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NEW RISK STRATIFICATION MODELS FOR PREDICTING MAJOR ADVERSE CARDIAC EVENTS AFTER OPEN ABDOMINAL AORTIC ANEURYSM REPAIR

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Patients undergoing open surgical repair of abdominal aortic aneurysm (AAA) represent a high-risk population for perioperative major adverse cardiovascular events (MACE), and accurate preoperative risk assessment remains challenging. The aim of this study was to evaluate the predictive value of established and novel risk models for MACE in patients undergoing elective open AAA repair. This prospective observational study included 41 patients who underwent elective open AAA repair in

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2017. Preoperative risk was assessed using multiple clinical and surgical risk scores, including POSSUM, V-POSSUM, NYHA, ASA, GSCRI, Gupta MICA, UCRS, VQI, ACS NSQIP, VSGNE, AUB-HAS2, and RCRI. Patients were followed for six months. The mean age was 68.1 ± 6.3 years, and 32.5% of patients developed MACE. A positive family history ($p = 0.007$), lower use of beta-blockers ($p = 0.038$), and higher use of calcium channel blockers ($p = 0.017$) were associated with MACE. Significant differences were observed in leukocyte count ($p = 0.021$), HDL ($p = 0.036$), CK ($p = 0.008$), and suPAR levels ($p < 0.001$). ASA score was significantly associated with MACE ($p = 0.046$). In univariate analysis, UCRS was a significant predictor (HR 1.106, $p = 0.018$), while in multivariate analysis both UCRS (HR 1.260, $p = 0.001$) and Gupta MICA (HR 2.102, $p = 0.035$) were independent predictors. UCRS and Gupta MICA demonstrated the best predictive performance and may be useful tools for preoperative cardiovascular risk stratification in patients undergoing open AAA repair.

Key words: abdominal aortic aneurysm, MACE, risk stratification, UCRS, Gupta MICA

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NOVI MODELI STRATIFIKACIJE RIZIKA ZA PREDVIĐANJE VELIKIH NEŽELJENIH KARDIOVASKULARNIH DOGAĐAJA NAKON OTVORENE REPARACIJE ANEURIZME ABDOMINALNE AORTE

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Pacijenti koji se podvrgavaju otvorenoj hirurškoj reparaciji aneurizme abdominalne aorte (AAA) predstavljaju visokorizičnu grupu za nastanak velikih neželjenih kardiovaskularnih događaja (MACE), a precizna preoperativna procena rizika i dalje predstavlja izazov. Cilj rada bio je da se proceni prediktivna vrednost postojećih i novijih modela rizika za MACE kod bolesnika podvrgnutih elektivnoj otvorenoj reparaciji AAA. U prospektivnu opservacionu studiju uključeno je 41 bolesnik operisan 2017. godine. Preoperativni rizik procenjivan je primenom više kliničkih i hirurških skorova, uključujući POSSUM, V-POSSUM, NYHA, ASA, GSCRI, Gupta MICA, UCRS, VQI, ACS NSQIP, VSGNE, AUB-HAS2 i RCRI. Bolesnici su praćeni šest meseci. Prosečna starost bila je 68,1 ± 6,3 godine, a kod 32,5% bolesnika registrovan je MACE. Pozitivna porodična anamneza (p = 0,007), ređa primena beta-blokatora (p = 0,038) i češća primena blokatora kalcijumskih kanala (p = 0,017) bile su povezane sa MACE. Značajne razlike uočene su u vrednostima leukocita (p = 0,021), HDL (p = 0,036), CK (p = 0,008) i suPAR (p < 0,001). ASA skor bio je značajno povezan sa MACE (p = 0,046). U univarijantnoj analizi UCRS je bio značajan prediktor (HR 1,106; p = 0,018), dok su u multivarijantnoj analizi i UCRS (HR 1,260; p = 0,001) i Gupta MICA (HR 2,102; p = 0,035) bili nezavisni prediktori. UCRS i Gupta MICA pokazali su najbolju prediktivnu vrednost i mogu biti korisni alati u preoperativnoj proceni rizika.

Ključne reči: aneurizma abdominalne aorte, MACE, stratifikacija rizika, UCRS, Gupta MICA

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1. INTRODUCTION

An abdominal aortic aneurysm (AAA) is defined as a permanent, localized dilation of the abdominal segment of the aorta measuring ≥ 3.0 cm in diameter or exceeding 50% of the vessel's expected normal diameter. This pathological condition arises from progressive structural weakening and degeneration of the aortic wall and carries a substantial risk of rupture, an event associated with extremely high mortality [1].

