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Risk Assessment of Hemodynamically Significant Arrhythmias after Elective Cardiac Operations with Cardiopulmonary Bypass Using the Modified Nomogram (Retrospective Study)

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Оценка риска развития гемодинамически значимых аритмий после плановых кардиальных операций в условиях искусственного кровообращения с использованием номограммы М (ретроспективное исследование)

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Summary

Aim of the study was to evaluate the feasibility of using a modified nomogram (the M nomogram) to predict the occurrence of new postoperative hemodynamically significant arrhythmias after elective cardiac surgery with cardiopulmonary bypass within 30 days post operation.

Materials and methods. This was a retrospective cohort study. The prognostic value of the model using ROC-analysis of the modified nomogram was estimated based on the medical records of 144 patients who underwent elective cardiac surgery with cardiopulmonary bypass.

Results. The incidence of new postoperative hemodynamically significant arrhythmias was 13.9% (20 of 144 patients). For the modified nomogram, the AUC was 0.777 [95% CI: 0.661–0.892] (P<0.001); at a cutoff of 12 points, the sensitivity was 60.0% and specificity was 89.52%. The odds ratio was 10.26 (95% CI: 3.63–29.06) (P<0.001).

Conclusion. The modified nomogram has an acceptable prognostic value for the occurrence of new hemodynamically significant arrhythmias after elective cardiac operations with cardiopulmonary bypass based on AUC 0.777 [0.661–0.892] (P<0.001), and is currently the best model for predicting the outcome.

Keywords: cardiac surgery; bypass; nomograms; arrhythmias; mortality.

Conflict of interest. The authors declare no conflict of interest.

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Introduction

Currently, there are a lot of studies concerning new-onset postoperative rhythm disturbances, both in cardiac [1–7], and in noncardiac surgery [1, 6, 8–11]. Atrial fibrillation (AF) occurs in 15–40% of patients after coronary artery bypass grafting, 37–50% of patients after heart valve surgery and

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60% of patients after combined valve and coronary surgery [12–14]. Hospital mortality in patients with sustained postoperative ventricular arrhythmias is 50% [1] vs 3.4% in the general population of cardiac surgery patients [15].

There are several prognostic models and scales allowing to estimate the risk of AF in the postoperative period [16–20]. However, these scales do not always provide definitive information on the hemodynamic significance of predicted AF, which reduces their value for intensive care unit doctors. Moreover, these prognostic models rely only on preoperative risk factors, ignoring important intraoperative predictors of AF such as myocardial ischemia, duration of bypass, hemodynamic support, etc. [21, 22]. The above disadvantages hamper targeted identification of patients at risk of new-onset hemodynamically significant AF.

Earlier we proposed a modified nomogram (the M nomogram) [23], which has demonstrated some advantages in predicting 30-day mortality, compared to the original version [24] and Euroscore 2. This nomogram includes assessment of age, sex, body mass index, glomerular filtration rate, recent use of antiplatelet agents, low mobility, resting angina, left ventricular ejection fraction, preoperative critical illness, vasoactive inotropic score (VIS) on admission to ICU after operating room.

The aim of the study was to evaluate the feasibility of using a modified nomogram (the M nomogram) to predict the occurrence of new-onset postoperative hemodynamically significant arrhythmias after elective cardiac surgery with cardiopulmonary bypass within 30 days after surgery.

Материал и методы

Design of the study. We performed a single-center retrospective cohort study.

We analyzed the medical records of the cardiac surgery patients of M. F. Vladimirsky Moscow Region Research and Clinical Hospital, who underwent cardiac surgery with cardiopulmonary bypass between June 2014 and September 2017.

The inclusion criteria were age older than 18 years and elective cardiac surgery with cardiopulmonary bypass. The exclusion criteria were congenital heart defects and preoperative cardiac rhythm disturbances.

