ORIGINAL ARTICLE

The incidence of cardiovascular and other major complications after open abdominal aortic surgery

Dorota Studzińska[1, 2], Kamil Polok[2], Maciej Chwała[1], Marcin Zaczek[3], Wojciech Szczeklik[2]

[1]Department of Vascular Surgery and Angiology, St. John Grande Hospital, Kraków, Poland
[2]Center for Intensive Care and Perioperative Medicine, Jagiellonian University Medical College, Kraków, Poland
[3]Department of Internal Medicine, St. John Grande Hospital, Kraków, Poland

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Correspondence to:
Wojciech Szczeklik, MD, PhD, Jagiellonian University Medical College, Centre for Intensive Care and Perioperative Medicine, Wrocławska 1–3, 30–901 Kraków, Poland, phone: +48 12 630 82 67, e-mail: wojciech.szczeklik@uj.edu.pl

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ABSTRACT

Background: Abdominal aortic aneurysms (AAAs) and peripheral artery disease significantly increase the risk of perioperative complications.

Aim: The study aimed to determine the incidence of myocardial injury after noncardiac surgery (MINS), its association with 30-day mortality, as well as predictors of postoperative acute kidney injury (pAKI) and bleeding independently associated with mortality (BIMS) in patients undergoing open vascular surgeries involving the abdominal aorta.

Methods: We performed a retrospective cohort study using a sample of consecutive patients who underwent open abdominal aortic surgery due to infrarenal AAA and/or aortoiliac occlusive disease in a single tertiary center. In each patient, at least two postoperative troponin measurements were performed (on the first and second postoperative day). Creatinine and hemoglobin levels were measured preoperatively and at least twice postoperatively. The outcomes included MINS (primary outcome), pAKI, and BIMS (secondary outcomes). We assessed the associations between them and 30-day mortality and performed multivariable analysis to identify risk factors for these outcomes.

Results: The study group comprised 553 patients. The mean age was 67.6 years, and 82.5% of patients were male. The incidence of MINS, pAKI, and BIMS was 43.8%, 17.2%, and 45.8%, respectively. The 30-day mortality rate was higher in patients who developed MINS (12.0% vs. 2.3%; P <0.001), pAKI (32.6% vs. 1.1%; P <0.001), or BIMS (12.3% vs. 1.7%; P <0.001) compared to patients who did not develop these complications.

Conclusion: This study demonstrated that MINS, pAKI, and BIMS are common complications after open aortic surgeries, and they are related to a substantial increase in the 30-day mortality rate.

Key words: bleeding independently associated with mortality, myocardial injury after noncardiac surgery, open aortic surgery, postoperative acute kidney injury

INTRODUCTION

Abdominal aortic aneurysms (AAAs) and peripheral artery disease (PAD) significantly increase perioperative cardiovascular risk. This is largely attributed to the frequent coexistence of coronary artery disease and other cardiovascular diseases [1, 2]. Pathogenesis of AAA involves a degenerative process of the aortic wall caused by inflammation, structural defects in aorta matrix proteins, and overactive proteolysis leading to the destruction of collagen and elastin fibers [3]. Inflammation of the arterial wall is also an underlying process in the development of atherosclerosis [4]. Although there is a significant overlap of risk factors and prevalence of AAA with atherosclerosis, the etiology of most AAAs appears distinct from atherosclerosis [2].

Each year, several patients with AAA and PAD require vascular surgery, and they pose a particular challenge for clinicians involved in perioperative care. Open aneurysm repair

WHAT'S NEW?

This retrospective study includes exclusively patients undergoing open vascular surgery on the abdominal aorta in whom routine perioperative troponin, creatinine, and hemoglobin monitoring was performed. This approach adds novel information to the current knowledge by describing in detail the incidence of postoperative acute kidney injury and recently introduced perioperative outcomes such as myocardial injury after noncardiac surgery (MINS) and bleeding independently associated with mortality (BIMS). It demonstrates that they are common after open surgeries on the abdominal aorta and can be responsible for a substantial increase in the 30-day mortality rate. The awareness of their significance and knowledge about associated risk factors can facilitate identifying patients requiring particular vigilance in the perioperative period.

involves the replacement of the diseased aortic segment with a tube or bifurcated prosthetic graft [2]. PAD affecting the aortoiliac segment, especially with extensive lesions comprising the aorta up to the renal arteries and iliac arteries (aortoiliac occlusive disease), also may require open reconstruction e.g. aortobifemoral bypass surgery [1]. Recent studies suggested that patients undergoing vascular surgeries are at significantly elevated risk of postoperative myocardial injury and postoperative acute kidney injury (pAKI), which increase morbidity and long-term mortality [5–13].

