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Risk factors of cardiac arrest during a percutaneous coronary intervention performed with rotational atherectomy — analysis based on a Large National Registry

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Abstract

Background: *Rotational atherectomy (RA) is traditionally administered for patients with heavily calcified lesions and is thereby characterized by a high risk of the performed intervention. However, the prevalence characteristics of cardiac arrest are poorly studied in this group of patients. We aimed to evaluate the frequency and risk factors of cardiac arrest during percutaneous coronary interventions (PCI) performed with RA and preceding coronary angiography (CA).*

Methods: *Based on the data collected in the Polish Registry of Invasive Cardiology Procedures (ORPKI) from 2014 to 2021, we included 6522 patients who were treated with RA-assisted PCI. We scrutinized patient and procedural characteristics, as well as periprocedural complications, subsequently comparing groups in terms of cardiac arrest incidence with the use of univariable and multivariable analyses.*

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Results: *Thirty-five (0.5%) patients suffered from cardiac arrest during RA-PCI or preceding CA. They were characterized by significantly higher rates of prior stroke, acute coronary syndromes (ACS) as indications and higher Killip class (P < 0.001) at the admission time. Among the confirmed independent predictors of in-procedure cardiac arrest, the following can be noted: factors related to patients' clinical characteristics (e.g., older age, female sex, and disease burden), periprocedural characteristics (e.g., PCI within left main coronary artery [LMCA]), and periprocedural complications (e.g., coronary artery perforation and no-reflow phenomenon).*

Conclusions: *Severe clinical condition at baseline, expressed by ACS presence and Killip class IV, as well as RA-PCI performed within LMCA and other periprocedural complications, were the strongest predictors of cardiac arrest during RA-assisted PCI and CA.* (Cardiol J 2024; 31, x: xxx–xxx)

Keywords: cardiac arrest, coronary angiography, percutaneous coronary intervention, rotational atherectomy

Introduction

In the current era of expanding percutaneous coronary interventions (PCIs) and population aging, rotational atherectomy (RA) has been used more frequently [1–3]. Despite the advantages of RA and its high success rate, it is predominantly used to treat heavily calcified lesions, often with left main coronary artery (LMCA) involvement and its dissemination [4]. Hence, patients undergoing RA-PCI are usually older, burdened with more comorbidities, and have worse clinical condition [5, 6]. Apart from periprocedural complications similarly noted in regular PCI, RA may additionally lead to burr entrapment, guidewire fracture or most importantly, coronary artery perforation (CAP) [3, 7]. As a result, this group of patients is high-risk, usually of poorer overall prognosis and at greater risk of periprocedural complications, including cardiac arrest [3, 6–8]. However, to our best knowledge, in all studies regarding this cohort of patients, insufficient attention was paid to cardiac arrest occurring at the catheterization laboratory (cath lab).

To address this gap in knowledge, based on a large national registry, we aimed to evaluate the risk factors of cardiac arrest during RA-PCI and coronary angiography (CA) followed by RA-PCI.

Methods

Study design and population

This retrospective analysis was conducted on the basis of prospectively collected data obtained from the Polish National Registry of Percutaneous Coronary Interventions (ORPKI). Most of the catheterization laboratories in Poland (> 98%) record their data in this registry. It is consecutively upgraded each year, reaching more than 250 variables. In this analysis, data were collected from the registry concerning the period between January 2014 and December 2021. The details of this registry have been described in previously published papers [1, 9]. We extracted the data from 6522 patients who were treated with PCI and RA, among whom 2507 underwent CA directly preceding RA. Patients were qualified for CA and PCI according to the current European Guidelines [10]. The technical aspects of the procedure, such as the choice of the access site, catheter size, as well as periprocedural anticoagulation use, were according to operator preference. The study protocol complied with the 1964 Declaration of Helsinki, and all participants provided their written informed consent to take part in the percutaneous intervention. Due to the retrospective nature and anonymization of the collected data in the registry, consent of the Bioethics Committee was waived.