The following data were summarized and analyzed: age, sex, height, body weight, glomerular filtration rate, left ventricular ejection fraction, recent use of antiplatelet agents [25], low mobility and severity of preoperative patients (according to E-CABG criteria [26] and Euroscore 2 [27]), presence of angina at rest, congestive heart failure, myocardial infarction, peripheral artery disease, hypertension, diabetes mellitus, stroke, transient ischemic attacks, chronic use of beta-blockers, calcium channel blockers, angiotensin-converting enzyme (ACE) inhibitors, angiotensin receptor blockers, diuretics, nitrates, statins, antiplatelet agents and anticoagulants, proteinuria, and VIS on admission to ICU after operating room.

The primary end point was new-onset postoperative hemodynamically significant arrhythmia. This term included any rhythm disturbances requiring either drug therapy, or cardioversion, or pacemaker implantation.

Statistical analysis.

For each patient, the values of the modified nomogram (Table 1), as well as POAF [17], CHA_2DS_2-VASc [18], ATRIA [20] and HATCH [16] scores were calculated. Then ROC analysis of the M nomogram and the above scales was performed to predict the occurrence of postoperative hemodynamically significant arrhythmias. After that, we determined the cutoff point for the M nomogram, which was used to form two groups of patients. Group 1 included patients who scored less than the

Table 1. The modified (M) nomogram.

Parameter	Points
VIS on admission to ICU (points)	
<8	0
8–15	2
>15	4
Critical illness prior to surgery	4.5
Left ventricular ejection fraction (%)	
>50	0
31–50	1
21–30	5
⩽20	6.5
Angina at rest	2
Low mobility	3
Recent administration of antiplatelet agents	2
eGFR MDRD (class)	
1	0
2	0
3a	1
3b	4.5
4	7
5	8
Body mass index (kg/m^2)	
15	2
20	2.5
25	3
30	4
35	4.5
40	5
50	6.5
Female	0.5
Age (years)	
20	2
30	3
40	4
50	5
60	6
70	7
80	8

Note. eGFR MDRD — glomerular filtration rate estimated using the MDRD equation; VIS — vasoactive inotropic score; ICU — intensive care unit.

Table 2. Preoperative patients' characteristics.

Parameter	Value
Mean age, years	59.8 ± 8.1
Men (%)	112 (77.8%)
Mean body mass index, kg/m^2	28.2 ± 3.9
Blood creatinine, μmol/l	93.5 [85.3; 104.0]
Glomerular filtration rate, ml/min	82.9 [67.1; 96.1]
Left ventricular ejection fraction (%)	59.0 [52.0; 66.8]
Vasoactive inotropic score on admission to ICU after the operating room, points	1.5 [0; 5.0]
CHA_2DS_2-VASc, points	3.0 [2.0; 3.8]
POAF, points	1.0 [0; 1.0]
ATRIA, points	2.0 [1.0; 4.0]
HATCH, points	3.0 [1.0; 3.0]

Note. ICU — intensive care unit; for table 2 and figure 2: CHA_2DS_2-VASc — risk assessment scale for stroke and systemic thromboembolism in patients with atrial fibrillation; POAF — risk assessment scale for postoperative atrial fibrillation; ATRIA — stroke risk assessment scale for patients with atrial fibrillation; HATCH — scale for assessing the likelihood of progression of atrial fibrillation from paroxysmal to permanent.

Table 3. Types of surgery.

Type of surgery	Number of patients (%)
Coronary artery bypass grafting	118 (81.95)
Cardiac valve surgery	11 (7.63)
Coronary artery bypass grafting and aneurysmectomy	7 (4.85)
Single valve surgery and aneurysmectomy	4 (2.77)
Coronary artery bypass grafting and single valve surgery	1 (0.7)
Coronary artery bypass grafting, single valve surgery and aneurysmectomy	1 (0.7)
Double valve surgery and aneurysmectomy	2 (1.4)

Table 4. Types of new-onset arrhythmias.

