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Multidisciplinary Insights into Perioperative Cardiac Events in Non-Cardiac Surgery: an ECG Holter Monitoring Study

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ABSTRACT

Background: *Cardiovascular complications after non-cardiac surgery have a major impact on perioperative morbidity and mortality. Despite several scales and scores for assessing the preoperative cardiovascular status, an individualized assessment focused on each patient is mandatory.*

Aim: *To identify the new cardiac events that occur after non-cardiac surgery.*

Methods: *In 100 patients hospitalized in the general surgery department with acute and chronic surgical pathologies, the perioperative cardiac events were assessed using Holter monitoring along with clinical and biochemical markers, including C reactive protein (CRP) and high-sensitive troponin (hscTnI).*

Results: *Out of the 100 participants with a mean age of 54.5 (43–77.9) years, 54% were men. Ten patients developed paroxysmal postoperative atrial fibrillation (AF), which was related with longer surgery time 165 (150-180) vs 120 (90-150) minutes (p=0.002) and postoperative anaemia [haemoglobin (Hg) 10.4 (9.37-12.6) vs 12.1 (11-13.2) g/dL, (p=0.041)]. Higher CRP levels were also corelated with paroxysmal AF. The AF group correlated with higher values of presurgical CRP: 81 (46.5-186.75) vs 27 (6-102.5) mg/dL, (p=0.041). Higher postsurgical CRP values were also found in the AF group: 76 (47.75-110.75)* vs *40.5 (12-82.5) mg/dL (p=0.045). Sinus pauses were present in nine patients and there*

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was a strong association between sinus pauses and age (p = 0.011), history of high blood pressure (HBP) (p = 0.031), intraoperative HBP (p = 0.026) and the preexisting AF (p = 0.028). Postsurgical ST changes were present in 30 patients and ST depression was correlated with age (p < 0.001), prolonged surgery time [150 (120-180) vs *120 (90-150) minutes (p<0.001)], history of HBP [(33.3%* vs *12.2%) (p=0.017)] and intraoperative maximum values of BP (p = 0.007).*

Conclusions: *There is an increased risk of cardiovascular events during the postoperative period of non-cardiac surgery in patients with advanced age, pre-existing diseases (hypertension, preexisting atrial fibrillation, diabetes mellitus), the level of inflammation and longer intraoperative stress. Holter monitoring revealed rhythm and conduction disorders as well as ST segment changes that were associated with the inflammatory status and slightly elevated cardiac enzyme levels. Future studies are needed to see the impact of cardiac complications in the long term.*

Keywords: non-cardiac surgery, cardiac events, perioperative cardiac monitoring, postoperative arrythmias.

INTRODUCTION

The global burden of pathologies that require surgery has increased significantly in the last decades rising up to 1533 operations *per* 100 000 people (1), meaning over 300 million patients worldwide. Most of these procedures are major non-cardiac interventions in patients with at least two cardiovascular risk factors and atherosclerotic cardiovascular disease, with these parameters being more common nowadays than ten years ago due to several interconnected factors such as substantial changes in lifestyle, chronic stress and population aging (2, 3).

Even though the modern era came with groundbreaking methods of prevention, early identification, diagnosis and treatment for all sorts of pathologies, the complications that may occur during the perioperative period are still unpredictable and life-threatening. These dangerous situations are the result of combining the emergency status of the disease that the patient was admitted for with his/her clinical condition at admission, comorbidities, type and risk of surgery and complications that may occur in this critical period. According to a cohort study that included over 40 000 patients, perioperative morbidity and mortality is associated with three major complications in non-cardiac surgery: haemorrhage, myocardial injury and sepsis, with one in seven patients experiencing a cardiovascular event within 30 days after surgery (4, 5).

Cardiac complications after non-cardiac surgery can vary widely. From minor myocardial injury, to infarction and new postoperative arrythmias, these complications are frequently found even in asymptomatic patients, but with great impact on the long term (6-8). Atrial fibrillation (AF), defined as episodes over 30 seconds and more than 110 bpm, can occur in up to 3% of patients; it is usually benign and disappears spontaneously, but if it persists, the risk of cerebrovascular events increases with 1.5% (9, 10) and it can also raise the risk of heart failure, myocardial infarction and cardiac arrest (6).