Definitions

With regard to the contemporary European Resuscitation Council Guidelines [11], cardiac arrest during PCI or CA was defined as cardiovascular collapse with co-existing, prolonged heart rhythm disturbance (e.g., ventricular fibrillation or asystole), potentially requiring subsequent cardiopulmonary resuscitation and/or defibrillation.

Study endpoints

The primary endpoint was the rate of cardiac arrest occurring during RA-PCI or CA, followed by RA-PCI. Based on its prevalence, patient characteristics and periprocedural variables were retrospectively studied.

Statistical analysis

Nominal variables are presented as absolute numbers and percentages. Continuous variables are expressed as means ±standard deviation and median [interquartile range], depending on their normality. This was evaluated using the Shapiro-Wilk test or Kolmogorov-Smirnov test with the Lilliefors correction for variables with more than 2000 observations. Levene's test was performed to assess the equality of variance. For normally distributed, continuous variables, differences were compared via Student's or Welch's *t*-tests, depending on the equality of variance. In the case of non-parametrical data, the U-Mann-Whitney was applied. Categorical variables were compared using Pearson's chi-squared or Fisher's exact test if 20% of the cells had an expected count of less than 5 (Monte Carlo simulation for Fisher's test using tables of higher dimensions than 2×2).

All factors that may have been associated with cardiac arrest during RA-PCI or CA were adopted in univariable logistic regression models. Based on their results, statistically significant variables (P-value < 0.2) or those of clinical significance were subsequently included in the multivariable model. Risk estimates were presented as odds ratios (OR) with 95% confidence intervals (CI). Final multivariable logistic regression models were constructed using minimization of the Akaike Information Criterion to find predictors of cardiac arrest incidents during PCI performed with rotational atherectomy or CA. The entire statistical analysis was carried out using R version 4.1.1 (R Foundation for Statistical Computing, Vienna, Austria, 2021) with the 'rms' package version 6.2-0.

Results

We studied 6522 patients undergoing RA-PCI. Thirty-five patients (0.5%) suffered from cardiac arrest during RA-PCI or CA preceding RA-PCI. One patient suffered cardiac arrest during both CA and RA-PCI.

General characteristics at baseline and clinical presentation

Patients' characteristics at baseline are shown in Table 1. The majority of the study group were men (68.8%) at a median age of 72 years (66; 79). In general, patients who experienced cardiac arrest were older, burdened with higher rates of concomitant diseases, and had less frequently undergone prior revascularization attempts, although these comparisons did not reach statistical significance (Tab. 1). However, patients who experienced cardiac arrest during PCI or CA had a history of stroke more often (17.1% vs. 3.9%, $P < 0.001$). They were also characterized by higher rates of acute coronary syndromes (ACSs) as well as greater mean Killip class, with IV class being more prevalent ($P < 0.001$). Furthermore, cardiac arrest before admission to the department and direct transport accounted for a significantly higher proportion among this group of patients ($P < 0.001$) (Tab. 1).

Vascular access and procedural characteristics

The procedural characteristics are shown in Supplementary Table 1. In both groups, radial vascular access was the dominant approach. LMCA involvement was more frequent in patients who underwent the procedure complicated by cardiac arrest, and so PCI within LMCA was performed more often in that group ($P = 0.02$). These patients were also characterized by higher usage of glycoprotein IIb/IIIa (GPIIb/IIIa) inhibitors during PCI ($P < 0.001$) and lower thrombolysis in myocardial infarction (TIMI) flow after the procedure ($P < 0.001$) (Suppl. Tab. 1).

Periprocedural complications

No-reflow phenomenon, CAP during PCI, and death rates were significantly greater among patients experiencing cardiac arrest during RA-PCI or CA ($P < 0.001$). More detailed data are shown in Table 2.