Intraoperative blood loss and postoperative blood transfusion are common in vascular surgery and are associated with greatly increased risk of both 30-day adverse cardiovascular events and mortality [14, 15]. Bleeding independently associated with mortality (BIMS) is a recently introduced perioperative outcome with the definition based on robust data from a large prospective cohort study [16]. BIMS is associated with all-cause mortality within 30 days of noncardiac surgery and may account for approximately one-quarter of deaths occurring within 30 days of major noncardiac surgery [16].

Considering the clinical importance of postoperative myocardial injury, pAKI, and bleeding, we conducted this study to determine the incidence of these complications in the population of patients undergoing open vascular surgeries involving the abdominal aorta, their associations with 30-day mortality, and their predictors.

METHODS

Study design and population

We performed a retrospective cohort study using a sample of consecutive patients who underwent open abdominal aortic surgery from November 2010 to July 2017 in a tertiary vascular surgery center i.e. the Department of Vascular Surgery, St. John Grande Hospital, Kraków, Poland. Patients aged ≥45 years and undergoing open abdominal aortic surgery were considered eligible for the study. Study personnel extracted data from hospital charts and entered these data in the case report forms.

The study received approval from the Bioethics Committee of the Regional Chambers of Physicians in Kraków on December 27, 2016, before data were extracted. Individual patient consent was not obtained as it was not required by the local bioethics committee.

Study population

We included patients undergoing open aortic surgery (OAS) due to infrarenal AAA and/or PAD (i.e. aortoiliac occlusive disease). Patients were qualified for the surgery at the discretion of the attending physician according to the applicable guidelines (e.g. for AAA diameter ≥ 55 mm in men and ≥ 50 mm in women or the presence of symptoms for aortoiliac occlusive disease, the presence of symptoms such as short-distance intermittent claudication, ulceration, or necrosis) [17, 18]. Patients who died on the day of surgery and did not have postoperative troponin monitoring (n = 16) were excluded from the analysis. All patients were admitted to the Intensive Care Unit after surgery as per the standard of care in the participating center.

Perioperative monitoring of troponin, creatinine, and hemoglobin levels

In each patient (n = 553) at least two postoperative troponin (Tn) measurements were performed (on the first and second postoperative day). An electrocardiogram (ECG) was performed routinely in any case of Tn elevation as per the standard of care at the participating center. In a subgroup of 242 patients, Tn level was also measured preoperatively. Troponin monitoring was performed using high-sensitivity troponin T (hs-TnT, Roche, Basel, Switzerland) or ultra-sensitive Vidas troponin I (us-TnI, Biomerieux, Marcy-l'Étoile, France). Creatinine and hemoglobin levels were measured preoperatively and at least twice postoperatively. Diuresis (ml per hour) was routinely monitored for 2 postoperative days or longer if necessary.

The Revised Cardiac Risk Index (RCRI) score was calculated for all patients (i.e., one point for each of the following: history of ischemic heart disease, congestive heart failure, cerebrovascular disease, preoperative insulin therapy, preoperative serum creatinine concentration > 176.8 umol/l, and undergoing high-risk surgery) [19].

The American Society of Anesthesiologists (ASA) physical status score was calculated by the attending anesthesiologist according to the current guidelines [20].

Outcomes

The primary outcome of this study was myocardial injury after noncardiac surgery (MINS). Secondary outcomes were postoperative acute kidney injury (pAKI) and bleeding independently associated with mortality (BIMS).

MINS was defined as [9, 21, 22]:

- absolute postoperative hs-TnT ≥65 ng/l or postoperative 20–64 ng/l AND at least 5 ng/l increase compared to preoperative hs-TnT level (thresholds established in the Vascular Events In Noncardiac Surgery Patients Cohort Evaluation [VISION] study);
- postoperative us-TnI over the 99th percentile upper reference limit (≥19 ng/l) in patients who had no evidence of a non-ischemic etiology for the troponin elevation [7, 9, 21].