Elective surgical repair remains the cornerstone of management for patients with clinically significant AAA, aiming to prevent rupture and improve survival. Although endovascular aneurysm repair (EVAR) has become widely adopted, open surgical repair (OSR) continues to represent a well-established and durable treatment modality, particularly in patients with unfavorable vascular anatomy or other contraindications to endovascular techniques. Despite its long-term reliability, OSR is associated with considerable perioperative morbidity and mortality [2,3].

Major adverse cardiac events (MACE), including myocardial infarction, arrhythmias, acute heart failure, stroke, and cardiac-related mortality, represent a leading cause of early postoperative morbidity and mortality following AAA repair. The reported incidence of MACE varies across studies but remains clinically significant, particularly in high-risk patient populations. Cardiovascular complications therefore constitute a major determinant of short-term surgical outcomes [4,5,6].

Patients undergoing major vascular surgery are especially vulnerable due to the high prevalence of underlying cardiovascular disease, most notably coronary artery disease (CAD). In addition to preexisting comorbidities, perioperative hemodynamic instability, metabolic disturbances, neuroendocrine stress responses, and thermoregulatory alterations further amplify cardiovascular risk [7].

Given the substantial cardiovascular burden associated with AAA repair, systematic preoperative risk stratification is of paramount importance. Accurate identification of patients at increased risk

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for MACE enables individualized perioperative planning, targeted optimization strategies, and appropriate allocation of monitoring and therapeutic resources.

Risk stratification represents a structured clinical approach aimed at identifying comorbid conditions, evaluating their severity and stability, and guiding further diagnostic assessment and perioperative management. In this context, validated predictive models and clinical risk indices play a central role in contemporary perioperative medicine.

Accordingly, the 2022 European Society of Cardiology (ESC) Guidelines for cardiovascular assessment and management of patients undergoing non-cardiac surgery recommend the routine use of validated clinical risk indices as part of perioperative risk evaluation but also decided against recommendation of any specific score. However, despite the availability of multiple risk assessment tools, accurate prediction of cardiovascular complications in patients undergoing AAA repair remains a persistent clinical challenge [8].

2. THE AIM OF STUDY

The aim of this study is to evaluate the prediction of major adverse cardiovascular events (MACE) based on previously established and novel risk models (risk scores) in patients undergoing open surgical repair for abdominal aortic aneurysm (AAA).

3. MATERIAL AND METHODS

This prospective observational study included 41 patients who underwent elective open surgical repair of abdominal aortic aneurysm (AAA) at the Clinic for Cardiovascular and Transplantation Surgery, Clinical Center Niš, in 2017. The study protocol was approved by the Ethics Committee of the Faculty of Medicine, University of Niš, and written informed consent was obtained from all participants prior to inclusion.

The primary objective of this study was to evaluate perioperative cardiovascular risk in patients undergoing elective open AAA repair, with particular focus on the prediction of major adverse cardiovascular events (MACE).

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Patients with unstable coronary artery disease, decompensated heart failure, or those younger than 21 years of age were excluded from the study.

All procedures were performed under general anesthesia. Prior to surgery, all patients underwent standardized preoperative assessment including medical history, physical examination, laboratory testing, electrocardiography, and chest radiography.

In accordance with the study objective, perioperative cardiovascular risk was assessed using established clinical and surgical risk prediction models :

The POSSUM score, introduced in 1991, was applied to estimate postoperative morbidity and mortality based on physiological and operative variables, including in patients undergoing AAA repair. Its vascular modification, V-POSSUM, developed to improve predictive accuracy in vascular surgery populations, was also used [9,10].

Functional cardiac status was assessed using the New York Heart Association (NYHA) classification, while overall preoperative physical status was evaluated using the American Society of Anesthesiologists (ASA) classification system [11].

The Gupta Surgical Cardiac Risk Index (GSCRI) was used to estimate perioperative cardiac risk based on patient-specific clinical and procedural variables [12].

The Gupta Myocardial Infarction or Cardiac Arrest (MICA) score was used to estimate the risk of perioperative major cardiac events. In the present study, MICA demonstrated statistical significance as a predictor of perioperative cardiovascular risk [12].