Risk factors of cardiac arrest during RA-PCI or CA

Multivariable analysis revealed that older age, female gender, a history of prior stroke, and MI were all associated with cardiac arrest, whereas previous revascularization attempts were linked with decreased risk of this event (Fig. 1). Considering concomitant diseases, we noted that diabetes mellitus and kidney disease were associated with cardiac arrest, while arterial hypertension was noted as a factor linked with lower in-procedure cardiac arrest risk (OR: 0.91 [95% CI: 0.85–0.98]; $P = 0.01$; Fig. 1). Variables indicating poor condition at baseline, i.e., initial TIMI 0/1 flow, cardiac arrest at baseline, and Killip class of IV, were all significant predictors, with the latter being the strongest (OR: 4.27 [95% CI: 3.88–4.71]; $P < 0.001$; Fig. 1). Regarding angiography findings, LMCA involvement, in comparison to multi-vessel disease (MVD) (OR, 1.50 [95% CI, 1.34–1.67];

Table 1. Demographics and clinical characteristics at baseline

	Total	PCI or CA complicated by cardiac arrest		P-value
	N = 6522	no N = 6487	yes N = 35	
Median age (Q1; Q3), years	72 (66; 79)	72 (66; 79)	74 (70; 80)	0.054
Gender, males	4470 (68.8)	4450 (68.9)	20 (57.1)	0.14
Diabetes mellitus	2155 (33.0)	2140 (33.0)	15 (42.9)	0.22
Prior stroke	257 (3.9)	251 (3.9)	6 (17.1)	< 0.001
Prior MI	3106 (47.6)	3092 (47.7)	14 (40.0)	0.40
Prior PCI	3611 (55.4)	3596 (55.4)	15 (42.9)	0.14
Prior CABG	821 (12.6)	819 (12.6)	2 (5.7)	0.31
Smoking	1006 (15.4)	1004 (15.5)	2 (5.7)	0.16
Psoriasis	15 (0.2)	15 (0.2)	0 (0.0)	0.78
Arterial hypertension	4868 (74.64)	4844 (74.7)	24 (68.6)	0.41
Kidney disease	762 (11.7)	755 (11.6)	7 (20.0)	0.12
COPD	233 (3.6)	232 (3.6)	1 (2.9)	0.81
Clinical presentation				
acute heart failure	16 (0.3)	15 (0.2)	1 (2.9)	< 0.001
cardiac arrest	16 (0.2)	15 (0.2)	0 (0.0)	
chronic heart failure	114 (1.8)	114 (1.8)	0 (0.0)	
congenital heart defect	6 (0.1)	6 (0.1)	0 (0.0)	
NSTEMI	829 (12.7)	823 (12.7)	6 (17.1)	
other	43 (0.7)	43 (0.7)	0 (0.0)	
stable angina	3672 (56.3)	3660 (56.4)	12 (34.3)	
STEMI	532 (8.2)	523 (8.1)	9 (25.7)	
unstable angina	1295 (19.9)	1288 (20.0)	7 (20.0)	
Killip class, mean ±SD and median (Q1, Q3)	1.1 ± 0.4 1.0 (1.0; 1.0)	1.1 ± 0.4 1.0 (1.0; 1.0)	1.7 ± 1.1 1.0 (1.0; 1.0)	< 0.001
Killip class				
I	1756 (92.9)	1744 (93.3)	12 (60.0)	< 0.001
II	96 (5.1)	91 (4.9)	5 (25.0)	
III	18 (1.0)	18 (1.0)	0 (0.0)	
IV	20 (1.1)	17 (0.9)	3 (15.0)	
Killip class IV	20 (1.1)	17 (0.9)	3 (15.0)	< 0.001
Cardiac arrest before procedure	14 (0.6)	8 (0.3)	6 (24.0)	< 0.001
Hypothermia at baseline	2 (0.1)	1 (0.04)	1 (4.0)	< 0.001
Direct transport	46 (1.8)	41 (1.7)	5 (20.0)	< 0.001

All data are expressed as absolute numbers (percentages), if not stated otherwise. CA — coronary angiography; CABG — coronary artery bypass grafting; COPD — chronic obstructive pulmonary disease; MI — myocardial infarction; NSTEMI — non-ST segment elevation myocardial infarction; PCI — percutaneous coronary intervention; Q — quartile, RA — rotational atherectomy; SD — standard deviation; STEMI — ST segment elevation myocardial infarction