For patients with an elevated troponin level, study personnel looked for evidence of ischemic symptoms and/or ECG changes reported in the internist or cardiologist consultation or electronic health records from the day of myocardial injury diagnosis. The Fourth Universal Definition of Myocardial Infarction was used to diagnose myocardial infarction [23].

pAKI was defined according to the Kidney Disease: Improving Global Outcomes (KDIGO) criteria [24]:

- Stage I: 1.5–1.9 times baseline or ≥0.3 mg/dl (≥26.5 μmol/l) increase or urine output <0.5 ml/kg/h for 6–12 hours;
- Stage II: 2.0–2.9 times baseline or urine output <0.5 ml/kg/h for ≥12 hours;
- Stage III: 3.0 times baseline or increase in serum creatinine to ≥4.0 mg/dl (≥353.6 μmol/l) or initiation of renal replacement therapy or anuria for ≥12 hours.

BIMS was defined as bleeding leading to postoperative hemoglobin <70 g/l, transfusion of ≥1 unit of red blood cells, or bleeding that was judged to be the cause of death [16].

The remaining outcomes included: 30-day mortality, in-hospital mortality, 30-day rehospitalization rate, in-hospital reoperation, gastrointestinal bleeding, requirement for transfusion, acute congestive heart failure, perioperative atrial fibrillation, stroke, nonfatal cardiac arrest, pneumonia, sepsis, pulmonary embolism, deep vein thrombosis, intestine ischemia, acute limb ischemia, and multiorgan failure. The detailed definitions of the remaining outcomes are presented in Supplementary material, *Table S1*.

Statistical analysis

The categorical variables were presented as counts and proportions and compared using the χ^2 test or Fischer's exact test. The continuous variables were presented as means (standard deviation, SD) or medians (interquartile ranges [IQR]). They were compared using the Mann-Whitney test or Student's t-test as appropriate. The differences in mortality were assessed using the log-rank test and visualized using the Kaplan-Meier curves. We performed multivariable analyses using logistic regression to evaluate the risk factors for MINS, pAKI, and BIMS. The model for MINS included age, sex, hypertension, coronary artery disease, chronic obstructive pulmonary disease (COPD), PAD, Lee's score, and duration of surgery. The model for pAKI additionally included preoperative estimated glomerular filtration rate (eGFR) according to the Modification of Diet in Renal Disease (MDRD) equation and intraoperative urine output per hour. The model for BIMS additionally included preoperative hemoglobin levels. This was a complete case analysis. All statistical analyses were performed using R, CRAN version 4.1.0 (packages: rms). A two-sided *P*-value < 0.05 was considered statistically significant.

RESULTS

Study population

This study included 553 patients undergoing open aortic surgery. The mean age was 67.6 (8.3) years, and males comprised 82.5% (456/553) of the study group. The median observation time was 30 days and ranged from 1 to 128 days. The majority of patients underwent open aneurysm repair with a tube prosthetic graft due to AAA (an aorta-aortic graft, 45.6%), aortobifemoral bypass surgery due to aortiiliac occlusive disease (20.6%), and simultaneous open aneurysm repair with aorto-biiliac bypass surgery (12.3%). Seven patients (1.3%) required suprarenal aortic clamping. Reimplantation of the mesenteric inferior artery to the prosthesis was performed in 5 patients (0.9%). Reimplantation of the accessory renal artery was performed in 2 patients (0.4%).

Baseline characteristics, laboratory results, and surgery characteristics in the total cohort and stratified by the incidence of MINS are presented in Table 1. Details on surgery and anesthesia type in the total cohort and stratified by the incidence of MINS are shown in Supplementary material, *Table S2*. Supplementary material, *Table S3* contains a comparison of baseline characteristics and complication rates stratified by the reason for surgery. Figure 1 demonstrates Kaplan-Meier curves comparing survival probability for patients who developed MINS, pAKI, and BIMS.