Type of arrhythmia	Number of patients (%)
New-onset postoperative atrial fibrillation	13 (9.0)
New-onset postoperative atrial fibrillation with atrioventricular block	1 (0.7)
New-onset postoperative atrial fibrillation with ventricular extrasystole	1 (0.7)
Atrioventricular junction rhythm with the rate <60 beats per minute	1 (0.7)
Ventricular extrasystole	2 (1.4)
Ventricular tachycardia	1 (0.7)
Ventricular fibrillation	1 (0.7)

cutoff point value; Group 2 consisted of patients who scored more or equal to the cutoff point value.

Normality of distribution was tested for the following parameters: age, body mass index, plasma creatinine before surgery, glomerular filtration rate, left ventricular ejection fraction, VIS value on admission to ICU after operating room, M nomogram, POAF, CHA_2DS_2-VASc, ATRIA and HATCH scores. Normally distributed data were presented as mean and standard deviation. Data with non-normal distributions were reported as median and quartiles.

Statistical data analysis was performed using the IBM SPSS Statistics 25.0 and MedCalc Statistical Software version 20.008 (MedCalc Software bv, Ostend, Belgium) software packages. Normality of the distribution was assessed using the Shapiro–Wilk test. Critical *P*-value was considered as 0.05. To assess the predictive ability of various parameters we used ROC-analysis with assessment of the AUC parameters (area under the ROC-curve and 95% confidence interval). The threshold value was chosen based on the optimal sensitivity/specificity ratio in accordance with the results of ROC-analysis (Yuden's statistics). Sensitivity, specificity, accuracy, and odds ratio (OR) were calculated for predictors.

Participants. In this study, 520 case records were studied. 158 patients met the inclusion criteria. Among the patients not included in the study, 169 were younger than 18 years, 193 patients underwent surgery without cardiopulmonary bypass. Of the 158 patients who met the inclusion criteria, 14 patients had exclusion criteria, i.e., preoperative cardiac rhythm disturbances. As a result, 144 patients were included in the analysis (Fig. 1).

Descriptive statistics. The preoperative characteristics of patients are shown in Table 2.

The types of surgical interventions are shown in Table 3.

The types of new-onset postoperative arrhythmias are summarized in Table 4.

Medications taken prior to surgery by patients with/without postoperative hemodynamically significant rhythm disturbances are listed in Table 5.

The median M nomogram score was 10.0 points [IQR, 9.0–11.4].

Table 5. Medications taken preoperatively by study participants.

Drug class	Postoperative patients		*P*-value
	Without arrhythmia (n=124)	With arrythmia (n=20)	
Beta-blockers	84 (67.7%)	16(80%)	0.310
Calcium channel blockers	24 (19.4%)	2 (10%)	0.530
ACE inhibitors	37 (29.8%)	8 (40%)	0.437
Angiotensin receptor blockers	13 (10.5%)	1 (5%)	0.693
Diuretics	62 (50%)	11(55%)	0.811
Nitrates	19 (15.3%)	2(10%)	0.738
Statins	60 (48.4%)	10 (50%)	0.999
Antiplatelet agents	44(35.5%)	7 (35%)	0.999
Anticoagulants	50 (40.3%)	9 (45%)	0.807

