BMC Anesthesiology

RESEARCH Open Access

# Preoperative electrocardiogram in prediction of 90-day postoperative mortality: retrospective cohort study

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## Abstract

**Background** There are conflicting data on the relationship between preoperative electrocardiogram and postoperative mortality. We aimed to assess the predictive value of preoperative ECG on postoperative all-cause mortality in patients undergoing non-cardiac surgery (NCS).

**Methods** We retrospectively reviewed records of hospitalized patients who underwent an internal preoperative examination and subsequent NCS in the years 2015–2021. We recorded patient comorbidities, vital functions, results of biochemical tests, ECG. The primary end point was 90-day postoperative all-cause mortality, acquired from the hospital records and the nationwide registry run by the Institute of Health Information and Statistics of the Czech Republic.

**Results** We enrolled a total of 2219 patients of mean age 63 years (48% women). Of these, 152 (6.8%) died during the 90-day postoperative period. There were statistically significant associations between increased 90-day postoperative all-cause mortality and abnormal ECG findings in resting heart rate (≥ 80 bpm, relative risk [RR] = 1.82 and ≥ 100 bpm, RR = 2.57), presence of atrial fibrillation (RR = 4.51), intraventricular conduction delay (QRS > 0.12 s, RR = 2.57), ST segment changes and T wave alterations, left bundle branch hemiblock (RR = 1.64), and right (RR = 2.04) and left bundle branch block (RR = 4.13), but not abnormal PQ and QT intervals, paced rhythm, incomplete right bundle branch block, or other ECG abnormalities. A resting heart rate (≥ 80 bpm, relative risk [RR] = 1.95 and ≥ 100 bpm, RR = 2.20), atrial fibrillation (RR = 2.10), and right bundle branch block (RR = 2.52) were significantly associated with 90-day postoperative all-cause mortality even in subgroup of patients with pre-existing cardiac comorbidities.

**Conclusions** Patients with abnormal preoperative ECG findings face an elevated risk of all-cause mortality within 90 days after surgery. The highest mortality risk is observed in patients with atrial fibrillation and left bundle branch block. Additionally, an elevated heart rate, right bundle branch block, and atrial fibrillation further increase the risk of death in patients with pre-existing cardiac conditions.

**Keywords** Preoperative electrocardiogram, Heart rate, Atrial fibrillation, Bundle branch block, Mortality

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## Introduction

An electrocardiogram (ECG) is a commonly used procedure in the preoperative assessment of patients undergoing non-cardiac surgery (NCS). It is frequently employed even before low-risk surgery despite guideline recommendations to limit testing in these groups [1, 2].

A multivariate analysis has shown that patients over the age of 64 years with a history of hypertension have a greater risk for the presence of major ECG changes [3, 4]. In low-risk patients undergoing low-risk surgery, a preoperative ECG did not predict early termination of the treatment and triggered very few cancellations of the surgery, having little effect on preoperative management [5].

Some studies have examined the prediction of postoperative mortality in patients with bundle branch block (BBB) or other ECG abnormalities. A study on 348 high-risk patients from Poland did not find any relationship between abnormal ECG and postoperative adverse cardiac outcome [6]. According to another study, the presence of BBB is not associated with a higher risk of postoperative cardiac complications or postoperative mortality [7]. However, an analysis of over 150 000 patients showed significant associations of various ECG abnormalities (including BBB) with in-hospital mortality, but not with perioperative myocardial infarction [8].

In patients with coronary artery disease (CAD), ST segment depression and higher heart rate are linked to all-cause mortality and major adverse cardiac complications (MACE) [9]. In liver transplant recipients there was no association between preoperative prolongation of the QTc interval and overall mortality [10]. A meta-analysis of hip-fracture patients showed an association between increased postoperative mortality and abnormal ECG [11]. In patients undergoing major vascular surgery in 1997, voltage criteria of left ventricular hypertrophy (Sokolow-Lyon index) and ST segment depressions were significantly associated with postoperative myocardial infarction and cardiac death [12]; however, there was a small number of primary events as only two cardiac deaths occurred in 405 patients. Preoperative myocardial ischemia on ECG was identified as an independent factor for long-term mortality after endovascular aneurysm repair of infrarenal abdominal aneurysm [13]. The value of preoperative ECG testing in predicting 90-day postoperative all-cause mortality in unselected populations undergoing NCS is still unknown.