Myocardial injury after noncardiac surgery

Perioperative troponin monitoring was performed using hs-TnT in 411 patients (74.3%) and us-TnI in 142 patients (25.7%). MINS was diagnosed in 242 (43.8%) patients and occurred at a similar rate in patients undergoing surgery for AAA and PAD (43.2% vs. 45.6%; *P* = 0.69). The MINS incidence was higher among patients with hs-TnT monitoring compared to us-TnI (48.7% vs. 29.6%; *P* <0.001). In patients with MINS, ischemic symptoms were present in 5.0% (12/242). Of 33 patients with MINS in whom echocardiography was performed, wall motion abnormalities were discovered in 14 patients (42.4%). Diagnostic criteria for myocardial infarction according to the Fourth Universal Definition of Myocardial Infarction were met in 16.1% of patients with MINS (39/242). The incidence of MINS was associated with a history of COPD (odds ratio [OR], 1.83; 95% confidence interval [CI], 1.24–2.70) and PAD (OR, 1.96; 95% CI, 1.33–2.90). Univariable analysis is summarized in Table 1 and multivariable analysis results are presented in Supplementary material, *Table S5*. Thirty-day mortality was

Table 1. Baseline characteristics, laboratory results, and surgery features

Feature	Total cohort (n = 553)	MINS (n = 242)	Non-MINS (n = 311)	*P*-value
Demographic and clinical characteristics				
Male sex, n (%)	456 (82.5)	196 (81.0)	260 (83.6)	0.49
Age, years, mean (SD)	67.6 (8.3)	68.38 (8.28)	66.95 (8.31)	0.045
Hypertension, n (%)	417 (75.5)	184 (76.3)	233 (74.9)	0.77
Coronary artery disease, n (%)	199 (36.1)	109 (45.2)	90 (28.9)	<0.001
High-risk coronary artery disease[a], n (%)	5 (0.9)	1 (0.4)	4 (1.3)	0.54
History of myocardial infarction, n (%)	103 (18.7)	58 (24.1)	45 (14.5)	0.006
History of cerebrovascular event, n (%)	41 (7.5)	21 (8.8)	20 (6.4)	0.37
Congestive heart failure, n (%)	41 (7.4)	21 (8.7)	20 (6.4)	0.40
Diabetes mellitus, n (%)	109 (19.7)	40 (16.5)	69 (22.2)	0.12
Chronic obstructive pulmonary disease, n (%)	167 (30.3)	92 (38.2)	75 (24.1)	0.001
Aortic stenosis, n (%)				0.16
None	531 (96.5)	227 (95.0)	304 (97.7)	
Mild	18 (3.3)	11 (4.6)	7 (2.3)	
Mechanical prosthesis	1 (0.2)	1 (0.4)	0 (0.0)	
Peripheral arterial disease, n (%)	340 (63.8)	174 (73.1)	166 (56.3)	<0.001
Chronic kidney disease requiring dialysis, n (%)	1 (0.2)	1 (0.4)	0 (0.0)	0.90
History of smoking (current or in the past), n (%)	469 (84.8)	197 (81.4)	272 (87.5)	0.07
Preoperative pharmacotherapy				
Acetylsalicylic acid, n (%)	392 (71.8)	159 (67.1)	233 (75.4)	0.04
Statin, n (%)	412 (75.5)	168 (70.9)	244 (79.0)	0.04
Angiotensin-converting-enzyme inhibitors, n (%)	284 (52.0)	129 (54.4)	155 (50.2)	0.37
Angiotensin receptor blockers, n (%)	43 (14.1)	9 (11.2)	34 (15.0)	0.51
Beta-blockers, n (%)	296 (54.1)	129 (54.4)	167 (53.9)	0.97
Non-dihydropyridine calcium channel blockers, n (%)	142 (26.0)	46 (19.4)	96 (31.1)	0.003
Dihydropyridine calcium channel blockers, n (%)	8 (1.5)	5 (2.1)	3 (1.0)	0.46
Diuretics, n (%)	174 (32.2)	74 (31.6)	100 (32.6)	0.89
Oral anticoagulants, n (%)	7 (1.3)	5 (2.1)	2 (0.6)	0.26
Low-molecular-weight heparin, n (%)	40 (7.4)	29 (12.4)	11 (3.6)	<0.001
Clopidogrel, n (%)	12 (2.2)	9 (3.8)	3 (1.0)	0.053
Fibrate, n (%)	11 (2.0)	4 (1.7)	7 (2.3)	0.87
Perioperative risk scores				
ASA score, n (%)				
2	140 (25.8)	50 (20.8)	90 (29.8)	<0.001
3	345 (63.7)	143 (59.6)	202 (66.9)	
4	49 (9.0)	39 (16.2)	10 (3.3)	
5	8 (1.5)	8 (3.3)	0 (0.0)	
The RCRI index, median (IQR)	1.0 (1.0–2.0)	2.00 (1.0–2.0)	1.0 (1.0–2.0)	<0.001
AAA characteristics				
AAA symptoms, n (%)				<0.001
Not symptomatic	342 (79.0)	133 (69.3)	209 (86.7)	
Symptomatic	56 (12.9)	27 (14.1)	29 (12.0)	
Ruptured	35 (8.1)	32 (16.7)	3 (1.2)	
AAA size based on CT scans, mm, median (IQR)	57.0 (52.0–65.0)	60.0 (53.0–70.0)	55.0 (52.0–61.0)	0.001
Laboratory results				
Baseline eGFR, ml/min/1.73 $m^{2,}$ median (IQR)	85.3 (68.0–105.1)	79.3 (59.2–96.7)	89.1 (73.7–110.5)	<0.001
Baseline hemoglobin, g/dl, median (IQR)	14.5 (13.3–15.4)	14.2 (12.6–15.2)	14.7 (13.7–15.5)	<0.001
Surgery characteristics				
Emergent surgery, n (%)	88 (15.9)	54 (22.3)	34 (10.9)	<0.001
Surgery duration, min, median (IQR)	140 (115–180)	145 (115–175)	140 (115–180)	0.70
Intraoperative blood loss, ml, median (IQR)	700 (500–1000)	700 (500–1275)	700 (500–1000)	0.13
Intraoperative urine output, ml, median (IQR)	270 (150–440)	260 (150–455)	280 (150–440)	0.69

