Allergic reactions during coronary angiography or PCI in Poland: Occurrence, trends, and long-term perspective based on the Polish ORPKI registry

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ABSTRACT

Background: Allergic reactions during coronary angiography and percutaneous coronary intervention (PCI) in patients with acute coronary syndromes can affect their outcomes.

Aims: We aimed to investigate the incidence of allergic reactions and predictors of their occurrence in the catheterization laboratory.

Material and methods: The study included 1 812 994 treatment cases available in the ORPKI Polish National Registry, of which 659 372 were for women and 1 144 689 for men. Data were collected from 161 interventional cardiology centers in Poland between 2014 and 2022 and included in the retrospective analysis. An allergic reaction was defined as any hypersensitive response of the immune system manifesting as bronchospasm, asthma exacerbation, conjunctivitis, urticaria, eczema, angioedema, or anaphylactic shock.

Results: There was a decreasing incidence of allergic reactions overall, in both sexes and all age subgroups. The incidence of allergic reactions each year oscillated between 0.02% and 0.11% (P <0.001), and the most recent one was 0.02% in 2022. The incidence of allergic reaction was associated with low-molecular-weight heparin (LMWH) (OR, 23.5 [95% CI, 18.92–29.19]), glycoprotein IIb/IIIa inhibitors (GPI IIb/IIIa) (OR, 2.31 [95% CI, 1.92–2.78]), previous PCI (OR, 1.55 [95% CI, 1.34–1.8]), radiation dose (OR, 1.25 per 1000 mGy [95% CI, 1.19–1.31]), and contrast dose (OR, 1.17 per 100 ml [95% CI, 1.08–1.28]).

Conclusions: The overall incidence of acute allergic reactions in the cath lab is low and decreased significantly between 2014 and 2022. The decrease in frequency did not depend on age or sex. Independent predictors of allergic reaction incidence were the use of GPI IIb/IIIa, LMWH, and dose of contrast agent and radiation.

Key words: allergic reaction, anaphylaxis, coronary angiography, iodinated contrast media, myocardial infarction, percutaneous coronary intervention

INTRODUCTION

Despite variable reports, the overall number of revascularization procedures has been increasing in recent years, the clinical profile of the patient has been changing, and higher risk procedures (left main coronary artery revascularization, rotablation and chronic total occlusion revascularization) are being performed more frequently [1–4].

Patients undergoing revascularization procedures are increasingly older and have more risk factors for atherosclerosis [2, 5]. Assessing the frailty of elderly patients remains crucial in selecting an appropriate revascularization strategy [6]. Despite these changes in patient profile, peri-procedural mortality in percutaneous coronary intervention (PCI) remains steady [3–5]. The rate of PCI complications,

WHAT'S NEW?

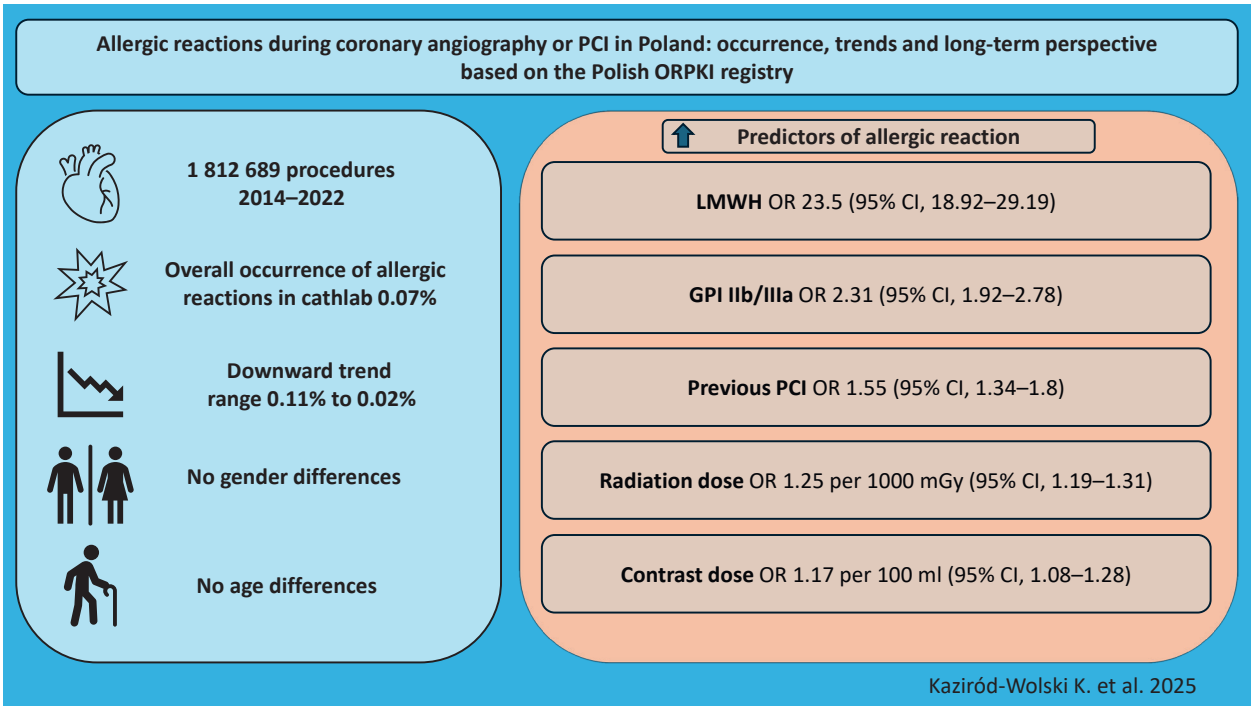
We present a retrospective study based on ORPKI (National Registry of Invasive Cardiology Procedures), which is the latest report on acute allergic reactions during coronary angiography and percutaneous coronary interventions. The overall incidence of acute allergic reactions in the cath lab is low and decreased significantly between 2014 and 2022. Recent data from other studies suggest that their incidence is higher. The decrease in frequency did not depend on age or sex. Independent factors that significantly increased the risk of allergic reaction were the use of glycoprotein IIb/IIIa inhibitors, low-molecular-weight heparin, contrast agents, and radiation.