The current study is essential because it addresses a significant gap in the literature concerning the role of preoperative ECG in predicting postoperative outcomes across a diverse patient population. While specific ECG abnormalities have been linked to adverse outcomes in targeted patient groups, there is limited evidence on their prognostic value in a general NCS population.

The Revised Cardiac Risk Index (RCRI) is a widely used tool to predict perioperative cardiac complications in non-cardiac surgery patients. It includes six independent variables: high-risk surgery, history of ischemic heart disease, history of congestive heart failure, history of cerebrovascular disease, insulin-dependent diabetes mellitus, and preoperative serum creatinine > 2 mg/dl. The RCRI is valuable for identifying patients at risk for cardiac complications; however, its predictive accuracy may be enhanced by incorporating additional diagnostic tools such as the ECG. While the RCRI provides a structured approach to risk assessment, our study explores whether preoperative ECG findings can offer complementary prognostic information.

This study seeks to provide robust evidence on the predictive value of preoperative ECG in a broad NCS population, thereby enhancing the current understanding and application of perioperative risk assessment tools. Our findings could lead to improved clinical guidelines and better outcomes for patients undergoing non-cardiac surgery.

## Methods

### Study design and patients

This study was designed as a retrospective, single-center analysis of hospital records of patients undergoing internal preoperative examination before non-elective NCS. We excluded patients who were not operated on and those without preoperative ECG testing.

A computerized search identified all consecutive patients who underwent an internal examination required by another specialty from November 2015 through September 2021. Data were collected from January through March 2022. Data collection and analysis were anonymized. The total number of reviewed internal examinations was 4074, of which 2362 were preoperative internal examinations. All of the enrolled patients were hospitalized and scheduled for non-elective NCS, ranging from postponable, semi-acute, and acute, to urgent, in the surgical fields of abdominal surgery, traumatology, urology, neurosurgery, gynecology, vascular surgery, proctosurgery, and otorhinolaryngology. For each enrolled patient, we recorded 53 parameters including age, sex, past history, height, weight, BMI, smoking, basic laboratory variables, blood pressure, detailed descriptions of ECG and chest X-ray, type and complications of surgery, changes in preoperative management, and 90-day postoperative all-cause mortality.

Data on all-cause mortality were obtained from the hospital records and the nationwide database supervised by the Institute of Health Information and Statistics of the Czech Republic.

**Table 1** Clinical and other characteristics of patients

| Variable | | |
|---|---|---|
| Age | Mean (± SD) | 63 (± 15) |
| Sex | Men | 1227 (51.9%) |
| | Women | 1135 (48.1%) |
| Hypertension | | 1332 (56.4%) |
| Dyslipidemia | | 604 (25.6%) |
| Atherosclerosis | | 271 (11.5%) |
| Chronic coronary syndrome | | 390 (16.5%) |
| Chronic heart failure | | 63 (2.7%) |
| Chronic kidney disease | | 140 (5.9%) |
| Ischemic or hemorrhagic stroke | | 205 (8.7%) |
| Atrial fibrillation | | 193 (8.2%) |
| Diabetes mellitus | | 538 (22.8%) |
| Pulmonary disease | COPD | 133 (5.6%) |
| | AB | 100 (4.2%) |
| | ACOS | 14 (0.6%) |
| | Other | 62 (2.6%) |
| Oncologic disease, malignancy | | 336 (14.2%) |
| BMI | Mean (± SD) | 28 (± 6) |
| Smoking | Smoker | 702 (29.7%) |
| | Ex-smoker | 279 (11.8%) |
| Potassium (mmol/l) | Mean (± SD) | 4.24 (± 0.48) |
| CRP (mg/l) | Median (IQR) | 8 (3–43) |
| Systolic blood pressure | Mean (± SD) | 139 (± 21) |
| Diastolic blood pressure | Mean (± SD) | 80 (± 12) |
| Heart rate | Mean (± SD) | 79 (± 16) |

SD = standard deviation; COPD = chronic obstructive pulmonary disease; AB = bronchial asthma; ACOS = asthma-COPD overlap syndrome; CRP = C-reactive protein; IQR = interquartile range

### Study goals

The primary goal of the analysis was to determine if ECG abnormalities (both individually and collectively) are associated with a higher risk of 90-day postoperative all-cause mortality.