The Universal Cardiac Risk Score (UCRS) was used to estimate the risk of major perioperative cardiovascular events and also demonstrated statistical significance in this patient population[13].

The Vascular Quality Initiative Cardiac Risk Index (VQI CRI) was used to estimate the risk of perioperative myocardial infarction in patients undergoing vascular surgery. This procedure-specific model was derived from a large multicenter registry within the Vascular Quality Initiative and

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incorporates clinical variables relevant to vascular surgical populations, including those undergoing open AAA repair[14].

The ACS NSQIP risk calculator is based on a large, multi-institutional database comprising millions of surgical procedures collected from participating hospitals. It enables individualized risk estimation using available patient-specific data, while maintaining predictive capability even when some variables are missing[15].

The Vascular Study Group of New England (VSGNE) cardiac risk model was used to assess perioperative cardiac risk in patients undergoing major vascular procedures[16].

The AUB-HAS2 cardiovascular risk index was used to estimate perioperative cardiovascular risk in patients undergoing noncardiac surgery [17].

Finally, the Revised Cardiac Risk Index (RCRI) was applied as a widely used clinical tool for estimating perioperative cardiac risk in patients undergoing noncardiac surgery, including open AAA repair [18].

Functional capacity was assessed according to the New York Heart Association (NYHA) classification [19]

3.1 STATISTICAL ANALYSIS

The collected data were analyzed using standard descriptive statistical measures, including mean, standard deviation, minimum and maximum values, as well as absolute and relative frequencies (%).

Comparisons between categorical variables were performed using the Chi-square test or Fisher's exact test, as appropriate. Numerical variables between two groups were compared using the Student's t-test or the Mann–Whitney U test, depending on data distribution.

Survival analysis was performed using Cox proportional hazards regression. The null hypothesis was tested at a significance level of $\alpha = 0.05$.

Statistical analyses were conducted using R software[20].

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4. RESULTS

A total of 41 patients were included in the study (5 males and 36 females). The mean age of the study population was 68.1 ± 6.3 years (range 55–84 years). Approximately one-third of patients had diabetes mellitus (32.5%). The majority were receiving ACE inhibitors (82.5%), beta-blockers (77.5%), and antithrombotic therapy (67.5%) (Table 1). During the six-month follow-up period, 13 patients (32.5%) experienced MACE.

Table 1. Baseline Demographic and Clinical Characteristics

Variable	N (%) / Mean ± SD
Age (years)	68.3 ± 6.3 (55–84)
Male	5 (12.2%)
Female	36 (87.8%)
Atrial fibrillation	3 (7.5%)
Prior stroke	4 (10.0%)
Coronary artery disease	10 (25.0%)
Cardiomyopathy	7 (17.5%)
Prior PCI	1 (2.5%)
Previous MI	9 (22.5%)
Diabetes mellitus	13 (32.5%)
Hyperlipidemia	12 (30.0%)
Smoking	24 (60.0%)
Positive family history	21 (52.5%)
Beta-blockers	31 (77.5%)
ACE inhibitors	33 (82.5%)
Calcium channel blockers	19 (47.5%)
Antithrombotic therapy	27 (67.5%)
Statins	12 (30.0%)

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† Mean ± standard deviation, range (min–max)

Patients with a positive family history had a significantly higher incidence of events (84.6% vs 37.0%, p = 0.007) (Table 2). Patients who developed MACE were significantly less likely to receive beta-blockers (53.8% vs 88.9%, p = 0.038) and more likely to be treated with calcium channel blockers (76.9% vs 33.3%, p = 0.017). No other demographic or clinical parameters showed a statistically significant association with the occurrence of events during the six-month follow-up period.

Table 2. Demographic and Clinical Characteristics According to MACE Occurrence (6-Month Follow-up)

Variable	Without MACE (n=27)	MACE (n=13)	p-value
Age (years)	68.59 ± 5.90	67.08 ± 7.12	0.481
Sex			0.363
Male	4 (17.4%)	1 (5.6%)	
Female	19 (82.6%)	17 (94.4%)	
Atrial fibrillation	1 (3.7%)	2 (15.4%)	0.242
Prior stroke	2 (7.4%)	2 (15.4%)	0.584
Coronary artery disease	7 (25.9%)	3 (23.1%)	1.000
Cardiomyopathy	7 (25.9%)	0 (0.0%)	0.074
Prior PCI	1 (3.7%)	0 (0.0%)	1.000
Previous MI	7 (25.9%)	2 (15.4%)	0.690
Hypertension	24 (88.9%)	11 (84.6%)	1.000
Diabetes mellitus	9 (33.3%)	4 (30.8%)	1.000
Insulin-dependent DM	8 (29.6%)	3 (23.1%)	1.000
Hyperlipidemia	9 (33.3%)	3 (23.1%)	0.716
Smoking	16 (59.3%)	8 (61.5%)	1.000
Positive family history	10 (37.0%)	11 (84.6%)	**0.007**