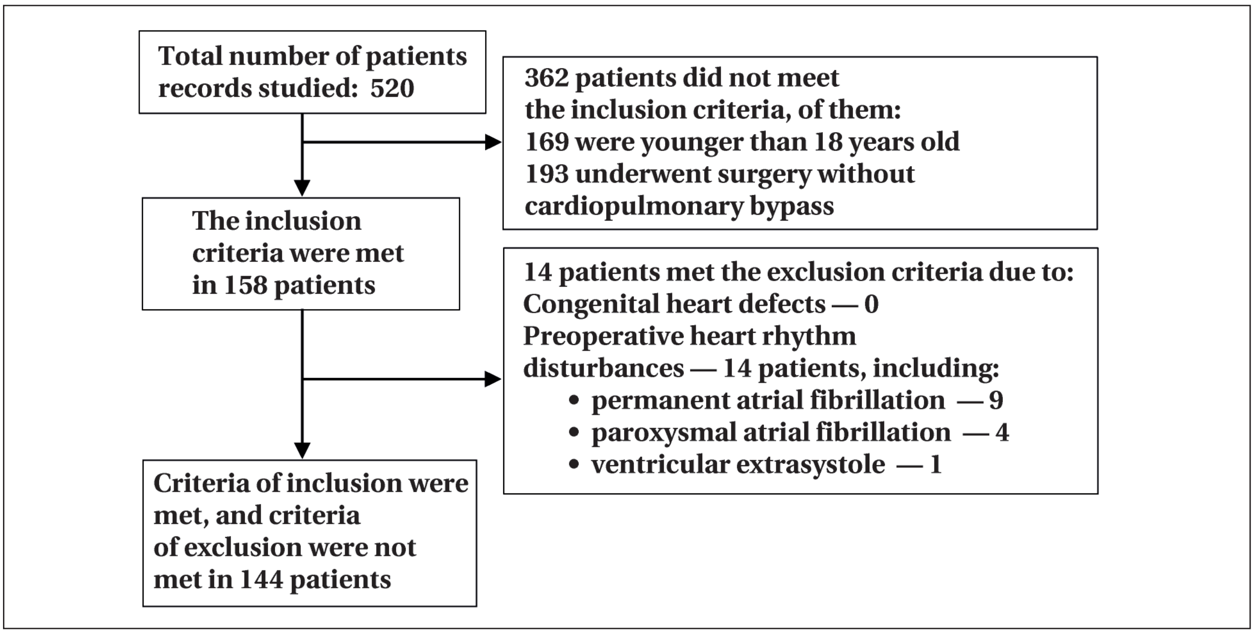

Fig. 1. Study flowchart.

Results

The overall mortality in the study group was 5.56%, the median ICU stay was 19.0 hours [17.1; 40.0] ranging from 12.5 to 334.0 hours.

The incidence of new-onset postoperative hemodynamically significant arrhythmias was 13.9% (20 of 144 patients). The mortality in the group of patients who developed postoperative hemodynamically significant arrhythmias was 35.0% (7 of 20 patients), whereas in the group of patients without postoperative hemodynamically significant arrhythmias it was 0.8% (1 of 124 patients) (P<0.001). For the M nomogram, the AUC parameter was 0.777 [0.661; 0.892] (P<0.001) (Fig. 2). The cutoff point was 12 points (sensitivity, 60.00% [95%CI, 36.05–80.90], specificity, 89.52% [95%CI, 82.74–94.30]). The accuracy of the prognostic model was 85.42% [95%CI, 78.58–90.74%]. The positive and negative predictive values were 48.0% [95%CI, 33.0–63.3] and 93.3% [95%CI, 89.0–96.0], respectively. The absolute risk of developing postoperative hemodynamically significant arrhythmias during hospital stay in group 1 was 6.25% (7 of 112 patients) and 40.63% (13 of 32 patients) in group 2. The odds ratio of group 2 versus group 1 was 10.26 [95% CI, 3.63–29.06] (P<0.001).

Of the «competitors», only ATRIA showed a significant result with AUC = 0.656 [0.539; 0.773] (P=0.026).

When assessing the prognostic value of POAF, CHA_2DS_2-VASc, and HATCH scales regarding the development of new-onset hemodynamically significant arrhythmias after cardiac surgery with cardiopulmonary bypass, no significant predictors were found with P=0.091, P=0.092, and P=0.525, respectively.

Discussion

Our data suggest that the M nomogram has an acceptable prognostic power regarding the new-onset hemodynamically significant arrhythmias with AUC = 0.777 [0.661; 0.892] (P<0.001) and could also be the best available model for predicting this outcome.