### Study oversight

The study was conducted in accordance with good clinical practice and was approved by the local ethics committee. Given the retrospective study design, patients did not provide informed consent before study entry.

All the authors involved had access to all patient data and results of statistical analyses. They guarantee the accuracy and completeness of the analyzed data.

### Statistical analysis

Standard descriptive statistics were used for analysis. Mean and standard deviation described continuous parameters, while absolute and relative numbers of patients described binary or categorical parameters. The Mann-Whitney test was used to assess the statistical significance of the differences for continuous variables, and the chi-squared test for other variables. The relative risk of adverse events based on patient characteristics was also calculated. A statistical significance level of $P=0.05$ was used in all analyses. Analyses were performed in SPSS 28.0.1.1 (IBM Corporation, Armonk, NY, USA).

**Table 2** Values of ECG characteristics considered physiological any findings on ECG other than the values listed below were recognized as abnormal

| Parameter | Normal Values |
|---|---|
| Rhythm | sinus rhythm including respiratory arrhythmia |
| Rate | below 100 bpm |
| PQ interval | 120–200 ms |
| QRS interval | below 120 ms |
| QT interval | below 450 ms |
| ST segment | no changes in ST segment |
| T wave | negative T wave in leads III, aVR, V1 |

bpm = beats per minute; ms = milliseconds

## Results

We enrolled a total of 2,362 consecutive patients scheduled for non-cardiac surgeries who underwent an internal preoperative assessment between September 2015 and November 2021. The mean age of the patients was 63.4 years, 48% were female, 56.4% had a history of hypertension, 22.8% had diabetes, 16.5% had chronic coronary syndrome, and 8.2% had atrial fibrillation. The mean heart rate was 79 beats per minute (bpm). Further clinical and other characteristics of the patients are provided in Table 1.

For the following statistical analysis, we excluded patients who were not operated on and those without preoperative ECG testing. The total number of patients excluded for these reasons was 143.

The characteristics of physiological ECG, as defined in this study, are described in Table 2 (all other ECG findings were considered abnormal).

The mortality analysis included 2,219 patients who had ECG tests prior to the surgery. Of these, 639 (28.8%) had a normal ECG, 131 (5.9%) had non-sinus rhythm, 105 (4.7%) had abnormal PQ interval, 258 (11.6%) had left anterior hemiblock (LAH), 38 (1.7%) had left bundle branch block (LBBB), 77 (3.5%) had right bundle branch block (RBBB), 219 (9.9%) had incomplete right bundle branch block (iRBBB), 25 (1.1%) had abnormal QT interval, 434 (19.6%) had ST segment changes (of whom 216 [9.7% of all included patients] had early repolarization ST elevation), 613 (27.6%) had T wave changes, and 527 (23.7%) had other abnormalities (including but not limited to hypertrophy signs, supraventricular extrasystoles [SVES] and ventricular extrasystoles [VES], Q wave pathologies, R wave changes, P pulmonale, P mitrale, pre-excitation). Some patients had multiple abnormalities. A detailed distribution of ECG abnormalities is provided in Table 3.