[a]Diagnosis ≤6 months before noncardiac surgery of myocardial infarction, acute coronary syndrome, Canadian Cardiovascular Society class III or IV angina
Abbreviations: AAA, abdominal aortic aneurysm; ASA, American Society of Anesthesiologists; CT, computed tomography; eGFR, estimated glomerular filtration rate; IQR, interquartile range; MINS, myocardial injury after noncardiac surgery; SD, standard deviation; RCRI, Revised Cardiac Risk Index

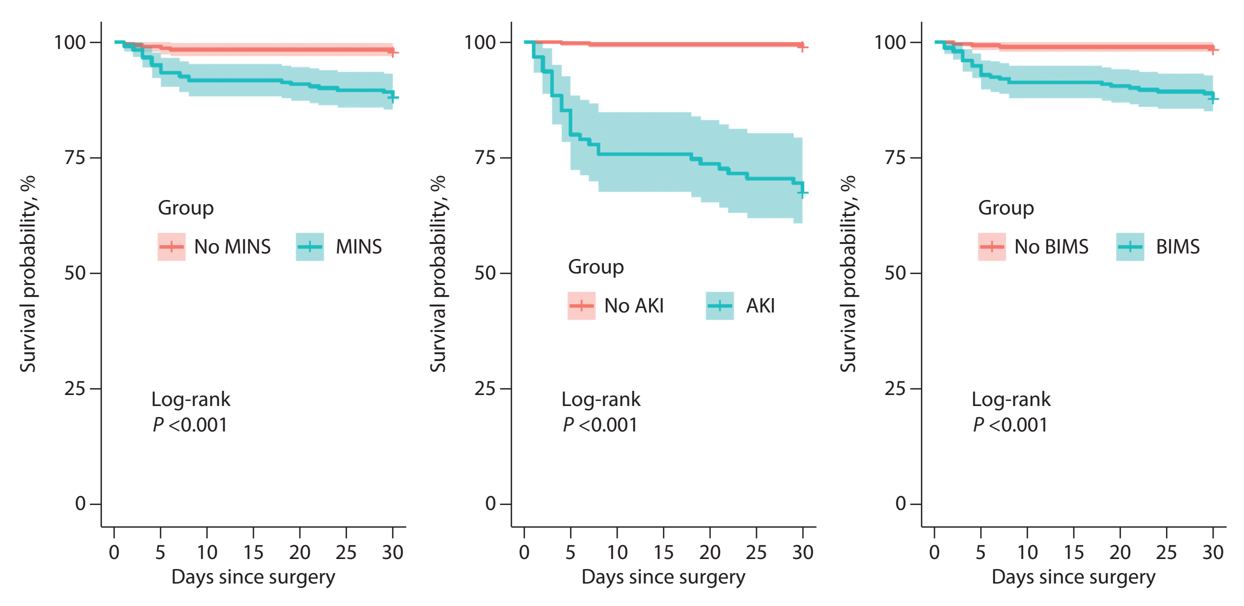

Figure 1. Kaplan-Meier curves comparing survival probability for patients who developed MINS, pAKI, and BIMS, respectively

Abbreviations: BIMS, bleeding independently associated with mortality; MINS, myocardial injury after noncardiac surgery; pAKI, postoperative acute kidney injury

higher in patients who developed MINS (12.0% vs. 2.3%; *P* <0.001).

