

Impact of Tramadol Administration on Cardio-Electrophysiological Balance following General Surgery

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Abstract: Tramadol is widely used for perioperative analgesia but has been implicated in electrophysiological effects on ventricular repolarisation and conduction. The index of cardiac electrophysiological balance (ICEB = QT/QRS) and its corrected form (ICEBc = QTc/QRS) are emerging ECG-derived markers linked to pro-arrhythmic risk. Evidence on tramadol's impact on these indices in surgical patients is limited. **Objective:** To assess the effect of intravenous tramadol on ICEB and ICEBc in adults undergoing general surgery. **Methods:** This prospective, single-centre, pre-post observational study was conducted in the General Surgery Department of Ibn-e-Siena Hospital, Multan, from June 2024 to June 2025. We enrolled 100 consecutive adults undergoing general surgery. All patients received intravenous tramadol 2 mg/kg. Standardized 12-lead ECGs were obtained immediately before and after tramadol administration to measure QT, QTc, and QRS; ICEB was calculated as QT/QRS and ICEBc as QTc/QRS . Vital signs (blood pressure, heart rate, oxygen saturation) were monitored throughout. Percentage change from baseline was computed for each parameter. Descriptive statistics summarized data; pre-post differences were tested using two-sided paired tests with $\alpha=0.05$. Linear regression explored the association between tramadol dose (total mg, reflecting weight-based dosing) and post-dose ICEBc, adjusting for the corresponding baseline value. **Results:** Heart rate changed by 0.5% from baseline. QT and QTc increased by 2.5% (both $p<0.001$). QRS duration decreased by 4.5% after tramadol. ICEB and ICEBc increased by 3.6% and 3.3%, respectively. In regression analysis, tramadol dose independently predicted higher corrected ICEB ($\beta=0.198$, $p=0.005$). No deaths or serious arrhythmias were observed during follow-up. **Conclusion:** Intravenous tramadol is associated with statistically significant, directionally pro-arrhythmic shifts in ECG-derived indices of electrophysiological balance (increased ICEB/ICEBc) in general-surgery patients, although no serious arrhythmias occurred. Peri-operative monitoring of repolarization and conduction parameters may be prudent when tramadol is used, particularly at higher weight-based doses.

Keywords: Arrhythmias, Cardiac; Electrocardiography; Electrophysiology; Postoperative Period; Surgical Procedures, Operative; Tramadol.

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Introduction

Postoperative pain is the most frequent complication of any surgical procedure. The management of pain has advanced over time. However, still 70% of surgical patients experience a mild to severe degree of pain. (1) Timely and effective pain management can improve outcomes, reduce the risk of complications and hospital stay and speed up recovery.

Pharmacological intervention with analgesics is the primary method of pain management. Opioids are the most prescribed analgesics, including tramadol, to patients experiencing mild to severe pain. Tramadol has a dual mechanism of action and is a perfect opioid for patients who have a contraindication to more potent drugs, but it can have some serious adverse effects. (2) Studies have shown that it can significantly affect the cardiac electrophysiology, leading to arrhythmias. (3, 4)

A recent ECG marker, the index of cardiac electrophysiological balance, has been discovered to predict arrhythmogenic risk, including ventricular arrhythmias and heart rate variations. (5, 6) There has been limited research on the impact of opioids like tramadol on the index of cardiac electrophysiological balance and its corrected version. Since tramadol is widely used in surgical patients, it is important to study its impact on ECG parameters.

Thus, this study was conducted to assess the impact of tramadol on the index of cardiac electrophysiological balance and its corrected version in patients who underwent general surgery.

Methodology

A prospective study was performed in the General Surgery Department of Ibn-e-Siena Hospital, Multan, from June 2024 to June 2025. A total of 100 adult patients who underwent general surgery procedures were selected for the study. Patients on antiarrhythmic drugs, with electrolyte imbalance, arrhythmias or rhythm changes as seen on ECG and chronic heart disease were excluded. The ethical committee of the hospital approved the study, and all patients agreed verbally to participate.

Patients were placed in the supine position, and 12-ECGs were recorded at 10mm/mV and 25 mm/s before and after giving tramadol. The index of cardiac electrophysiological balance was calculated by dividing the QT interval by the QRS duration, and the corrected index was calculated by dividing the corrected QT interval by the QRS duration. A 2mg/kg tramadol dosage was administered intravenously. Blood pressure, heart rate and oxygen saturation were observed regularly.

All data was evaluated by SPSS version 22. The Kolmogorov-Smirnov test checked data normalcy. Percentage, mean, and standard deviation were used to present categorical parameters and continuous parameters, respectively. Variables before and after the procedure were compared by paired t-tests. Significant predictors of the corrected index of cardiac electrophysiological balance were determined by linear regression analysis. Statistical significance was set at a probability value of less than 0.05.



Results

Hundred patients underwent general surgery with a mean age of 45.1 years. The majority of the population (60%) was female. Mean tramadol dosage was 97.17 ± 8.56 mg. Patients were stable with a mean ASA score of 2 and haemoglobin of 11.93 g/dL. Average surgery time was 55 minutes, and patients stayed in the hospital for 3 days. All laboratory parameters were in the normal range, as shown in Table I.

