinki and all patients provided written informed consent to participate and to have their data published.

Consent for publication

Not Applicable

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Author Contribution

OC, SU : study coordinator, study concept and design, drafting of the manuscript; OC, SU, MH, CY, YT, ID : study concept and design, data interpretation, and critical editing; OC, SU, MH, CY, YT, ID : randomization and manuscript revision; OC, SU, MH, CY, YT, ID : data interpretation and manuscript revision; OC, SU, MH, CY, YT, ID : supervision of the study and manuscript revision. All authors critically reviewed the manuscript and approved the final version.

Data Availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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Figures

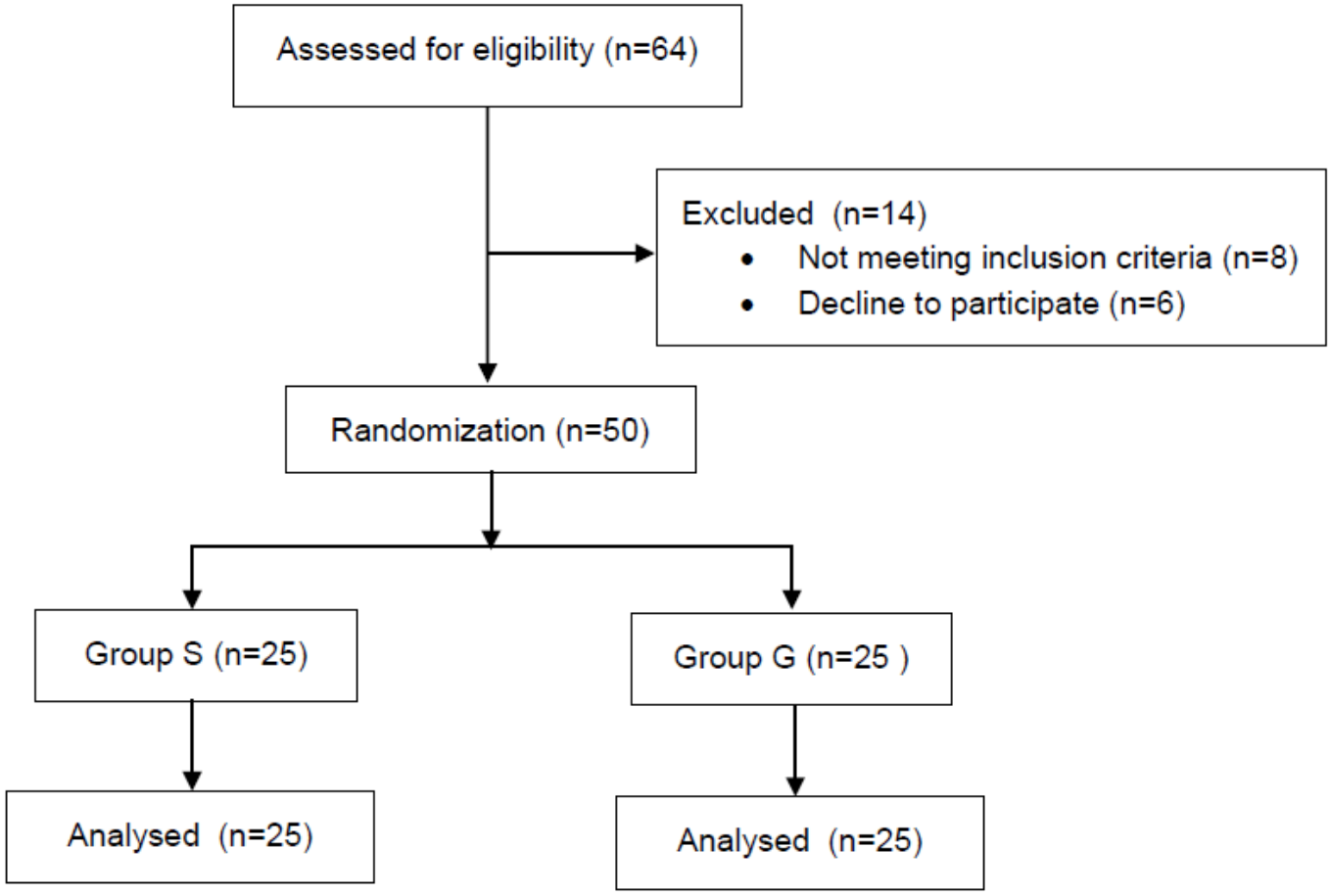


Figure 1

Flowchart diagram of the study.