**Table 3** Relationship between abnormal ECG and postoperative 90-day all-cause mortality

| Characteristics | | Control *N* = 2067 | Death *N* = 152 | *P* |
|---|---|---|---|---|
| Age | Mean (± SD) | 62 (± 15) | 77 (± 10) | **< 0.001** |
| Rhythm | Sinus | 1968 (95.2%) | 120 (78.9%) | **< 0.001** |
| | Atrial fibrillation | 80 (3.9%) | 28 (18.4%) | |
| | Pacemaker | 16 (0.8%) | 2 (1.3%) | |
| | Other | 3 (0.1%) | 2 (1.3%) | |
| Heart rate (bpm) | Mean (± SD) | 79 (± 16) | 86 (± 19) | **< 0.001** |
| PQ interval | < 0.2 s | 1970 (95.3%) | 144 (94.7%) | 0.711 |
| | 0.2–0.3 s | 96 (4.6%) | 8 (5.3%) | |
| | > 0.3 s | 1 (0.0%) | 0 (0.0%) | |
| QRS interval | < 0.12 s | 1969 (95.3%) | 133 (87.5%) | **< 0.001** |
| | > 0.12 s | 98 (4.7%) | 19 (12.5%) | |
| Left bundle branch hemiblock | No | 1834 (88.7%) | 125 (82.2%) | **0.044** |
| | LAH | 231 (11.2%) | 27 (17.8%) | |
| | LPH | 2 (0.1%) | 0 (0.0%) | |
| Bundle branch block | No | 1762 (85.2%) | 120 (78.9%) | **< 0.001** |
| | iRBBB | 207 (10.0%) | 12 (7.9%) | |
| | RBBB | 67 (3.2%) | 10 (6.6%) | |
| | LBBB | 28 (1.4%) | 10 (6.6%) | |
| | Non-specific | 3 (0.1%) | 0 (0.0%) | |
| QT interval | < 0.45 s | 2,045 (98.9%) | 149 (98.0%) | 0.243 |
| | > 0.45 s | 22 (1.1%) | 3 (2.0%) | |
| ST segment changes | No | 1,673 (80.9%) | 112 (73.7%) | **0.003** |
| | Depressions (> 0.5 mm) | 43 (2.1%) | 5 (3.3%) | |
| | Elevations | 8 (0.4%) | 1 (0.7%) | |
| | Depressions and elevations | 10 (0.5%) | 5 (3.3%) | |
| | Early repolarization ST elevations | 203 (9.8%) | 13 (8.6%) | |
| | Depressions (< 0.5 mm) | 130 (6.3%) | 16 (10.5%) | |
| T wave changes | No | 1518 (73.4%) | 88 (57.9%) | **< 0.001** |
| | Yes | 549 (26.6%) | 64 (42.1%) | |
| Other ECG abnormalities* | No | 1585 (76.7%) | 107 (70.4%) | 0.093 |
| | Yes | 482 (23.3%) | 45 (29.6%) | |
| ECG overall | Normal | 619 (29.9%) | 20 (13.2%) | **< 0.001** |
| | Abnormal | 1448 (70.1%) | 132 (86.8%) | |

SD = standard deviation; bpm = beats per minute; LAH = left anterior hemiblock; LPH = left posterior hemiblock; iRBBB = incomplete right bundle branch block; RBBB = right bundle branch block; LBBB = left bundle branch block; * including but not limited to hypertrophy signs, supraventricular extrasystoles (SVES) and ventricular extrasystoles (VES), Q wave pathologies, R wave changes, P pulmonale, P mitrale, pre-excitation

In total, 152 of 2,219 (6.8%) patients died in the 90-day period after the surgery, 32 (1.4%) patients died within 7 days, 54 (2.4%) died between day 8 and day 30, and 66 (3.0%) died between day 31 and 90. Ninety-day postoperative all-cause mortality was significantly increased in patients with the following abnormal ECG findings: atrial fibrillation, increased heart rate above 80 bpm, intraventricular conduction delay, LAH, RBBB, LBBB, and the combination of ST segment elevations and depressions and T-wave alterations (Table 4). Atrial fibrillation and LBBB were associated with the highest relative risk of 90-day postoperative all-cause mortality (Table 4).

Additionally, patients with elevated heart rates had a significantly increased relative risk of 90-day postoperative all-cause mortality correlated with further increases in heart rate. The relative risks of 90-day postoperative all-cause mortality for patients with heart rates above 80 bpm, 90 bpm, and 100 bpm were 1.82, 2.16, and 2.57, respectively.

Abnormal PQ and QT intervals, iRBBB, pacemaker-stimulated rhythm, variables other than the above-mentioned ST segment changes, and other abnormalities (including but not limited to hypertrophy signs, SVES and VES, Q wave pathologies, R wave changes, P pulmonale, P mitrale, pre-excitation) were not associated with increased 90-day postoperative all-cause mortality. There were not enough data for left posterior hemiblock and nonspecific intraventricular conduction delay (Table 4).