The percentage change in heart rate before and after the procedure was 0.5%. Similarly, QT and QTc ($p < 0.001$) changed by 2.5%. QRS had a difference of -4.5% between pre and post tramadol administration. ICEB and ICEBc changed significantly by 3.6% and 3.3%, respectively (Table II). Tramadol dosage was an independent predictor of high corrected cardiac electrophysiological balance index ($\beta = 0.198$, $p = 0.005$) (Table III). No patients died during follow-up or reported any serious arrhythmias.

Table I: Patients' demographic and clinical data

| Parameters | N (%) |
|---------------------|--------------------|
| Mean age | 45.18 \pm 16.22 |
| Sex | |
| Male | 40 (40%) |
| Female | 60 (60%) |
| Surgical duration | 55 (40-100) |
| Mean ASA score | 2.02 \pm 0.76 |
| Hospital stays | 3 (3-5) |
| Mean tramadol dose | 97.17 \pm 8.56 |
| Mean glucose | 115.12 \pm 40.68 |
| Mean urea | 27 (20-35) |
| Mean creatinine | 0.81 \pm 0.17 |
| AST | 23 (17-29) |
| ALT | 21 (15-30) |
| Mean sodium | 137.59 \pm 3.24 |
| Mean potassium | 4.13 \pm 0.51 |
| Mean calcium | 9.02 \pm 0.89 |
| C-reactive protein | 2 (0-4) |
| WBCs | 6 (5-10) |
| Mean hemoglobin | 11.93 \pm 2.26 |
| Mean hematocrit (%) | 40.05 \pm 5.42 |

Table II: ECG parameters before and after the procedure

| Parameters | Before surgery | After surgery | P |
|------------|--------------------|--------------------|--------|
| Heart rate | 76.57 \pm 14.57 | 76.87 \pm 13.70 | 0.496 |
| QT | 340.22 \pm 35.31 | 350.91 \pm 29.90 | 0.001 |
| QTc | 406.11 \pm 25.25 | 420.59 \pm 30.84 | <0.001 |
| QRS | 79.80 \pm 10.45 | 77.63 \pm 10.7 | 0.023 |
| ICEB | 3.32 \pm 0.74 | 3.65 \pm 0.75 | <0.001 |
| ICEBc | 4.09 \pm 0.92 | 4.37 \pm 0.81 | <0.001 |

Table III: Strong predictors of corrected ICEB

| Variables | B | SE | β | T | P |
|-------------------|-------|-------|---------|-------|-------|
| Age | 0.005 | 0.005 | 0.088 | 1.339 | 0.178 |
| BMI | 0.011 | 0.010 | 0.069 | 1.093 | 0.282 |
| Surgical duration | 0.002 | 0.002 | 0.028 | 0.421 | 0.670 |
| Hemoglobin | 0.033 | 0.028 | 0.084 | 1.148 | 0.248 |
| Potassium | 0.209 | 0.121 | 0.120 | 1.731 | 0.073 |
| Sodium | 0.021 | 0.020 | 0.066 | 1.059 | 0.291 |
| Tramadol dose | 0.024 | 0.009 | 0.198 | 3.040 | 0.005 |

Discussion

This study was conducted to investigate the impact of administering tramadol on ECG findings in patients who underwent general surgery. The results showed that there was a significant independent association between tramadol dose and ICEB and ICEBc, which are risk factors of arrhythmogenic risk. This is the first local study to determine this

relationship in postoperative patients. Literature also shows that tramadol can affect electrocardiographic variables like prolonging QT and QTc interval, which makes patients more susceptible to arrhythmias. (7, 8) We noted a significant increase in QT and QTc interval after the tramadol dose. However, since we included the indices of cardioelectrophysiological balance, we explored a new predictor of arrhythmogenic risk. These parameters account for the connection

between repolarisation and ventricular conduction as determined by previous studies. (9, 10) We also assessed that tramadol significantly decreases the QRS duration and impacts the depolarisation and repolarisation of ventricles. Hence, the shorter QRS duration and prolonged QT interval result in higher indices indicating electrophysiological imbalance.

The percentage change in ICEB and ICEBc was significantly different after tramadol, suggesting that even a therapeutic dose can increase the risk of arrhythmias. In addition, this risk is dose dependent, as tramadol was independently linked to ICEBc, which is important to note, as patients are already predisposed to arrhythmias after surgery. Although no case of arrhythmias was observed in the present study, a higher index suggests that administering a higher dose of tramadol would have yielded different results. (9, 11) Hence, patients with preexisting cardiac conditions should be carefully monitored after surgery. (12)

Conclusion

There is a significant independent association between tramadol and indices of cardioelectrophysiological balance in patients post-general surgery.

Declarations

Data Availability statement

All data generated or analysed during the study are included in the manuscript.

Ethics approval and consent to participate

Approved by the department concerned. (IRBEC-24)

Consent for publication

Approved

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Conflict of interest

The authors declared the absence of a conflict of interest.

Author Contribution

MAA (HO)

Manuscript drafting, Study Design,

SMR (HO)

Review of Literature, Data entry, Data analysis, and drafting articles.

MK (HO)

Conception of Study, Development of Research Methodology Design,

AA (HO)

Study Design, manuscript review, and critical input.

NSA (HOD)

Manuscript drafting, Study Design,

All authors reviewed the results and approved the final version of the manuscript. They are also accountable for the integrity of the study.

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