Table 2. Periprocedural complications of coronary angiography and PCI

	Total	PCI or CA complicated by cardiac arrest		P-value
	N = 6522	no N = 6487	yes N = 35	
Death during PCI or CA	22 (0.3)	14 (0.2)	8 (22.9)	< 0.001
Bleeding at puncture-site during PCI or CA	11 (0.2)	11 (0.2)	0 (0.0)	0.82
Allergic reaction PCI or CA	3 (0.1)	3 (0.1)	0 (0.0)	0.90
Stroke during angiography	5 (0.2)	0 (0.0)	5 (0.2)	0.82
MI during PCI	30 (0.5)	30 (0.5)	0 (0.0)	0.81
No-reflow phenomenon during PCI	50 (0.8)	48 (0.7)	2 (5.7)	< 0.001
CAP during PCI	66 (1.0)	57 (0.9)	9 (25.7)	< 0.001

All data are expressed as absolute numbers (percentages). CA — coronary angiography; CAP — coronary artery perforation; MI — myocardial infarction; PCI — percutaneous coronary intervention

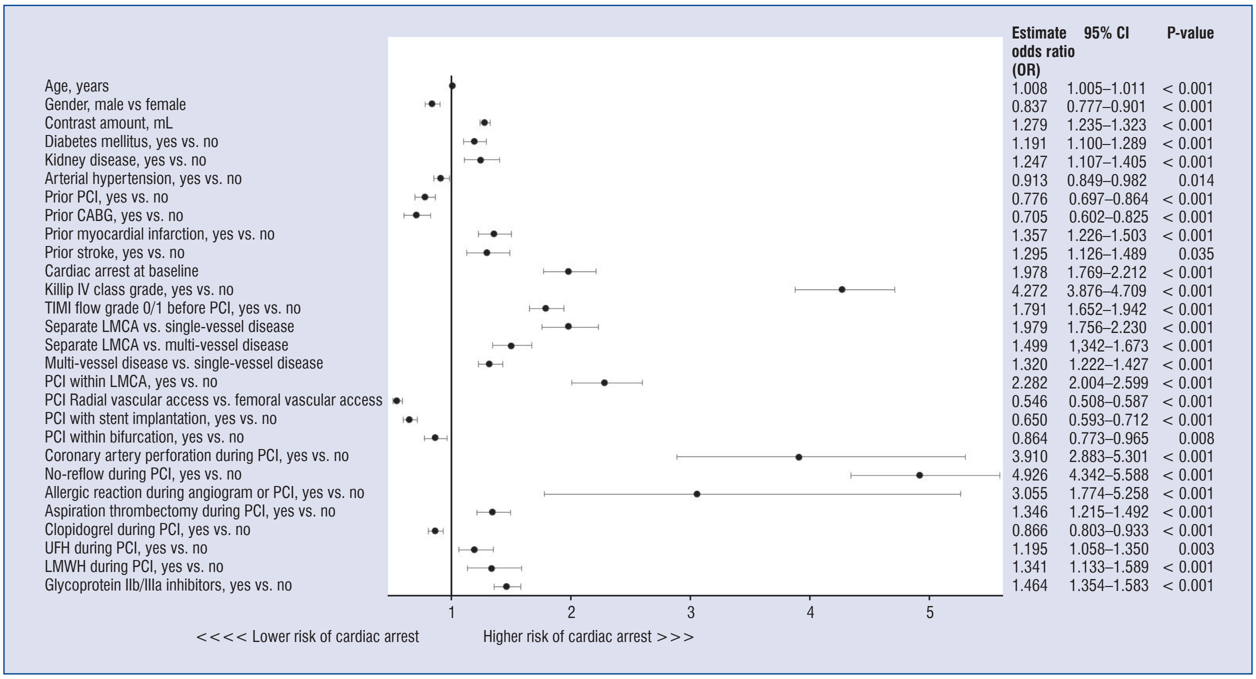

Figure 1. Risk factors of cardiac arrest during coronary angiography and PCI — multivariable analysis. CABG — coronary artery bypass graft; CI — confidence interval; LMCA — left main coronary artery; LMWH — low molecular weight heparin; PCI — percutaneous coronary intervention; TIMI — thrombolysis in myocardial infarction