**Table 4** Relative risk of 90-day postoperative all-cause mortality by ECG abnormality

| ECG variables | | 90-day mortality | |
|---|---|---|---|
| | | RR (95% CI) | *P* |
| Heart rate [bpm] | ≥ 80 (ref. < 80) | 1.82 (1.33–2.50) | **< 0.001** |
| | ≥ 90 (ref. < 90) | 2.16 (1.59–2.93) | **< 0.001** |
| | ≥ 100 (ref. < 100) | 2.57 (1.83–3.60) | **< 0.001** |
| Rhythm | Sinus | Reference | |
| | Atrial fibrillation | 4.51 (3.14–6.49) | **< 0.001** |
| | Pacemaker | 1.93 (0.52–7.22) | 0.327 |
| | Other | 6.96 (2.35–20.6) | **< 0.001** |
| PQ interval | < 0.2 s | Reference | |
| | 0.2–0.3 s | 1.13 (0.57–2.24) | 0.728 |
| | > 0.3 s | - | |
| QRS interval | < 0.12 s | Reference | |
| | > 0.12 s | 2.57 (1.65–4.00) | **< 0.001** |
| Left bundle branch hemiblock | No | Reference | |
| | LAH | 1.64 (1.10–2.44) | **0.014** |
| | LPH | - | |
| Bundle branch block | No | Reference | |
| | iRBBB | 0.86 (0.48–1.53) | 0.607 |
| | RBBB | 2.04 (1.14–3.72) | **0.021** |
| | LBBB | 4.13 (2.36–7.22) | **< 0.001** |
| | Non-specific | - | |
| QT interval | < 0.45 s | Reference | |
| | > 0.45 s | 1.77 (0.6–5.17) | 0.298 |
| ST segment changes | No | Reference | |
| | Depressions (> 0.5 mm) | 1.66 (0.71–3.88) | 0.242 |
| | Elevations | 1.77 (0.28–11.34) | 0.546 |
| | Depressions and elevations | 5.31 (2.54–11.11) | **< 0.001** |
| | Early repolarization ST elevations | 0.96 (0.55–1.67) | 0.147 |
| | Depressions (< 0.5 mm) | 1.75 (1.06–2.87) | **0.028** |
| T wave changes | No | Reference | |
| | Yes | 1.91 (1.40–2.59) | **< 0.001** |
| Other ECG abnormalities * | No | Reference | |
| | Yes | 1.34 (0.96–1.87) | 0.084 |
| ECG overall | Normal | Reference | |
| | Abnormal | 2.67 (1.68–4.23) | **< 0.001** |

RR=relative risk; CI=confidence interval; LAH=left anterior hemiblock; LPH=left posterior hemiblock; iRBBB=incomplete right bundle branch block; RBBB=right bundle branch block; LBBB=left bundle branch block; * including but not limited to hypertrophy signs, supraventricular extrasystoles (SVES) and ventricular extrasystoles (VES), Q wave pathologies, R wave changes, P pulmonale, P mitrale, pre-excitation

The Pearson correlation coefficient for the relationship between hemoglobin and heart rate was −0.094, indicating a very weak negative correlation (Table 5).

It is well known that patients with pre-existing cardiac comorbidities have a higher postoperative mortality compared to patients without these conditions. The same results are evident in our study population (Table 6).

**Table 5** Relation between hemoglobin and heart rate

| Hemoglobin level [g/L] | Heart rate [bpm] – mean (± SD) |
|---|---|
| < 100 | 85 (± 19) |
| 100–119 | 80 (± 16) |
| 120–139 | 79 (± 16) |
| 140–159 | 77 (± 15) |
| ≥ 160 | 81 (± 18) |

**Table 6** Comparison of 90-day postoperative all-cause mortality based on patient comorbidities

| Characteristics | | *N* | Proportion of death | *P* |
|---|---|---|---|---|
| Chronic coronary syndrome | No | 1879 | 98 (5.2%) | **< 0.001** |
| | Yes | 340 | 54 (15.9%) | |
| Chronic heart failure | No | 2175 | 145 (6.7%) | **0.028** |
| | Yes | 44 | 7 (15.9%) | |
| Atrial fibrillation | No | 2047 | 126 (6.2%) | **< 0.001** |
| | Yes | 172 | 26 (15.1%) | |
| No. of comorbidities | 0 | 1784 | 88 (4.9%) | **< 0.001** |
| | 1 | 326 | 43 (13.2%) | |
| | 2 | 97 | 19 (19.6%) | |
| | 3 | 12 | 2 (16.7%) | |
| At least 1 comorbidity | No | 1784 | 88 (4.9%) | **< 0.001** |
| | Yes | 435 | 64 (14.7%) | |