Prevention of perioperative cardio-vascular complications remains one of the most important considerations. The goal can only be achieved by carefully evaluating the perioperative cardiovascular risk and individualizing the assessment according to each patient, using various tools such as revised cardiac risk index (11), ACS NSQIP (The American College of Surgery National Surgical Quality Improvement Program) (12), SORT (surgical outcome risk tool) (13), or The American University of Beirut – cardiovascular risk index – AUB-HAS2 (14-16). Other studies suggest introducing pre- and postoperative troponin as an assessment tool for evaluating survival after major surgery (17). Nutritional status may also be one important tool for preoperative overall assessment (18), especially in cancer patients (19).

Although all these perioperative cardiovascular risk assessment scores have demonstrated their reproducibility, applicability and especially their utility, they are not yet considered to be a gold standard in the individualized assessment of patients. Our main purpose was to identify the new onset cardiac events such as arrhythmias and conduction disorders or ischemic events that occur after non-cardiac surgery and the factors that triggers them, in an attempt to improve the preoperative management of patients in order to reduce the overall cardiovascular risk in non-cardiac surgery (20, 21).

MATERIAL AND METHODS

Study design and population

We conducted an unicentric, prospective, observational, descriptive, exploratory, clinical study on a sample of 100 patients who were hospitalized and surgically treated in the 3rd Department of the General and Emergency Surgery of the University Emergency Hospital of Bucharest, Romania, between October 2022 and January 2024.

For analysis and data processing we selected the following pathologies that required emergency and elective surgical interventions: acute cholecystitis, acute diverticulitis, acute appendicitis, intestinal occlusion, splenic laceration, gastric ulcer, incisional hernias, ventral hernias, groin hernias, colorectal cancers, gastric cancers, uterine cancers, uterine fibromas, perianal fistulas, haemorrhoids. Exclusion criteria were age under 18 years old, the impossibility of monitoring the patient and the patient's refusal to participate in the study, acute coronary syndrome within the last 90 days, advanced heart failure, severe valvulopathies and chronic kidney disease in the hemodialysis stage.

Data collection and Holter monitoring

Patients' data were obtained from the observational sheet of each patient, operating protocol, anesthetic monitoring sheet and from data obtained through perioperative Holter monitoring. The perioperative Holter monitoring was defined as a 24-hour period of time starting at least one hour before surgery (the preoperative period was one hour before surgery, while the intraoperative and postoperative periods – up to 24 hours from the beginning of the monitoring process). The data processed for cardiovascular evaluation comprised the cardiovascular history and background medication of each patient, the electrocardiogram interpretation upon admission, the monitoring of blood pressure and heart rate (upon admission, preoperatively, during surgery, postoperatively and upon discharge) and the interpretation of perioperative Holter monitoring (Table 1).

During the Holter recording, we monitored standard parameters, including heart rate, preexisting or newly developed conduction and rhythm disturbances, ventricular arrhythmias, and ST segment changes – both supra- and sub-deviations greater than 2 mm in the interrogated leads. Lastly, sinus pauses were also evaluated, as shown in Table 1. The interpretation of the Holter results was initially automatically performed by the software used in the present study and subsequently reviewed by a clinical cardiologist.

Biochemical and clinical variables

Biochemical parameters, including hemoglobin (Hg) (g/dL), white blood cell count (WBC) ($1000/mm^3$), creatinine (mg/dL), CK-MB (creatine kinase MB) (U/l), sodium (mmol/L), potassium (mmol/L) and C-reactive protein (CRP) (mg/dL), were all measured pre- and postoperatively. High-sensitive troponin I (hscTnI) was measured on days 1 and 2 after surgery.

Other parameters taken into consideration were the patients' age, gender, smoker/non-smoker status, diabetic or non-diabetic status, body mass

TABLE 1. Parameters analyzed on both resting electrocardiogram (ECG) and 24 hours Holter ECG

Heart rate (HR)	**Bradycardia (HR ≤60 bpm)**	**Tachycardia (HR >100 bpm)**
Conduction abnormalities	Atrioventricular block: grade I/II/III	Left bundle branch
Rhythm	Sinus rhythm	Atrial fibrillation: - newly diagnosed sustained episodes* - paroxysmal episodes in patients known with paroxysmal AF - permanent AF
Ventricular arrhythmia	Ventricular premature beats	Sustained ventricular tachycardia
ST changes	ST elevation**	ST depression**
Others	Sinus pauses (> five seconds)	

*Newly diagnosed sustained episodes=an episode with a duration of at least 30 seconds.
**ST changes with a duration of at least 30 seconds.

index (BMI), type of anesthesia (general or spinal) used for each patient and duration of surgical intervention.