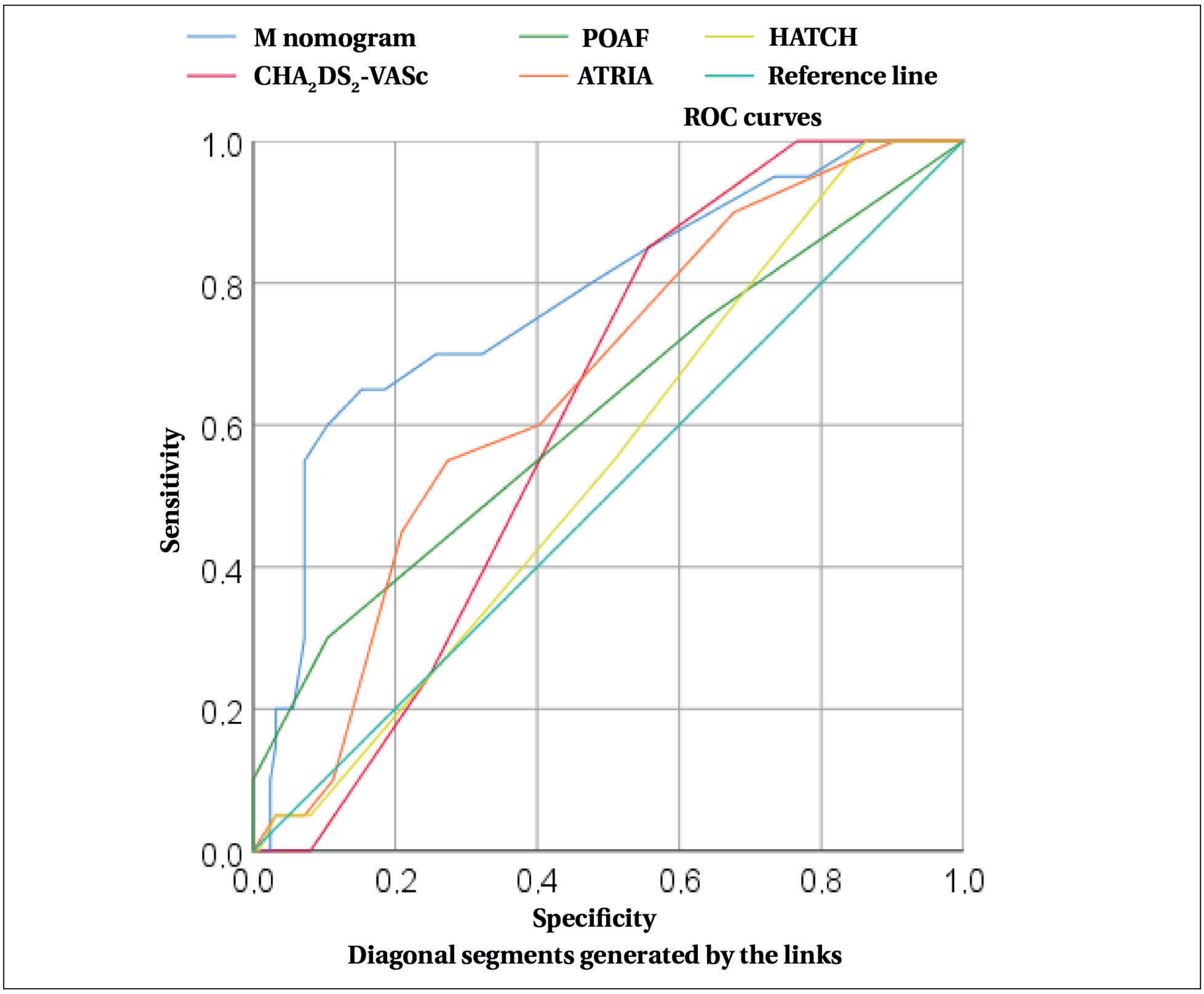

Fig. 2. The validity of different predictive models for the new-onset postoperative hemodynamically significant arrhythmias.