The ninety-day postoperative all-cause mortality rate was significantly increased in patients with the following abnormal ECG findings: atrial fibrillation, increased heart rate above 80 bpm, intraventricular conduction delay, LAH, RBBB, LBBB, and the combination of ST segment elevations and depressions, and T-wave alterations as previously mentioned, however the sub-analysis of patients with preexisting cardiac conditions revealed something interesting.

The ninety-day postoperative all-cause mortality rate in patients with at least one pre-existing cardiac comorbidity (chronic coronary syndrome, chronic heart failure, atrial fibrillation) was significantly correlated only with preoperative findings of atrial fibrillation, an elevated heart rate above 80 bpm and right bundle branch block (which was not associated with increased mortality in patients without pre-existing cardiac comorbidities) (Table 7). The relative risks of 90-day postoperative all-cause mortality for patients with pre-existing cardiac comorbidities and with heart rates above 80 bpm, 90 bpm, and 100 bpm were 1.95, 2.36, and 2.20, respectively.

**Table 7** Relative risk of 90-day postoperative all-cause mortality by ECG abnormality in patients without comorbidities or with at least one comorbidity (chronic coronary syndrom, chronic heart failure, atrial fibrillation)

| ECG variables | | Patients without comorbidities | | Patients with at least one comorbidity | |
|---|---|---|---|---|---|
| | | RR (95% CI) | *P* | RR (95% CI) | *P* |
| Heart rate [bpm] | ≥ 80 (ref. < 80) | 1.84 (1.21–2.79) | **0.004** | 1.95 (1.23–3.10) | **0.004** |
| | ≥ 90 (ref. < 90) | 1.97 (1.31–2.98) | **0.001** | 2.36 (1.52–3.67) | **< 0.001** |
| | ≥ 100 (ref. < 100) | 2.56 (1.62–4.06) | **< 0.001** | 2.20 (1.36–3.54) | **0.001** |
| Rhythm | Sinus | Reference | | Reference | |
| | Atrial fibrillation | 6.60 (3.43–12.69) | **< 0.001** | 2.10 (1.31–3.37) | **0.002** |
| | Pacemaker | 2.16 (0.15–30.17) | 0.568 | 1.21 (0.33–4.52) | 0.774 |
| | Other | - | | 3.39 (1.12–10.34) | **0.031** |
| PQ interval | < 0.2 s | Reference | | Reference | |
| | 0.2–0.3 s | 1.32 (0.50–3.49) | 0.572 | 0.62 (0.24–1.63) | 0.333 |
| | > 0.3 s | - | | 1.62 (0.15–18.11) | 0.694 |
| QRS interval | < 0.12 s | Reference | | Reference | |
| | > 0.12 s | 1.62 (0.68–3.84) | 0.276 | 2.02 (1.20–3.39) | **0.008** |
| Left bundle branch hemiblock | No | Reference | | Reference | |
| | LAH | 1.97 (1.19–3.28) | **0.009** | 1.05 (0.56–1.96) | 0.875 |
| | LPH | 5.56 (0.49–62.01) | 0.163 | 1.70 (0.15–18.95) | 0.667 |
| Bundle branch block | No | Reference | | Reference | |
| | iRBBB | 1.00 (0.51–1.96) | 0.995 | 0.71 (0.23–2.15) | 0.544 |
| | RBBB | 0.78 (0.20–3.10) | 0.727 | 2.52 (1.35–4.72) | **0.004** |
| | LBBB | 7.77 (3.09–19.54) | **< 0.001** | 1.77 (0.87–3.56) | 0.113 |
| | Non-specific | 3.43 (0.27–43.54) | 0.341 | 1.87 (0.17–21.00) | 0.610 |
| QT interval | < 0.45 s | Reference | | Reference | |
| | > 0.45 s | 4.13 (1.17–14.50) | **0.027** | 0.44 (0.07–2.99) | 0.405 |
| ST segment changes | No | Reference | | Reference | |
| | Depressions (> 0.5 mm) | 2.07 (0.69–6.25) | 0.195 | 0.88 (0.24–3.32) | 0.854 |
| | Elevations | 7.37 (1.46–37.17) | **0.016** | 0.50 (0.03–7.33) | 0.614 |
| | Depressions and elevations | 7.37 (2.32–23.43) | **0.001** | 2.35 (0.90–6.16) | 0.081 |
| | Early repolarization ST elevations | 1.09 (0.55–2.16) | 0.796 | 0.83 (0.32–2.17) | 0.705 |
| | Depressions (< 0.5 mm) | 1.53 (0.72–3.25) | 0.266 | 1.41 (0.74–2.69) | 0.292 |
| T wave changes | No | Reference | | Reference | |
| | Yes | 2.02 (1.33–3.05) | **0.001** | 1.25 (0.80–1.97) | 0.326 |
| Other ECG abnormalities * | No | Reference | | Reference | |
| | Yes | 1.40 (0.89–2.19) | 0.146 | 1.04 (0.64–1.70) | 0.864 |
| ECG overall | Normal | Reference | | Reference | |
| | Abnormal | 2.33 (1.35–4.03) | **0.002** | 1.92 (0.80–4.60) | 0.141 |