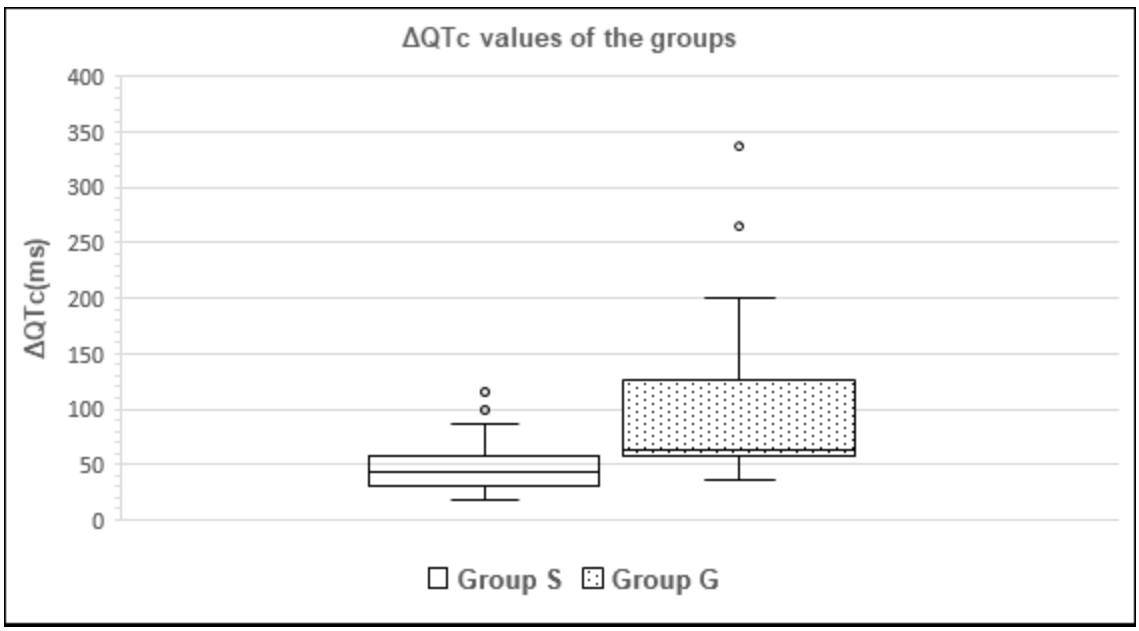


Figure 2

Boxplot distribution of the ΔQTc values of the groups. The horizontal lines from the bottom to the top represent the 10th, 25th, 50th (median), 75th, and 90th percentiles. Outlying values are represented by circles.