P < 0.001) and single-vessel disease (SVD) (OR, 1.98 [95% CI, 1.76–2.23]; *P* < 0.001), was associated with a higher risk of intraprocedural cardiac arrest (Fig. 1). Moreover, patients receiving radial vascular access were less likely to experience cardiac arrest (*P* < 0.001). However, patients exposed to higher contrast and radiation dose, as well as those who underwent aspiration thrombectomy (AT) prior to cardiac arrest, were at substantial risk (*P* < 0.001). Periprocedural complications were also linked with higher risk, with the no-reflow phenomenon being the strongest predictor (OR, 4.93 [95% CI, 4.34–5.59]; *P* < 0.001). Regarding patients' indications for RA-PCI, coronary acute syndrome was a significant predictor, especially ST segment elevation myocardial infarction (STEMI) or non-ST segment elevation myocardial infarction (NSTEMI) (Fig. 2).

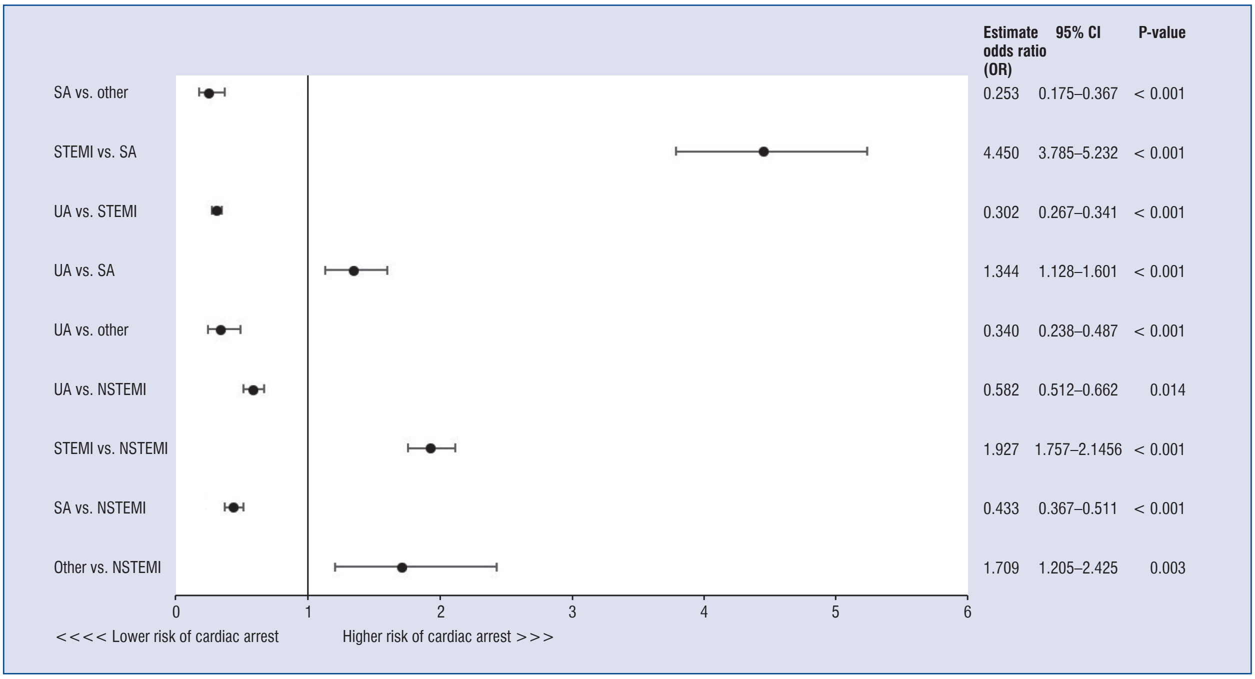

Figure 2. Risk factors of cardiac arrest during coronary angiography and PCI regarding patients' clinical presentation – multivariable analysis. CI — confidence interval; NSTEMI — non-ST segment elevation myocardial infarction; PCI — percutaneous coronary intervention; RA — rotational atherectomy, SA — stable angina; STEMI ST — segment elevation myocardial infarction; UA — unstable angina

Discussion

Among the 6522 patients included in our study, 35 (0.5%) experienced cardiac arrest during RA-PCI or during CA. In the performed multivariable analysis, we found several independent factors associated with a higher risk of cardiac arrest during RA-PCI and CA, including those related to the patients' baseline characteristics (e.g., greater age, female sex, and disease burden), periprocedural covariates (e.g., PCI within LMCA, contrast amount, and radiation exposure), periprocedural complications (CAP, no-reflow phenomenon, and allergic reaction during procedure), and applied pharmacotherapy. All factors are discussed in detail below.