RR = relative risk; CI = confidence interval; LAH = left anterior hemiblock; LPH = left posterior hemiblock; iRBBB = incomplete right bundle branch block; RBBB = right bundle branch block; LBBB = left bundle branch block; * including but not limited to hypertrophy signs, supraventricular extrasystoles (SVES) and ventricular extrasystoles (VES), Q wave pathologies, R wave changes, P pulmonale, P mitrale, pre-excitation

## Discussion

Our study shows that many preoperative ECG abnormalities significantly increase risk for 90-day postoperative all-cause mortality, even in patients with pre-existing cardiac conditions.

Several of our results differ from those of previously reported studies. An analysis from the year 2000 did not show a statistically significant connection between preoperative ECG with bundle branch block (BBB) and mortality, but there was a numerical trend in the LBBB group [7]. Our data not only confirm but also expand this numerical trend and add statistically significant results to support this association. This difference may be attributed to our larger study population and higher event rate.

Other studies have revealed a statistically significant relationship between abnormal preoperative ECG findings and increased mortality. However, these studies analyzed either in-hospital mortality [8], or studied very select study populations: patients with coronary artery disease [9], only patients with hip fractures [11], or patients undergoing major vascular surgery [12, 13]. The data from our study confirm these previous studies, extending the results to an unselected group of patients and over a longer period. In the end we can state that

an abnormal ECG is associated with increased risk of 90-day postoperative all-cause mortality, with few exceptions - in our results, there is no association between PQ and QT intervals, paced rhythm, and iRBBB with 90-day postoperative all-cause mortality.

A recent study of major vascular surgery reported higher prevalences of cardiac complications in patients with higher heart rates and longer QT intervals [14], but there was no clear correlation between mortality and elevated heart rate (or any other ECG abnormality). Contrary to this, our study demonstrates that elevated heart rate has a significant association with 90-day postoperative all-cause mortality; moreover, the higher the heart rate, the more pronounced the relative risk of mortality.

In a rather small study, a group of patients with metabolic syndrome had significantly longer PQ and QT intervals on preoperative ECG [15]. While this may be true, we did not find an increased 90-day postoperative mortality risk associated with these findings.

A large database (Medicare) study from 2022 showed an association between preexisting atrial fibrillation and 30-day postoperative all-cause mortality after NCS [16]. Our results confirm and extend this finding to a longer period.

In our study, right bundle branch block (RBBB) was associated with increased risk of 90-day postoperative all-cause mortality in patients with preexisting cardiac comorbidities (but not without), with strong statistical significance. Thus, RBBB can now be seen as an independent predictor of postoperative mortality in patients with cardiac conditions, adding additional risk to an already increased postoperative mortality rate in cardiac patients. There are no other studies for comparison.