such as coronary artery perforation and major vascular access complications, remains constant [7, 8]. Other complications, such as allergic reactions, are less studied. Based on available data, the incidence of allergic reactions during PCI is estimated to be 0.08% in patients without psoriasis and 0.4% in patients with psoriasis [9]. Allergic reactions during PCI can be caused by antiplatelet and anticoagulant drugs, as well as drug-eluting stents and contrast alone [10–12]. The incidence of contrast reactions, regardless of study type and mechanism of the allergic reaction, varies between 1% and 3% [13].

The purpose of this study is to accurately analyze the incidence of allergic reactions during coronary angiography and/or PCI, to select the most sensitive groups, and to identify predictors of such reactions.

MATERIAL AND METHODS

The National Registry of Invasive Cardiology Procedures (ORPKI) was launched in 2004 by the Association of Cardiovascular Interventions of the Polish Cardiac Society. Currently, the registry is coordinated by the Jagiellonian University College of Medicine in Krakow [14]. The data used in the statistical analysis in our study were accessed on January 10, 2024. All consecutive patients who underwent coronary angiography or coronary angiography with immediate PCI at 161 interventional cardiology centers in Poland between 2014 and 2022 were included in this retrospective analysis. The total number of patients referred to all assessed patients in consecutive years of the registry. Patients with incomplete data on baseline characteristics were excluded. No methods were used to impute missing data. An allergic reaction was defined as any hypersensitive response of the immune system manifesting as bronchospasm, asthma exacerbation, conjunctivitis, urticaria, eczema, angioedema, or anaphylactic shock. All of these symptoms had to be detected during the patient's stay in the catheterization laboratory and had not been present before admission to the hospital. Other complications or adverse events were diagnosed at the operator's discretion according to the current European Society of Cardiology



Graphical abstract

Abbreviations: CI, confidence interval; GPI, glycoprotein inhibitor; LMWH, low-molecular-weight heparin; OR, odds ratio; PCI, percutaneous coronary intervention