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Beta-blockers	24 (88.9%)	7 (53.8%)	**0.038**
ACE inhibitors	23 (85.2%)	10 (76.9%)	0.662
Calcium channel blockers	9 (33.3%)	10 (76.9%)	**0.017**
Antithrombotic therapy	17 (63.0%)	10 (76.9%)	0.484
Statins	6 (22.2%)	6 (46.2%)	0.154
Nitrates	1 (3.7%)	0 (0.0%)	1.000

[1] Fisher's exact test, [2] Student's t-test

Patients who experienced events within the first six months showed statistically significant differences in leukocyte count ($p = 0.021$), HDL levels ($p = 0.036$), and creatine kinase ($p = 0.008$) compared to those without events (Table). Additionally, suPAR levels were significantly higher in patients who developed MACE during the six-month follow-up period ($p < 0.001$) (Table 3).

Table 3. Laboratory Parameters According to MACE (6 months)

Parameter	Without MACE	MACE	p-value
Hemoglobin	13.30 ± 1.82	13.18 ± 1.53	0.840
Creatinine	102.42 ± 21.74	103.84 ± 17.06	0.838
Leukocytes	7.29 ± 1.72	9.08 ± 2.88	**0.021**
Platelets	211.78 ± 73.23	218.85 ± 53.44	0.588
CRP	6.99 ± 4.70	8.12 ± 6.51	0.908
LDL	3.33 ± 0.90	3.19 ± 1.20	0.401
HDL	1.06 ± 0.29	1.23 ± 0.25	**0.036**
CK	108.97 ± 176.80	279.85 ± 263.89	**0.008**
Urea	7.07 ± 2.42	6.85 ± 1.86	0.919
suPAR	3.33 ± 0.90	6.15 ± 1.81	**<0.001**
Ejection fraction (%)	55.07 ± 6.28	50.31 ± 5.94	0.052

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[1] Mann-Whitney test

No statistically significant difference in the incidence of events during the first six months was observed in relation to the level of dyspnea (p = 0.145). Patients with an ASA score of 3 had a significantly higher incidence of MACE (p = 0.046). The values of the evaluated risk scores did not differ significantly with respect to the occurrence of MACE at six months (Table 4).

Table 4. NYHA, ASA and Risk Scores According to MACE

Variable	Without MACE	MACE	p-value
NYHA I	3 (11.1%)	0 (0.0%)	0.145
NYHA II	16 (59.3%)	5 (38.5%)	
NYHA III	8 (29.6%)	8 (61.5%)	
ASA 2	16 (59.3%)	3 (23.1%)	**0.046**
ASA 3	11 (40.7%)	10 (76.9%)	
AUB-HAS2	2.56 ± 1.09	2.62 ± 0.77	0.648
RCRI	4.31 ± 4.00	5.72 ± 3.86	0.240
V-POSSUM morbidity	1.93 ± 1.07	1.92 ± 0.95	0.878
V-POSSUM mortality	28.19 ± 9.34	27.85 ± 8.65	0.942
GSCRI	2.76 ± 2.63	4.73 ± 5.22	0.206
VQI score	4.09 ± 1.66	4.55 ± 2.49	0.817
UCRS	4.57 ± 2.98	7.72 ± 6.55	0.071
NSQIP MACE	3.21 ± 1.68	3.10 ± 1.63	0.761
NSQIP mortality	2.48 ± 2.74	2.27 ± 2.17	0.534
POSSUM morbidity	5.05 ± 1.82	5.34 ± 2.18	0.738
POSSUM mortality	27.46 ± 9.04	28.65 ± 10.02	0.738

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MICA	1.19 ± 0.94	1.84 ± 0.91	0.101
VSGNE	1.30 ± 0.87	1.45 ± 1.22	0.618

[1] Fisher's exact test

Univariate Cox regression analysis showed that UCRS was a statistically significant predictor of MACE during the six-month follow-up period (HR = 1.106, p = 0.018) (Table 5).