Statistical analysis

The data set was processed in Microsoft Excel and data analysis was performed using IBM SPSS version 26. Shapiro-Wilk test was used to analyze the distribution of quantitative variables, which were reported as averages with standard deviations or medians with interquartile ranges according to their distribution. Fisher's exact test was used to determine if there were nonrandom associations between two categorical variables. The difference between continuous variables with non-normal distribution (by median, range) were compared using the Mann-Whitney U test. The tests were performed to materiality $p = 0.05$ and statistical significance was considered for p values less than the threshold value of significance. Logistic regression models were verified for goodness-of-fit and used for estimating the prediction value of comorbidities, medication history, HR/BP (heart rate/blood pressure) (presurgical, intraoperative and postsurgical values), laboratory values (serum creatinine, CK-MB, potassium, sodium, hemoglobin) and postsurgical cardiac events (in univariate and multivariate models), expressed as odds ratio (OR) at a confidence interval (CI) of 95%. Given the binary nature of the primary outcome (major adverse cardiac events), logistic regression was chosen as the appropriate modeling method. Bivariate analyses were conducted initially and variables with a p-value < 0.05 were selected for inclusion in the multivariate model. This threshold was chosen to ensure inclusion of potentially relevant predictors without overfitting. The final model was constructed using backward stepwise selection guided by both statistical significance ($p < 0.05$) and clinical relevance, as supported by the literature. Pearson's correlation coefficient was used for the linear relationship between two variables, with values of > 0.6 or < -0.6 being considered powerful enough for a correlation. Spearman's correlation coefficient was used to measure the monotonicity between ordinal or continuous variables, with values of > 0.6 or < -0.6 being considered powerful enough for a correlation.

Ethical approval

The present study was conducted in compliance with the Declaration of Helsinki and in accordance with the previsions of the Romanian Constitutional Law 206/2004 updated in 2021 as well as all European Union professional ethics. We also obtained the informed consent signed by each patient included in our study. The anonymity and confidentiality of responses was guaranteed and the participation in the study was voluntary. Our monitoring did not interfere with the therapeutic conduct in any way.

RESULTS

Clinical characteristics and their association with postoperative cardiac events

The present study included 100 subjects, of whom 54 were men and 46 women. Participants' profiles are shown in Table 2. There were no correlations between patients' sex and a specific

TABLE 2. Characteristics of participants in the present study

Parameter	Number of patients
Gender	
- male	54
- female	46
Age (years)	
- 18-39	20
- 40-69	59
- ≥70	21
Body mass index (BMI)	
- 18.5-25	16
- 25-30	54
- 30-35	27
- >35	3
Smoker	
- yes	44
- no	56
Diabetes	
- yes	24
- no	76
Hypertension	
- yes	51
- no	49
Preexistent atrial fibrillation (AF) (both paroxysmal and permanent AF)	
- yes	20
- no	80
Dyslipidemia	
- yes	61
- no	39
Treatment	
- anticoagulants	23
- ACE-i/ARBs	39
- beta-blockers	30
- statins	38
Type of surgery	
- elective	42
- emergency	58
Duration of intervention	
- <one hour	10
- 1-3 hours	67
- >three hours	23
Type of anesthesia	
- general	69
- spinal	31

postsurgical cardiac event (AF-R=-0.125; atrioventricular block-R=-0.104; sinus arrest-R=0.246; LBBB-R=0.040; VPC-R=-0.087; sustained ventricular tachycardia-R=0.141; ST elevation-R=0.073; ST depression-R=0.453). The age of subjects did not follow a normal distribution (p=0.043) and had a median of 54.5 (43–77.9) years.

The median age was higher among patients with sinus pauses than those without them: 73 (61-80) *vs* 52 (42-65) years old, respectively (p=0.011). Moreover, postoperative ST depression was also correlated with an older age, 55 (47-74) *vs* 54 (42-66) years old (p<0.001). In addition, we found a positive correlation between patients with AF and older age: 72 (43-79.75) *vs* 50 (38.75-61.25) years (p=0.045).

Forty-four patients were smokers. There was no statistical correlation between the smoking status and a specific postsurgical cardiac event (p>0.05).