Postoperative acute kidney injury

Postoperative acute kidney injury was diagnosed in 95 patients (17.2%), 20 of whom (21.1%) required postoperative continuous dialysis. According to the KDIGO criteria, pAKI was categorized as stage I in 54 patients (9.8%), stage II in 20 patients (3.6%), and stage III in 21 patients (3.8%). Patients undergoing surgery for AAA more often suffered from AKI (19.2% vs. 11.0%; *P* = 0.04) but not from pAKI requiring dialysis (3.6 vs. 3.7%; *P* = 1.0). There was no difference in the incidence of pAKI between patients who required suprarenal aortic clamping and the remaining patients (42.9% vs. 16.8%; *P* = 0.10). The risk of pAKI was associated with lower preoperative eGFR (OR, 0.97; 95% CI, 0.96–0.98 [per increase by 1 ml/min/1.73 m^2]) and longer surgery duration (OR, 1.92; 95% CI, 1.45–2.59 [per increase by 1 hour of surgery]). The univariable analysis is summarized in Supplementary material, *Table S4*, and multivariable analysis results are presented in Supplementary material, *Table S5*. Thirty-day mortality was higher in patients who developed pAKI (32.6% vs. 1.1%; *P* <0.001).

Bleeding independently associated with mortality (BIMS)

BIMS criteria were met by 253 patients (45.8%), among whom 197 (77.9%) required blood product transfusion. The BIMS incidence was similar in patients undergoing procedures for AAA and PAD (46.3 vs. 44.1%; *P* = 0.73). The risk of bleeding was associated with increasing age (OR, 1.05; 95% CI, 1.02–1.08), longer surgery duration (OR, 2.91; 95% CI, 2.21–3.92 [per increase by 1 hour of surgery]), and lower preoperative hemoglobin level (OR, 0.58; 95% CI, 0.50–0.67 [per increase by 1 g/dl of hemoglobin]). The univariable analysis is summarized in Supplementary material, *Table S4*, and multivariable analysis results are presented in Supplementary material, *Table S5*. Thitry-day mortality was higher in patients who developed BIMS (12.3% vs. 1.7%; *P* <0.001).

Other postoperative complications

Thirty-day mortality accounted for 6.5% (36/553) and hospital mortality was 6.9% (38/553). The most common postoperative complications were the need for reoperation (8.3%), pneumonia (7.8%), and postoperative atrial fibrillation (7.1%). All recorded postoperative complications and their incidence stratified by the coexistence of MINS are summarized in Table 2.

DISCUSSION

In this retrospective study aimed at assessment of perioperative complications, we demonstrated that MINS, pAKI, and BIMS are common after OAS and are associated with an increased 30-day mortality rate. Our results suggest that this population requires particular vigilance and an active approach toward the detection of postoperative complications.

Myocardial injury is a common complication in vascular surgery, often remains asymptomatic, and is associated with an almost 10-fold increase in short-term mortality [10, 25, 26].

In our study, in comparison to the data reported by Biccard et al. (a vascular surgery sub-analysis of the VISION study), the prevalence of MINS was higher (43.8% vs. 19.1%), with 95% of patients not presenting any symp-

Table 2. Summary of outcomes in the entire cohort and stratified by the incidence of MINS