Table 5. Univariate Cox Regression Analysis

Variable	HR	95% CI	p-value
V-POSSUM mortality	0.983	0.918–1.052	0.616
GSCRI	1.014	0.889–1.157	0.835
VQI score	1.126	0.850–1.491	0.409
UCRS	1.106	1.017–1.202	**0.018**
NSQIP MACE	1.019	0.734–1.415	0.911
NSQIP mortality	0.987	0.792–1.229	0.907
POSSUM morbidity	0.996	0.736–1.346	0.977
POSSUM mortality	0.998	0.938–1.061	0.939
MICA	1.583	0.912–2.745	0.102
VSGNE	1.207	0.703–2.074	0.495

Multivariate Cox regression analysis was performed to evaluate the association between UCRS and MICA scores and the occurrence of MACE. Both risk scores were identified as independent predictors of MACE during the six-month follow-up period (UCRS: HR = 1.260, p = 0.001; MICA: HR = 2.102, p = 0.035) (Table 6).

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Table 6. Multivariate Cox Regression Analysis

Variable	HR	95% CI	p-value
Model 1			
Age	0.862	0.768–0.967	0.011
Sex	1.681	0.205–13.803	0.629
UCRS	1.260	1.096–1.448	**0.001**
Model 2			
Age	0.906	0.806–1.018	0.098
Sex	1.489	0.191–11.610	0.704
MICA	2.102	1.052–4.202	**0.035**

B – regression coefficient; HR – hazard ratio; 95% CI – confidence interval

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5. DISCUSSION

Patients undergoing open surgical repair of abdominal aortic aneurysm represent a high-risk surgical population due to the significant cardiovascular burden associated with both the disease and the procedure itself. Despite advances in perioperative care, major adverse cardiovascular events remain a leading cause of postoperative morbidity and mortality in these patients. Therefore, accurate preoperative risk stratification plays a crucial role in identifying individuals at increased risk and guiding perioperative management.

In our cohort, the average patient age was 68 years, placing the population within the elderly category according to World Health Organization criteria. Increasing age is known to be independently linked with a higher incidence of perioperative complications, including cardiovascular, respiratory, and renal events. This elevated risk is primarily related to decreased physiological reserve and the frequent coexistence of comorbidities such as coronary artery disease, chronic kidney dysfunction, and frailty[21]. Although age contributes to the prediction of perioperative MACE, it also represents a confounding factor that may complicate accurate risk assessment.

This is further reflected in the fact that both the UCRS and Gupta MICA models incorporate patient age as a key variable in perioperative cardiovascular risk prediction.

An additional characteristic of the study population was the predominance of female patients, which, together with advanced age, may have contributed to the relatively high incidence of MACE observed. One potential explanation for the elevated cardiac risk in women relates to sex-specific differences in cardiovascular pathophysiology and response to surgical stress. Women are more likely to exhibit preserved systolic function alongside a higher prevalence of diastolic dysfunction and microvascular coronary disease, factors that may increase susceptibility to perioperative myocardial ischemia that is often more difficult to recognize and manage. Furthermore, postmenopausal hormonal changes, particularly reduced estrogen levels, may promote vascular stiffness, endothelial impairment, and pro-inflammatory states, thereby increasing perioperative cardiovascular risk[22].

One possible explanation for the predictive value of the Gupta MICA score in our cohort is its incorporation of functional status through the ASA classification. In the present study, ASA status emerged as a significant predictor of MACE, suggesting that the inclusion of global physiological reserve and systemic disease burden may enhance risk estimation beyond isolated comorbid conditions. The ASA classification has been consistently associated with perioperative morbidity and mortality and reflects the cumulative impact of underlying health status on surgical outcomes. Another potential explanation for the predictive performance of the Gupta MICA score may be the inclusion of patient functional status in the risk assessment.Frailty has been recognized in the 2022 ESC guidelines as an important component of preoperative risk assessment, particularly in elderly patients undergoing high-risk procedures. In the context of open AAA repair, frailty may further contribute to increased vulnerability to perioperative complications and major adverse cardiovascular events by reflecting reduced physiological reserve beyond traditional comorbidity-based risk models[23].