According to subjects' (BMI), the majority of them were overweight (54%), 30% obese and 16% normal weight. We found no correlation between BMI and postsurgical cardiac events (AF-R=-0.371; atrioventricular block-R=-0.196; sinus arrest-R=0.296; LBBB-R=0.381; VPC-R=-0.186; sustained ventricular tachycardia-R=0.266; ST elevation-R=0.343; ST depression-R=0.331).

Sixty-eight of all surgeries were performed under general anesthesia and 32 under spinal anesthesia. There was no association between the type of anesthesia and postsurgical cardiac events (p>0.05).

The duration of surgery had a median of 120 (97.5-150) minutes. There was no difference between emergency and elective surgeries in terms of surgical duration (p=0.418). The time of intervention was shorter in patients with spinal anesthesia: 90 (67.5-120) minutes *vs* 150 (120-180) minutes (p<0.001). Those with postsurgical AF had a longer operative time: 165 (150-180) *vs* 120 (90-150) minutes (p=0.002). Also, subjects with postsurgical ST depression were correlated with a longer surgery time: 150 (120-180) *vs* 120 (90-150) minutes (p<0.001).

The rate of ST depression was higher among the 51 patients with a history of high blood pressure (HBP) [33.3% *vs* 12.2% (p=0.017)], the 24 subjects with a history of diabetes mellitus (DM) and the 20 ones with a history of atrial fibrillation (AF) [50 % *vs* 16.3 %) (p = 0.003)].

Sinus pauses, sustained ventricular tachycardia and ST depression were correlated with higher values of intraoperative systolic blood pressure (sBP) max value: 153.22±22.68 *vs* 137.64±19.46 mm Hg (p=0.026), 164.67±8.73 *vs* 138.25±19.9 mm Hg (p=0.025), and 148.87±21.54 *vs* 137.1±18.88 mm Hg (p=0.007), respectively.

Newly diagnosed AF patients correlated with lower values of postsurgical haemoglobin than those without AF: 10.4 (9.37-12.6) *vs* 12.1 (11-13.2) g/dL (p=0.041).

The ST depression group was correlated with higher values of both presurgical serum creatinine [1 (0.85-1.6) *vs* 0.78 (0.7-0.93) mg/dL (p<0.001)] and postsurgical serum creatinine [0.9 (0.74-1.8) *vs* 0.88 (0.7-0.99) (p=0.031)].

Sustained ventricular tachycardia was correlated with higher values of day 1 postsurgical high sensitivity troponin, 164 (118-168.5) *vs* 10 (2-40) ng/mL (p=0.011).

The ST depression group was correlated with higher values of both day 1 and day 2 postsurgical troponin: 70 (29-169) *vs* 7 (1-20.5) ng/mL (p<0.001) and 49 (21-83) *vs* 5 (2-14) ng/mL (p<0.001), respectively.

ST elevation was correlated with higher values of day 1 and day 2 postsurgical troponin: 78 (3-164) *vs* 10 (1.5-35.5) ng/mL (p=0.035) and 90 (4-103) *vs* 10 (3-29.5) ng/mL (p=0.027), respectively.

The AF group correlated with higher values of day 2 postsurgical troponin 35 (3.5-97.75) *vs* 4.5 (2-15.5) ng/mL (p=0.044).

Perioperative determinants of Holter abnormalities

Table 3 shows the number of patients with specific cardiac events which were registered during Holter monitoring.

Clinical and hemodynamic predictors of postoperative sinus pauses

We found an association between relevant parameters and sinus arrest according to the p value. The use of Mann-Whitney U test enabled us to find not only a strong correlation between age and sinus pauses (p=0.011), but also a strong association with intraoperative HBP (p=0.026) and low values of heart rates in the postoperative period (p=0.006). Applying the Fisher's exact test, we found an association between sinus pauses

TABLE 3. Postsurgical cardiac events

New postsurgical cardiac events	Number of patients
Atrioventricular block type I	2
Atrioventricular block type II	4
Sinus pause/arrest	9
Transient left bundle branch block (LBBB)	4
Ventricular premature complex (VPC)	47
Sustained ventricular tachycardia*	3
ST elevation	7
ST depression	23
Atrial fibrillation	10

*Sustained episodes of five to 10 QRS complexes, spontaneously converted

and history of HBP with a p value of 0.031. Moreover, strong correlations between sinus pauses and preexisting AF (p=0.028) were found too. The medication based on beta-blockers increased the odds of sinus arrest by 2.59 (95% CI 1.07-6.26).