In general, the pivotal pattern behind cardiac arrest in the catheterization laboratory is a mix of the patient's predispositions and periprocedural complications, such as CAP [12, 13]. Those, in turn, may spark off an ischemic threat, leading to myocardial electric instability, subsequent cardiac rhythm disturbances and, eventually, hemodynamic collapse. Because preceding complications occur relatively rarely, cath lab cardiac arrest for the all-comers group also remains a rare scenario, emphasizing the safety of PCI [2, 8]. However, this frequency is anticipated to increase in the future due to the high-risk patients accounting for more and more PCI cases [12]. Indeed, in a specific cohort of patients, e.g., presenting with acute myocardial infarction, the frequency may reach as much as 4.3%, significantly deteriorating long-term survival [14, 15].

Because our study is based on the national registry, we did not have insights into the specific outcomes following cardiac arrest, including the return of spontaneous circulation (ROSC) and long-term survival rates. We noted, however, that patients suffering from cardiac arrest died significantly more often than those in the control group, i.e., in 19.4% and 40% of performed RA-PCI and angiography cases, respectively. In other studies, reported short-term survival rates varied greatly, from 46.7% to 75%, and equaled approximately 25% at the time of discharge [13, 16–19]. Wagner et al. reported also an 87% survival rate after one year among patients who were alive at the discharge time [17]. It is known that these outcomes depend heavily on the severity of the patient's condition, their initial heart rhythm, and measures undertaken by the staff to achieve ROSC [13, 17].

Based on our multivariable analysis, age and female gender were both risk factors of cardiac arrest, which may reflect the fact that women qualified for PCI have smaller caliber coronary arteries, are presented with more comorbidities and more advanced coronary artery disease. These themselves are associated with higher risk of periprocedural complications [20, 21]. In our research, diabetes mellitus and kidney disease were independent predictors of cardiac arrest. Comorbidities are well-recognized as impairing long-term outcomes following RA-PCI, which may be attributable to an increased risk of more extended coronary artery calcification and target vessel restenosis [22–24]. On the other hand, in studies on these diseases, no significant increases in periprocedural complications have been reported, including ventricular arrhythmias. This suggests the high safety of RA [22, 23].

In our analysis, patients experiencing cardiac arrest were presented with ACS and cardiogenic shock more often, which were revealed as strong predictors of in-procedure cardiac arrest. As described in other studies, patients with ACS have lower left ventricular ejection fraction (LVEF) and more comorbidities. They are also characterized by more complex coronary lesions, which may be followed by longer and more complex RA-PCI [25]. Similarly, patients suffering from MVD and LMCA involvement were at a higher risk of cardiac arrest, which is coherent with previously referred studies [8, 12, 21]. Indeed, high-risk patients with greater SYNTAX scores constitute the group of coronary artery bypass graft (CABG) exclusion, and off-label RA is used instead [3, 26–28]. Additionally, any emerging complications during LMCA-PCI are usually more challenging to manage with more rapid ischemic deterioration, thus accounting for a higher risk of cardiac arrest.

Based on the current analysis, the radial approach was associated with less frequent occurrence of cardiac arrest. Usually, patients with severe condition, such as cardiogenic shock, are less likely to be treated via radial access due to lack of pulse. Therefore, in these patients, the only available efficient access is femoral. Lack of pulse could be solved by ultrasound guidance, but this takes more time, which is of the essence in such scenarios.