The most important message of our study is that irrespective of pre-existing cardiac comorbidities (chronic heart failure, chronic coronary syndrome, atrial fibrillation) there are ECG abnormalities that showed strong association with 90-day postoperative all-cause mortality in both groups (patients with cardiac comorbidities and without cardiac comorbidities) - atrial fibrillation and elevated heart rate over 80 bpm. These results strongly suggest that atrial fibrillation and elevated heart rate are independent predictors of 90-day postoperative all-cause mortality and therefore could improve widely used risk prediction tools as already mentioned Revised Cardiac Risk Index (RCRI).

There are no previous studies that compared ECG abnormalities and their association with postoperative mortality between cardiac and non-cardiac group.

The incidence of preoperative ECG abnormalities differs greatly among different studies. In our study population, there was relatively high incidence of abnormal ECG findings, which might be in part explained by the stringent criteria used to define physiological ECG limits.

The main limitation of our study is its single-center and retrospective design; the results obtained from other hospitals could be different. Another limitation is the lack of distinction in mortality causes (therefore, cardiovascular mortality cannot be evaluated). On the other hand, the large number of enrolled patients in our study and the enrollment of all consecutive patients within the given time period suggests the results are statistically solid.

## Conclusion

Our study demonstrates that preoperative ECG abnormalities significantly increase the risk of 90-day postoperative all-cause mortality in patients undergoing non-cardiac surgery, with specific abnormalities showing stronger associations depending on the presence of pre-existing cardiac comorbidities. In patients with pre-existing cardiac comorbidities, the risk factors for increased 90-day postoperative mortality include atrial fibrillation, elevated heart rate (over 80 bpm), and RBBB, which was not a significant predictor of mortality in patients without pre-existing cardiac conditions.

These results suggest that certain preoperative ECG findings, notably atrial fibrillation and elevated heart rate, can serve as independent predictors of 90-day postoperative all-cause mortality and should be considered in perioperative risk assessment. The incorporation of ECG abnormalities into risk prediction tools like the Revised Cardiac Risk Index (RCRI) could enhance the accuracy of perioperative risk stratification.

Further research is needed to confirm these findings in multi-center studies and to explore the potential additive value of ECG findings in perioperative predictive risk models. Atrial fibrillation and elevated heart rate seem to have great additive value in the prediction of postoperative mortality, even beyond clinical characteristics. Preoperative ECG testing is valuable for predicting postoperative mortality in a broad patient population undergoing non-cardiac surgery, and implementing ECG findings into existing risk prediction models could improve patient outcomes by identifying high-risk individuals who may benefit from more intensive perioperative management.

**Abbreviations**

| | |
|---|---|
| ECG | Electrocardiogram |
| NCS | Non-cardiac surgery |
| RR | Relative risk |
| BBB | Bundle branch block |
| CAD | Coronary artery disease |
| MACE | Major adverse cardiac events |
| RCRI | The Revised Cardiac Risk Index |
| BMI | Body mass index |
| LAH | Left anterior hemiblock |
| LBBB | Left bundle branch block |
| RBBB | Right bundle branch block |
| iRBBB | Incomplete right bundle branch block |
| SVES | Supraventricular extrasystoles |
| VES | Ventricular extrasystoles |

**Acknowledgements**
Not applicable.

**Author contributions**
B.Č. designed the study, collected data and wrote the manuscript. J.V. supervised all parts of the study, provided valuable insights, reviewed and edited the manuscript. K.B. and J.J. performed statistical analysis of the study data.

**Funding**
The authors declare that they did not have any funding.

**Data availability**
All data is provided within the Manuscript and Related files section.

## Declarations

**Ethics approval and consent to participate**
The Ethics Committee of Associated Medical Facility Krnov approves this clinical research in the form of a retrospective data analysis of patients who underwent preoperative internal examination during hospitalization in Associated Medical Facility Krnov in the years 2015–2021. Informed consent was waived by an IRB (Associated Medical Facility Krnov Ethics Committee, Ivan Pavlák, MD, chairman) or is deemed unnecessary according to national regulations.

**Consent for publication**
Not applicable.

**Competing interests**
The authors declare no competing interests.

Received: 17 January 2024 / Accepted: 26 September 2024
Published online: 30 September 2024

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