For the "sinus pauses" parameter we conducted a univariate logistic regression. Each increase of one year in age raised the odds of sinus arrest by 1.06 (95% CI 1-1.12). The presence of HBP history increased the odds of sinus arrest by 8.93 (95% CI 1.07-74.33). Preexisting atrial fibrillation increased the odds of postoperative sinus arrest by 5.06 (95% CI 1.23-20.81). Each increase of intraoperative BPs max value by one unit (1 mm Hg) raised the odds of sinus arrest by 1.04 (95% CI 1-1.07). Each increase of HR postsurgical min value by one unit (1 bpm) decreased the odds of sinus arrest by 0.91 (95% CI 0.86-0.97).

A multivariate regression model was constructed using the variables included in the univariate models (age, HBP history, preexisting AF, intraoperative BPs max value and HR postsurgical min value) as prediction variables. In this model, only the preexisting AF and HR postsurgical min value had a significant effect.

Preexisting AF increased the odds of sinus arrest by 11.33 (95% CI 1-127.88). Each increase of HR postsurgical min value by one unit (1 bpm) decreased the odds of sinus arrest by 0.87 (95% CI 0.78-0.96).

Risk factors and biomarker correlates of ST segment depression after surgery

Another result from the Holter monitoring was the ST depression. The use of Fisher's exact test enabled us to find out that there were strong associations with personal history of HBP (p=0.017), preexisting AF (p=0.003) and DM (p=0.005).

By using the Mann-Whitney U test we also found a strong association between ST depression and age ($p < 0.001$), surgical duration ($p < 0.001$), intraoperative maximum value of BP (p=0.007) and minimum value of the blood pressure with a p value of 0.048. By using the Mann-Whitney U test we noticed correlations with presurgical serum creatinine ($p < 0.001$) and days 1 and 2 postsurgical troponin ($p < 0.001$).

The same parameters as for the Fisher's exact test and Mann-Whitney U test were considered when we applied a univariate logistic regression for ST depression. Intraoperative BPs min value and presurgical serum creatinine did not have a significant effect. Each increase in age by one year raised the odds of ST depression by 1.08 (95% CI 1.04-1.13). Each increase in surgical duration of one unit (minute) increased the odds of ST depression by 1.01 (95% CI 1-1.02). The history of HBP raised the odds of ST depression by 3.58 (95% CI 1.27-10.07) and that of DM by 4.51 (95% CI 1.64-12.42). Preexisting AF increased the odds of ST depression by 4.96 (95% CI 1.78-13.82). Each increase of intraoperative BPs max value by one unit (1 mm Hg) increased the odds of ST depression by 1.03 (95% CI 1-1.08). Each increase of day 1 postsurgical troponin by one unit (ng/mL) raised the odds of ST depression by 1.01 (95% CI 1-1.02). Each increase of day 2 postsurgical troponin by one unit (ng/mL) increased the odds of ST depression by 1.02 (95% CI 1.01-1.03). A multivariate regression model was constructed using the variables included in the univariate models (age, surgery time, HBP history, DM history, AF history, DOACs, statins, intraoperative BPs max value, presurgical troponin, day 1 postsurgical troponin and day 2 postsurgical troponin) as prediction variables. In this model, none of the prediction variables had a significant effect ($p > 0.05$).

Inflammatory and procedural predictors of new-onset atrial fibrillation

Atrial fibrillation was an important postoperative finding on the Holter monitoring. We performed the Fisher's exact test and found a strong association with high values of presurgical CRP (p=0.041), postsurgical CRP (p=0.045) and day 2 postoperative troponin (p=0.044). We have also applied the Mann-Whitney U test and found strong associations with postoperative haemoglobin (p=0.041) and surgical duration (p = 0.002).

We used a univariate logistic regression for AF and obtained the following correlations: postsurgical Hb, presurgical CRP, postsurgical CRP did not have a significant effect. Each increase in operative time by one unit (minute) raised the odds of AF by 1.01 (95% CI 1-1.02). Each increase in day 2 postsurgical troponin by one unit (ng/mL) raised the odds of AF by 1.02 (95% CI 1-1.04).