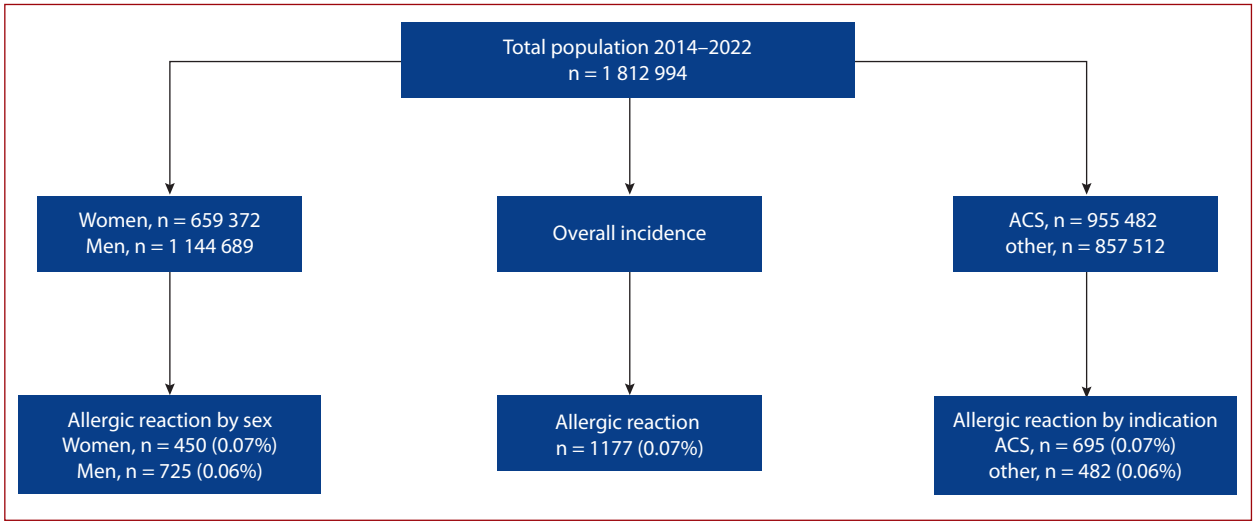


Figure 1. Incidence of allergic reactions in study population

Abbreviations: ACS, acute coronary syndrome

definitions. No further evaluation or follow-up of patients was performed. ORPKI is a national PCI registry in which all PCI patients from various hospitals are enrolled. The signed informed consent for PCI hospitalization contains consent for data transfer to the ORPKI registry. Since this is a mandatory and central national registry, ethics committee approval was waived. The study complied with the ethical principles of clinical research based on the Declaration of Helsinki, as amended. We had access to information that could identify individual participants during or after data collection, and this information was used only for long-term observation, which does not apply to the current study. No external funding was used to support this registry.

Clinical variables such as arterial hypertension, diabetes mellitus, chronic obstructive pulmonary disease, active smoking status, kidney disease, and history of stroke or myocardial infarction were defined as positive if confirmed by the patient during clinical history taking or based on documentation. Kidney disease was defined by a reduced estimated glomerular filtration rate of <60 ml/min/1.73 m^2. The use of unfractionated heparin (UFH), therapeutic doses of low-molecular-weight heparin (LMWH), glycoprotein IIb/IIIa inhibitor (GPI IIb/IIIa), and thrombolysis during angiography or PCI was determined by documentation. Cardiac arrest at baseline referred to cases where this event occurred before the procedures were performed. Using the Killip–Kimball classification, the severity of heart failure was determined (I — no clinical evidence of left ventricular failure, II — mild-to-moderate failure, III — severe failure, pulmonary edema, IV — cardiogenic shock) [15]. Variable "angiography" referred to cases in which only coronary angiography was performed, and variable "PCI" referred to all types of revascularization procedures. Variable "stent" indicated implantation of a specific type of stent (drug-eluting stent, bare metal stent, bioabsorbable stent). Variable "drug-eluting balloon" concerned the use of antimitotic drug-releasing balloons. Variable "chronic total occlusion" referred to procedures during which chronic total occlusion of at least one vessel was found. Variable "TIMI" (Thrombolysis in Myocardial Infarction) refers to perfusion in the culprit vessel: 0 — no perfusion, 1 — penetration without perfusion, 2 — partial perfusion, 3 — complete perfusion) [16].

Statistical analysis

In this study, nominal variables were represented as percentages along with their respective counts. The temporal variation in the proportion of allergic reactions was analyzed using the Cochran–Armitage test for trend. The logistic regression model was employed to identify the predictors of periprocedural allergic reactions. All potential demographic, baseline, and procedural characteristics were incorporated into a multivariable model if the *P*-value in a univariable model was less than 0.2 or if they were considered to have clinical significance. The final model was derived by minimizing the Akaike information criterion. The robustness of the model was validated using bootstrap resampling. To evaluate the presence of multicollinearity, variance inflation factors were analyzed. The results were expressed as odds ratios with 2-sided 95% confidence intervals. The entire statistical analysis was conducted using R software (version 4.3.1)

RESULTS

The study included 1 812 994 coronary and PCI procedures available in the ORPKI registry, of which 659 372 were for women and 1 144 689 for men (Figure 1). We found a declining incidence of allergic reactions overall, as well as in subgroups of men and women, between 2014 and 2022. The overall incidence of allergic reactions oscillated between 0.02% and 0.11% (p<0.001), and the most recent one, noted in 2022, was 0.02% (Table 1). When assessing the incidence of allergic reactions according to the indications for coronary/PCI, there was a decrease in the frequency of allergic reactions regardless of acute

Table 1. Incidence of allergic reaction in general and according to gender and indication