When considering the procedure itself, other risk factors were pre-cardiac arrest use of AT, greater total contrast amount, and radiation exposure during the procedure. The latter increases with greater RA-PCI complexity, while the AT impact may be explained by its more frequent use among ACS patients with occluded target coronary vessel as well as an association with a greater no-reflow phenomenon rate during the procedure [10, 29]. Moreover, we observed that patients suffering from cardiac arrest who received GPIIb/IIIa inhibitors were at a higher risk of cardiac arrest. This could be explained by worse clinical presentation of patients receiving such pharmacotherapy, bail-out RA use, and the PCI course complicated by no-reflow phenomenon [10, 30]. In addition, this might simply be a consequence of the cardiac arrest event.

Limitations

Firstly, despite the large sample size, the population of patients experiencing cardiac arrest remained small, which lowered the precision of odds ratio estimates. Moreover, due to the registry-based population cohort, extensive data concerning RA-PCI were not available. This regarded, for instance, precipitating factors of cardiac arrest and variables well-known to influence the difficulty and outcomes of performed RA, such as length of the calcified lesion, target vessel diameter, burr size, or lesion type according to the distinction proposed by the American College of Cardiology/American Heart Association (ACC/AHA). On the other hand, the retrospective nature of this study, the great variety of patients, as well as the inclusion of patients who had cardiac arrest at the baseline could have obliterated the results. Moreover, there was not a double-check of data entered by the operator vs. medical documentation and there was a lack of further follow-up. In addition, the collection of data from multiple centers imposes a bias related to the first operators' divergency, because the ultimate recognition of periprocedural complications and ongoing PCI scenario depends on their experience, habits, and inclinations. Hence, although the missing facts on the procedure could undermine the results, in our approach, we thoroughly analyzed patient-oriented variables instead, and we propose that further research is demanded.

Conclusions

The incidence of cardiac arrest during CA and RA-PCI was infrequent (0.5%), which is in accordance with the results of other studies. Among the many risk factors of cardiac arrest, we found poor patient condition at the time of admission (low TIMI flow and presence of ACS, especially MI or cardiogenic shock), LMCA involvement, and the occurrence of periprocedural complications (CAP, no-reflow phenomenon, and allergic reaction) to be the strongest predictors of cardiac arrest during CA or RA-PCI. Based on the results of this study, it can be concluded that in selected groups of patients characterized by the aforementioned risk factors, supportive therapies (e.g., mechanical support of the left ventricle), as well as a referral to highly experienced operators, should be considered.

Data availability statement: Upon special request.

Ethical approval: The study protocol complied with the 1964 Declaration of Helsinki, and all participants provided their written informed consent to take part in the percutaneous intervention. Due to the retrospective nature and anonymization of the collected data in the registry, obtaining consent from the Bioethics Committee was waived.

Author contribution statement: All authors contributed greatly to this study, and their specific contributions are as follows: 1) conceptualization: Wojciech Siłka (WS), Zbigniew Siudak (ZS), Rafał Januszek (RJ), Wojciech Wańha (Wwańha), Jacek Legutko (JL), Stanisław Bartuś (SB), Janusz Sielski (JS) and Wojciech Wojakowski (Wwojakowski); 2) Data curation: RJ, ZS, Wwańha, JS; 3) Formal Analysis: Krzysztof Piotr Malinowski (KPM), Tomasz Pawłowski (TP), Karol Kaziród-Wolski (KKW), Łukasz Kołtowski (ŁK), Arkadiusz Pietrasik (AP), JS, WS, and Wwojakowski; 4) Funding acquisition: RJ, SB; 5) Investigation: ZS, RJ, Wwańha, TP, ŁK, AP, KPM and KKW; 6) Methodology: RJ, ZS, Wwojakowski, TP, KPM, WS; 7) Project administration: RJ, WS; 8) Resources: RJ, ZS, Wwańha, AP, ŁK, and KKW; 9) Software: KPM; 10) Supervision: RJ, ZS, SB, and JL; 11) Validation: RJ, WS, Wwojakowski, and JS; 12) Visualization: WS, RJ; 13) Writing — original draft: WS, RJ, ZS, Wwańha, Wwojakowski, JL, and SB; 14) Writing — review & editing: WS, ZS, KPM, TP, AP, JS, ŁK, SB, JS, KKW, and RJ.

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Conflict of interest: None declared.

Supplementary material: Supplementary Table 1.

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