A multivariate regression model was constructed using the variables included in the univariate models. Only day 2 postsurgical troponin had a significant effect (p=0.044). Each increase in day 2 postsurgical troponin by one unit (ng/mL) raised the odds of AF by 1.02 (95% CI 1-1.04);

Hemodynamic and biomarker associations with sustained ventricular tachycardia

The associations between sustained ventricular tachycardia and intraoperative maximum value of BP, HR and postoperative day 1 troponin after applying the Fisher's exact test and Mann-Whitney U test are presented in Table 4.

When we used the univariate logistic regression for sustained ventricular tachycardia, the following results were obtained. Each increase in intraoperative BPs max value by one unit (1 mm Hg) raised the odds of sustained ventricular tachycardia by 1.07 (95% CI 1-1.15). Each increase in day 1 postsurgical troponin by one unit (ng/mL) increased the odds of sustained ventricular tachycardia by 1.01 (95% CI 1-1.12).

TABLE 3. Association between intraoperative systolic blood pressure (sBP) max value, heart rate (HR) intraoperative max value and day 1 postsurgical troponin and sustained ventricular tachycardia

Sustained ventricular tachycardia	Association
Intraoperative sBP max value (mm Hg)	p=0.025**
Day 1 postsurgical troponin (pg/mL)	p=0.011*
HR intraoperative max value (bpm)	p=0.042**

Incidence of transient left bundle branch block (LBBB) and lack of significant predictors

The logistic regression did not find any significant effect between the studied parameters and transient left bundle branch block (LBBB).

DISCUSSIONS AND CONCLUSIONS

Postoperative cardiovascular events can frequently occur after non-cardiac surgery. These complications represent a major source of morbidity and mortality increasing the burden on global healthcare. The determining factors for postoperative cardiac arrythmias are usually hypoxemia, cardiac ischemia, high concentrations of catecholamines and hydro-electrolyte and acid-base imbalances (22, 23).

One of our findings concerns the sinus pauses, as we previously stated. Sinus pause represents the two seconds or more delayed impulse from the sinoatrial node, measured from the start of the P wave to the start of the next one, and is usually considered either idiopathic or related to a degeneration of the nodal tissue typically seen in older patients (24, 25). We obtained similar data regarding the fact that the occurrence of sinus pauses was correlated with older age. Patients with sinus pauses were also correlated with higher intraoperative sBP and preexisting AF. The association between sinus pauses and AF or atrial flutter was usually described at the end of the arrythmia followed by a syncopal episode (26). In the literature we found no direct correlations between HBP and sinus pauses, but there were links between the medication used to treat HBP, such as beta-blockers or calcium channel blockers, and sinus sick syndrome that could manifest with recurrent sinus pauses (27, 28). Our patients had asymptomatic sinus pauses and the majority of them were previously treated with beta-blockers, primarily for HR control.

Atrial fibrillation is the most frequent arrythmia that can occur after non-cardiac surgery with incidence varying from 0.4% to 26% (29). There are many possible risk factors that may increase the chance of developing postoperative AF such as older age, male gender, current tobacco use, other comorbidities such as hypertension, congestive heart failure, chronic pulmonary diseases, valvular diseases, diabetes (30-32). Other causes may include severe anemia, hypokalemia and hypomagnesaemia, hypotension, hypervolemia, severe infections (29, 33). Our study demonstrates a strong association between postoperative AF and the duration of surgery: 165 (150-180) *vs* 120 (90-150) minutes (p=0.002). Each increase in operative time by one unit (minute) raised the oddsof AF by 1.01 (95% CI 1-1.02). We also noticed a higher incidence of AF in the older population: 72 (43-79.75) *vs* 50 (38.75-61.25) years (p=0.045). Even though we found that newly diagnosed AF group correlated with lower values of postsurgical haemoglobin [10.4 (9.37-12.6) *vs* 12.1 (11-13.2) g/dL (p=0.041)], the univariate logistic regression found that postsurgical haemoglobin did not have a significant effect ($p>0.05$). Other studies have identified an association between lower hemoglobin levels and the onset of AF; however, no causal relationship has been conclusively identified (34).

Systemic inflammation has one of the most important roles in the etiopathogenesis of cardiovascular pathologies. Endothelial dysfunction starts manifesting from any kind of acute or chronic inflammation, such as infections, autoimmune illnesses, presence of traditional risk factors (hypercholesterolemia, smoking, diabetes, obesity, physical inactivity, hypertension), aging, emotional stress (35). The inflammatory stress is directly affecting the endothelium by reducing its protective properties and creating an atherogenicity status of the vessel (36, 37).