Feature	Total cohort (n = 553)	MINS (n = 242)	Non-MINS (n = 311)	*P*-value
In-hospital death, n (%)	38 (6.9)	30 (12.4)	8 (2.6)	<0.001
30-day mortality, n (%)	36 (6.5)	29 (12.0)	7 (2.3)	<0.001
30-day rehospitalization, n (%)	5 (0.9)	2 (0.8)	3 (1.0)	1.00
Hospital LOS, days, median (IQR)	11.0 (9.0–15.0)	11.0 (9.0–16.0)	11.0 (9.0–14.0)	0.15
ICU LOS, days, median (IQR)	3.0 (2.0–3.0)	3.0 (2.0–4.0)	3.0 (2.0–3.0)	0.01
Myocardial infarction, n (%)	39 (7.1)	39 (16.1)	0 (0.0)	–
AKI, n (%)	95 (17.2)	67 (27.7)	28 (9.0)	<0.001
AKI requiring dialysis, n (%)	20 (3.6)	18 (7.5)	2 (0.6)	–
BIMS, n (%)	253 (45.8)	139 (57.4)	114 (36.7)	<0.001
Gastrointestinal tract bleeding, n (%)	5 (0.9)	3 (1.2)	2 (0.6)	–
Requirement for transfusion after surgery, n (%)	197 (35.6)	115 (47.5)	82 (26.4)	<0.001
Acute congestive heart failure, n (%)	17 (3.1)	13 (5.4)	4 (1.3)	0.01
Perioperative atrial fibrillation, n (%)	39 (7.1)	31 (12.8)	8 (2.6)	<0.001
Stroke, n (%)	2 (0.4)	0 (0.0)	2 (0.6)	0.59
Nonfatal cardiac arrest, n (%)	7 (1.3)	4 (1.7)	3 (1.0)	0.74
Pneumonia, n (%)	43 (7.8)	34 (14.0)	9 (2.9)	<0.001
Sepsis, n (%)	27 (4.9)	23 (9.5)	4 (1.3)	<0.001
Pulmonary embolism, n (%)	0 (0.0)	0 (0.0)	0 (0.0)	–
Deep vein thrombosis, n (%)	1 (0.2)	1 (0.4)	0 (0.0)	–
Intestine ischemia, n (%)	7 (1.3)	5 (2.1)	2 (0.6)	0.27
Acute limb ischemia, n (%)	32 (5.8)	19 (7.9)	13 (4.2)	0.10
Multiorgan failure, n (%)	31 (5.6)	24 (9.9)	7 (2.3)	<0.001
In-hospital reoperation, n (%)	46 (8.3)	27 (11.2)	19 (6.1)	0.048

Abbreviations: AKI, acute kidney injury; BIMS, bleeding independently associated with mortality; ICU, intensive care unit; MINS, myocardial injury after noncardiac surgery; LOS, length of stay

toms of cardiac ischemia [10]. Markedly higher incidence of MINS in our cohort is probably related to the type of OAS procedures, which are some of the most complex procedures in vascular surgery encompassing clamping and cutting the aorta. Moreover, common prolongation of sedation in this population likely contributes to the high percentage of asymptomatic cases. Our study corroborates previously cited data indicating that MINS is associated with poorer short-term prognosis and higher rates of complication such as perioperative atrial fibrillation, pneumonia, sepsis, pAKI, and 30-day mortality.

Until now, the data on the prevalence of MINS in patients undergoing OAS have been scarce. A small cohort study of 31 patients who underwent open aortic repair due to AAA and had routine troponin I (TnI) measurements in the first 3 postoperative days revealed that 9 patients (29%) experienced significant elevation of TnI levels above the upper limit of normal [27]. In another small study including 38 patients who underwent OAS and had routine TnI measurement before surgery and in the first 3 postoperative days 31% of patients had increased levels of TnI postoperatively [28]. In our study, the incidence of myocardial injury was higher compared to those reports (43.8% vs. 29% and 31%). Moreover, the presented prevalence of myocardial infarction diagnosed according to the Fourth Universal Definition of Myocardial Infarction (16.1%) was higher than in some previous studies — i.e. 3.7% in a study by La Manach and al. and 4.2% in a study by Steely et al. [29, 30]. This difference is likely explained by the routine troponin monitoring using high-sensitivity assays in our study.

The available studies on major vascular surgeries demonstrated an association between preoperative renal dysfunction, prior stroke, prolonged surgery, surgical priority, requirement for red cell transfusion, and cardiovascular complications such as myocardial infarction, arrhythmias, pulmonary edema, and stroke [31, 32]. Our study extends the current knowledge by showing that COPD and PAD, but not age, sex, hypertension, coronary artery disease, duration of surgery, or RCRI, are related to increased risk of MINS in this population.