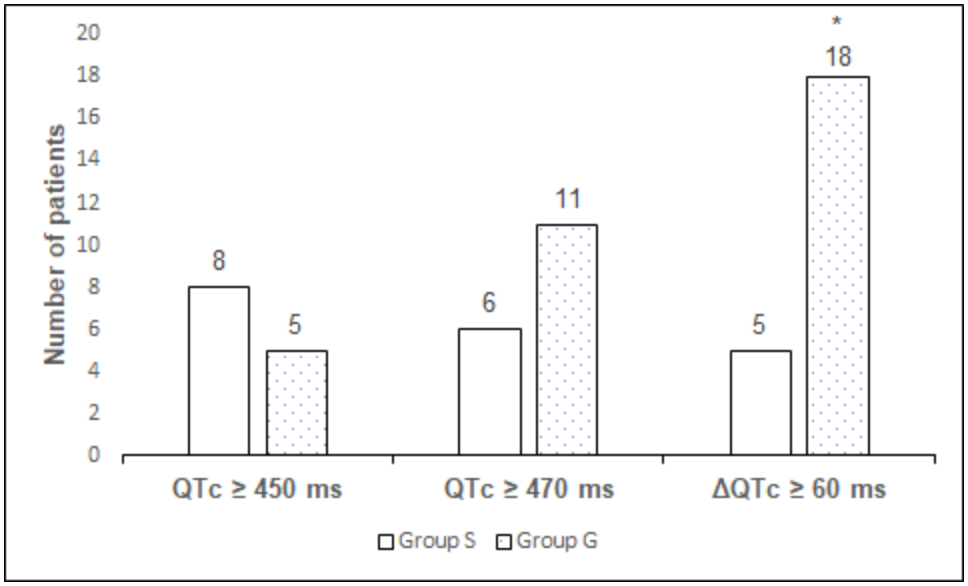


Figure 3

Comparison of groups based on the prolongation of QTc and ΔQTc. Group S: spinal anesthesia group, Group G: general anesthesia group. * p< 0.001.

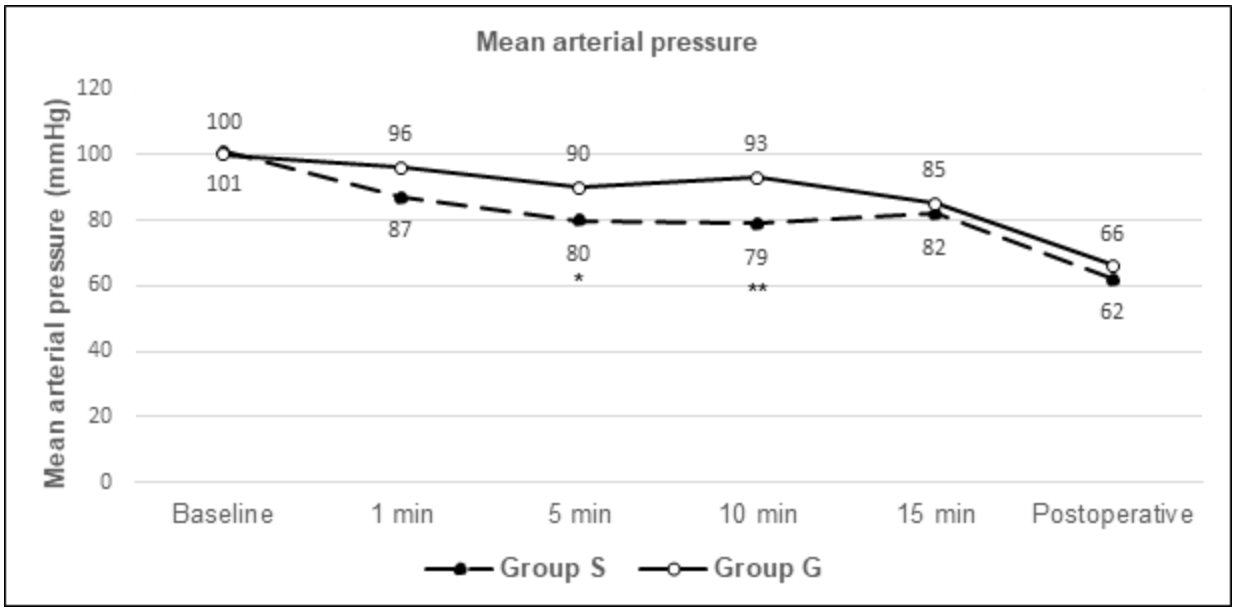


Figure 4

Comparison of the mean arterial pressure during the procedure at different time points between the groups. Group S: spinal anesthesia group, Group G: general anesthesia group. * p< 0.001.