Acute or chronic infection determine an increased number of white blood cells. Elevated preoperative neutrophil-lymphocyte ratio is associated with systemic inflammation. Lymphopenia and increased number of monocytes can determine myocardial injury (38, 39). White blood cell count can also be used as an independent factor for predicting cardiovascular events (40).

The ST segment depression is usually considered a sign of ischemia, related to increased cardiovascular mortality. But ST-depression is highly associated with incidental AF, likely due to the bidirectional ischemic implications (41). Our results also indicate a strong association between AF and ST segment depression (50 % *vs* 16.3 %) ($p=0.003$). Our study also found an association between DM and ST segment depression. As well, we found correlations between ST depression and HBP history and with higher values of intraoperative sBP max value: 148.87 ± 21.54 *vs* 137.1 ± 18.88 mm Hg ($p=0.007$). The mechanism can be explained by the subendocardial ischemia determined by the increasing afterload and intraventricular pressure and decreasing intracoronary perfusion due to ventricular hypertrophy (if it is present) (41). Postsurgical ST depression also involved a longer surgical duration: 150 (120-180) *vs* 120 (90-150) minutes ($p<0.001$). This result could be explained by the hypoxemia which can determine ischemia that may occur during and after non-cardiac surgery as reported by many studies (42-45).

Silent myocardial ischemia (SMI), an important event that is commonly missed, is caused by inadequate perfusion of the heart. It is usually underdiagnosed due to lack of symptoms. Specific symptoms, such as chest pain or discomfort, dyspnea or sweating, occur late in the progression of the narrowing of the coronary vessels. These types of cardiac transient events are asymptomatic in 50 to 70% of cases (46). The etiopathogenesis of SMI has many intricate pathways, including vascular, neuronal, hormonal and metabolic factors (47).

Perioperative SMI is more common due to the specificity of the situation. For example, 65% of patients with myocardial infarction in the POISE-1 trial were asymptomatic (48). Angina was reported in only 6% of patients diagnosed with myocardial infarction after non-cardiac surgery (49). One of the most comprehensive studies, The Vascular Events in Noncardiac Surgery Patients Cohort Evaluation Study (VISION), evaluated over 40 000 patients and reported 13.0% of deaths were caused by myocardial infarction that occurred more commonly in the first day after surgery; 93% of patients did not experience any symptoms related to the cardiac injury (4). One explanations for the lack of symptoms may be that the analgesic medication usually received by patients after major surgery can hide the symptoms of myocardial injury (50).

Even though modern medicine evolved incommensurably in the past decades, the surgical act, of any nature, is perceived by our body as an aggression or an invasive traumatic stimulus. There are two types of responses to this aggression: a metabolic response and an immune response (51). These are complex neuroendocrine and inflammatory responses responsible for generating systemic changes that should be integrated and understood as a whole (52). The cardiovascular system is its main target being influenced by the catabolic processes and the increased sympathetic tone. New and innovative technologies are now available, helping healthcare personnel to monitor and make a precise preoperative assessment of patients, so that cardiovascular events can be avoided in the perioperative period (53, 54). Further studies are needed in order to comprehend the complexity of the cardiovascular system response to the multitude of changes taking place in the perioperative period.

The clinical implications of our findings, although preliminary, are noteworthy and warrant further exploration. Early detection of non-fatal cardiac events such as transient arrhythmias, ST-segment changes, or subclinical ischemia in the immediate postoperative period may serve as an early warning signal for underlying myocardial stress or vulnerability. Incorporating routine or targeted perioperative ECG monitoring in selected high-risk patients could facilitate prompt identification and management of these events, potentially mitigating progression to more severe complications. Additionally, the integration of specific perioperative risk markers – such as postoperative troponin dynamics, intraoperative blood pressure variability and haemoglobin fluctuations – into existing risk assessment models may enhance the predictive accuracy of current clinical protocols.

Our study suggests that even transient or subclinical cardiac manifestations should not be overlooked, as they may have prognostic value. Ultimately, our findings support the need for a more nuanced and individualized approach to perioperative cardiovascular surveillance, which could inform future updates to clinical guidelines and standard operating procedures in non-cardiac surgical care. ❑

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