Importantly, the odds ratio of developing new hemodynamically significant arrhythmias in patients who scored 12 or more on the M nomogram versus patients who scored less than 12 is 10.26 [95% CI, 3.63–29.06] ($P<0.001$). Moreover, the lower limit of the 95% confidence interval of the odds ratio is 3.63, indicating truly significant differences in the odds of new hemodynamically significant arrhythmias after elective cardiac surgery with cardiopulmonary bypass between these two groups.

The presence of the lower limit of the 95% confidence interval for sensitivity below 50%, as well as the positive prognostic value less than 50%, indicates that only a one-sided interpretation of the results is possible based on the M nomogram. The M nomogram allows to identify with a high degree of probability a group of patients with a low risk of hemodynamically significant arrhythmias in the postoperative period (patients who scored less than 12 points). At the same time, when the M nomogram score is 12 or more, one cannot be sure about the likelihood of hemodynamically significant arrhythmias. Nevertheless, it allows identifying a group of patients who require more careful postoperative monitoring.

Also, the rate of arrhythmias was 13.9%, while in the studies of other authors who validated the above-mentioned scales, it varies from 21.0% [16] to 33.8% [19]. Probably, it is related to the prevalence of CABG in our study which is rather specific cardiac surgery.

The mortality of patients with hemodynamically significant arrhythmias was 35.0%, whereas in the studies of other authors it varies from 3.6% [20] to 9.0% [16]. This difference is probably due to the fact that close, but not identical phenomena were evaluated: in the present study the «new-onset hemodynamically significant arrhythmias», in the cited publications the «new-onset atrial fibrillation» were in the spotlight. Thus, here we can speak only about a comparison «by analogy», and not about a comparison of the frequency of identical phenomena.

In our comparison of the prognostic significance of the M nomogram with the POAF, CHA_2DS_2-

VASc, HATCH and ATRIA scales widely used for this purpose, all but the latter were not reliable.

Earlier reports suggested a sufficient significance of the discussed scales in predicting AF [16, 17, 19, 20]. A possible explanation for the discrepancy between the results of this study and the literature has already been suggested above. The following considerations are also important.

1. New hemodynamically significant arrhythmias were evaluated, whereas in the cited papers atrial fibrillation was an inclusion criterion. Obviously, not all episodes of AF are hemodynamically significant.

2. Hemodynamically significant ventricular rhythm disturbances were to be included in the present study and were not considered in the cited papers.

3. We studied patients who underwent surgery with cardiopulmonary bypass.

It is difficult to define what is more important to assess from the practical point of view, AF or hemodynamically significant arrhythmias. Given the higher risk of mortality, the broader concept should prevail. In terms of specificity of effect, AF should probably be preferred. In any case, the M nomogram appears to be a reliable tool for predicting adverse events after cardiac surgery performed with cardiopulmonary bypass.

External validity. We evaluated the medical records, not the experimental models, which indicates a high external validity of the study. At the same time, limitation of the sample patients to those who underwent cardiopulmonary bypass, had no congenital heart defects and preoperative rhythm disturbances actually reduces the external validity of this study by hampering extrapolation of its results to other groups of patients.

Limitations. This single-center retrospective cohort study was probably less valid compared to prospective studies in the context of evidence-based medicine. The significance of this study could also be reduced by the fact that 81.95% of the patients underwent CABG which decreases the reliability of extrapolation of the results to other types of surgery. The unidirectional interpretation of the nomogram results reduces the prognostic potential of this model regarding the occurrence of hemodynamically significant arrhythmias.

Conclusion

The modified (M) nomogram has an acceptable prognostic value for predicting new-onset hemodynamically significant arrhythmias after elective cardiac surgery with cardiopulmonary bypass with AUC = 0.777 [0.661; 0.892] (P<0.001). It could also be the best available model for predicting this complication in the postoperative period.

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