The reported incidence of pAKI within 30 days after OAS varies widely in available studies and ranges from 8.4 to 52.5%. This is very likely due to heterogeneity in definitions used in different studies [29, 31, 33, 34]. A recent report using the Acute Kidney Injury Network (AKIN) criteria for pAKI (analogous to the KDIGO definition), reported an incidence of 22.4% in patients who underwent OAS with an 8-fold increase in 30-day mortality [33]. Overall, the risk factors for pAKI in this study were intraoperative red blood cell transfusion and chronic kidney disease [33]. Another study in which pAKI was defined using the Aneurysm Renal Injury Score (ARISe), reported the incidence of pAKI equal to 26.3% in patients undergoing OAS and a higher mortality rate in patients who developed this complication (4.8% vs. 0.6%) [35]. According to this study, current smoking, hypertension, chronic kidney disease, and arrhythmias were predictors of pAKI. Our study confirms a high incidence of pAKI in patients undergoing OAS (17.2%) and its association with higher 30-day mortality (32.6% vs. 1.1%). We additionally showed that lower preoperative eGFR and longer surgery duration were related to higher risk of pAKI. Interestingly, we did not confirm the previously described association between pAKI and intraoperative red blood cell transfusion. Finally, in both mentioned studies, analysis of pAKI predictors was performed on the whole study population without distinction regarding the type of surgery (open vs. endovascular) [33, 35].

Another crucial perioperative outcome with a multitude of definitions is bleeding. The most recent approach to define bleeding was the introduction of BIMS based on data from a prospective study of 16 079 patients aged ≥45 years having noncardiac surgery. Simultaneously an electronic risk calculator for BIMS was developed and internally validated [16]. The diagnostic criteria for BIMS were created based on their association with all-cause mortality within 30 days of noncardiac surgery. In our study, we showed that BIMS is a common complication after OAS affecting nearly every second patient, and it is associated with a substantial increase in the 30-day mortality rate (12.3% vs. 1.7% in the non-BIMS group). We identified age, longer surgery duration, and low preoperative hemoglobin level as predictors of BIMS. We believe there is an urgent need to standardize definitions of perioperative outcomes, particularly pAKI and bleeding. This will improve researchers' ability to reliably pool data from different reports to improve our understanding of incidence and risk factors of postoperative complications and their impact on short- and long-term mortality.

The main strength of our study is a relatively large and homogenous cohort of patients undergoing major open surgery involving the aorta. To our knowledge, this is the largest study describing the incidence of MINS, pAKI, and BIMS in this population encompassing routine measurement of appropriate markers. Such an approach enabled us to provide researchers and clinicians with precise estimates. From a practical point of view, preoperative evaluation of patients to identify risk factors for MINS, pAKI, and BIMS could allow the introduction of some interventions before the surgery recommended in the appropriate guidelines. These include e.g. temporarily withholding angiotensin-converting enzyme inhibitors, angiotensin receptor blockers, and aldosterone antagonists before surgery for pAKI prevention and correction of anemia for BIMS prevention [24, 36].

Our study also has several limitations. First, we did not perform routine troponin measurements before surgery in all patients (preoperative Tn level was available only in a subgroup of 242 patients). Thus, we could not exclude patients with chronic troponin elevation. However, available data suggest that elevated troponins before surgery account for only 13.8% of perioperative elevations [7, 10]. Second, the study carries limitations associated with its retrospective design e.g. lack of some potentially significant parameters (e.g. body mass index) prevented us from evaluating their association with postoperative complications. Third, due to the lack of troponin monitoring on the day of surgery, we had to exclude patients who died on the day of surgery and did not have postoperative troponin monitoring. Four, the recruitment period for this study ended five years before this analysis, and some clinical practices changed over that time. Fifth, this was a single-center study which limits the generalizability of the results due to the possible impact of the surgical approach typical for this center (e.g. lack of cell saver technique). Sixth, we did not gather precise data about preoperative electrocardiograms so we were unable to evaluate their association with postoperative complications in this cohort and thus validate some of our previous findings [37]. Finally, we were unable to perform a multivariable analysis of the association between mortality and outcomes of interest due to a relatively low 30-day mortality.

CONCLUSION

MINS, pAKI, and BIMS are common complications after OAS and are related to a substantial increase in the 30-day mortality rate. The majority of these events are asymptomatic and without systematic monitoring would likely go undetected. The awareness of their independent predictors can facilitate identifying high-risk patients susceptible to experiencing such complications.

Supplementary material

Supplementary material is available at https://journals.viamedica.pl/kardiologia_polska.

Article information

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