Heart failure occurred as a MACE outcome in 17.1% of patients during the six-month follow-up period. This may partly explain the favorable predictive performance of the UCRS model, which includes heart failure as a key risk variable. Although the NYHA score showed a significant association with

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MACE within the first 30 days after AAA repair, it appears to lose its predictive value when it comes to long-term prediction of MACE.

Both the Gupta MICA and UCRS models incorporate chronic kidney insufficiency as a predictor variable. In patients undergoing open AAA repair, renal dysfunction may further increase the risk of perioperative MACE due to its association with systemic atherosclerosis, endothelial dysfunction, and impaired physiological reserve[24].

Although neither the Gupta MICA nor the UCRS models were specifically developed for vascular surgery, both incorporate high-risk surgery as a predictor variable. Open aortic procedures, including AAA repair, fall within this category, which may partly explain the strong predictive performance of these models in our cohort despite their non–vascular-specific design.

In contrast to several models used in this study that primarily focus on patient-related cardiovascular risk (e.g., ASA, NYHA, RCRI), both the Gupta MICA and UCRS incorporate surgical risk as an explicit predictor through the inclusion of high-risk procedures. Open AAA repair represents a major surgical stressor and is classified within this category. This combined consideration of patient-related factors and procedural burden may explain the superior predictive performance of these models in our cohort. While vascular-specific scores such as V-POSSUM and VQI are designed to estimate surgical outcomes, they mainly reflect operative severity and physiological status rather than broader perioperative cardiac risk. The inclusion of high-risk surgery as a variable may therefore provide an advantage in predicting MACE following open aortic procedures[25].

In univariate Cox regression analysis, only the Universal Cardiac Risk Score (UCRS) was significantly associated with the occurrence of MACE within the 6-month follow-up period (HR 1.106, 95% CI 1.017–1.202, p=0.018).

In multivariable Cox regression models adjusted for age and sex, both UCRS (HR 1.260, 95% CI 1.096–1.448, p=0.001) and the MICA score (HR 2.102, 95% CI 1.052–4.202, p=0.035) were identified as independent predictors of MACE during the 6-month follow-up.

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Although UCRS and MIKA did not show statistically significant differences in cross-sectional group comparisons, Cox regression identified them as significant predictors, likely because survival modeling captures the timing of events. Even with complete 6-month follow-up, dichotomous analyses treat early and late MACE equally and may miss prognostic gradients, especially in small cohorts with substantial score variability (notably UCRS).

In the present study, the Universal Cardiac Risk Score (UCRS) demonstrated a stronger and more consistent association with 6-month MACE, as it remained significant already in univariate Cox regression analysis. In contrast, the Gupta MICA score reached statistical significance only after adjustment for age and sex in the multivariable model, suggesting that its predictive value may be partially influenced by patient characteristics included in the model.

One possible explanation for the observed findings lies in the differences in outcome definitions used by the investigated risk scores. The Gupta Myocardial Infarction or Cardiac Arrest (MICA) score was originally developed to predict the risk of perioperative myocardial infarction and cardiac arrest, which were not the dominant components of MACE in our study population. In contrast, the primary endpoint in our study included a broader spectrum of cardiovascular complications, such as acute heart failure, stroke, and high-grade atrioventricular block requiring pacing. Similarly, the study that validated the Universal Cardiac Risk Score (UCRS) also incorporated a wider range of cardiovascular outcomes, which may explain why UCRS demonstrated a stronger predictive performance in our cohort.

6. CONCLUSION

Patients undergoing elective open repair of abdominal aortic aneurysm represent a high-risk population for perioperative major adverse cardiovascular events. In this study, the Universal Cardiac Risk Score (UCRS) and the Gupta MICA score demonstrated the strongest predictive value for MACE, particularly when assessed using time-to-event analysis.

The superior performance of these models may be attributed to their ability to integrate both patient-related factors and procedural risk, including high-risk surgery, as well as key clinical variables such

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as age, heart failure, and renal dysfunction. In contrast, models primarily focused on physiological status or general surgical outcomes showed limited predictive ability in this setting.

These findings highlight the importance of selecting appropriate risk assessment tools tailored to both the patient profile and the surgical procedure. The use of models that incorporate procedural complexity and broader cardiovascular endpoints may improve perioperative risk stratification in patients undergoing open AAA repair.

Further studies with larger cohorts are warranted to validate these findings and to refine risk prediction strategies in vascular surgery populations.

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