Variable	Year	2014, n (%)	2015, n (%)	2016, n (%)	2017, n (%)	2018, n (%)	2019 (n, %)	2020 (n, %)	2021 (n, %)	2022 (n, %)	Total	*P*-value
Total	Yes	221 0.10	244 0.11	231 0.10	200 0.09	148 0.07	34 0.02	30 0.02	31 0.02	38 0.02	1177	<0.001
	Total	227 971	224 642	230 324	226 484	210 836	199 230	150 924	166 096	176 487	1 812 994	
Gender	Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	Total	
Women	Yes	93 0.11	93 0.11	84 0.1	68 0.08	54 0.07	15 0.02	13 0.02	12 0.02	18 0.03	450	<0.001
	Total	85 266	83 102	84 790	83 411	77 154	72 139	52 945	58 288	62 277	659 372	
Men	Yes	128 0.09	150 0.11	147 0.1	132 0.09	94 0.07	19 0.02	17 0.02	19 0.02	19 0.02	725	<0.001
	Total	142 625	140 763	142 566	142 989	132 817	125 935	97 176	107 060	112 758	1 144 689	
Indication	Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	Total	
ACS	Yes	162 0.12	153 0.12	119 0.1	112 0.09	85 0.08	12 0.01	18 0.02	16 0.02	18 0.02	695	<0.001
	Total	135 410	129 203	124 830	120 862	105 443	97 686	78 689	81 909	81 450	955 482	
Other	Yes	59 0.06	91 0.1	112 0.11	88 0.08	63 0.06	22 0.02	12 0.02	15 0.02	20 0.02	482	<0.001
	Total	92 561	95 439	105 494	105 622	105 393	101 544	72 235	84 187	95 037	857 512	

Table 2. Incidence of allergic reaction according to age decades

Age, decades	Count	Row %	2014, n (%)	2015, n (%)	2016, n (%)	2017, n (%)	2018, n (%)	2019, n (%)	2020, n (%)	2021, n (%)	2022, n (%)	Total	*P*-value
10–19	Yes		0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0	NA
	Total		82	77	73	47	59	45	16	18	21	438	
20–29	Yes		0 0	0 0	1 0.33	0 0	0 0	0 0	0 0	0 0	0 0	1	0.28
	Total		348	326	304	309	287	233	175	232	201	2415	
30–39	Yes		2 0.1	1 0.05	1 0.05	2 0.1	3 0.15	0 0	0 0	0 0	0 0	9	0.047
	Total		1969	1996	2010	1967	1950	1911	1427	1520	1600	16350	
40–49	Yes		9 0.08	18 0.18	7 0.07	10 0.1	10 0.11	2 0.02	2 0.03	1 0.01	1 0.01	60	<0.001
	Total		10 661	10 242	10 491	10 063	9417	9231	7169	8067	8203	83 544	
50–59	Yes		52 0.11	65 0.15	43 0.11	40 0.1	21 0.06	4 0.01	3 0.01	2 0.01	10 0.04	240	<0.001
	Total		46 806	43 427	40 776	38 340	33 590	30 667	22 658	23 938	24 417	304 619	
60–69	Yes		81 0.1	72 0.09	84 0.1	76 0.09	49 0.06	13 0.02	10 0.02	15 0.03	15 0.02	415	<0.001
	Total		81 549	83 160	86 718	85 850	79 457	73 732	55 467	59 426	61 482	666 841	
70–79	Yes		51 0.09	49 0.08	66 0.11	40 0.07	39 0.07	9 0.02	12 0.03	8 0.02	7 0.01	281	<0.001
	Total		59 620	57 671	60 470	61 071	59 189	57 780	45 323	52 654	59 290	513068	
80–89	Yes		26 0.1	38 0.15	26 0.09	30 0.11	24 0.1	6 0.03	2 0.01	5 0.03	5 0.03	162	<0.001
	Total		25 388	26 117	27 478	27 007	24 980	23 646	17 220	18 719	19 450	210 005	
90–99	Yes		0 0	1 0.07	2 0.12	2 0.12	2 0.12	0 0	1 0.08	0 0	0 0	8	0.18
	Total		1363	1467	1661	1689	1667	1652	1273	1374	1477	13 623	
100–109	Yes		0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0	NA
	Total		27	18	32	28	22	19	19	26	18	209	
110–119	Yes		0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0	NA
	Total		5	4	9	10	3	7	6	10	8	62	

coronary syndromes (ACS) (Table 1). In the analysis of age subgroups by decades, a significant decrease in the incidence of allergic reactions was found in the age range of 30-90 years; in other groups, the number of recorded allergic reactions was very low, which influenced the lack of significance of the difference in years (Table 2). Among clinical and pharmacological factors, the risk of allergic reactions was increased by a history of myocardial infarction, a history of coronary artery by-pass grafting, a diagnosis of ST-segment elevation myocardial infarction (STEMI), a diagnosis of ACS, the use of IIb/IIIa glycoprotein inhibitor (GPI IIb/IIIa), low molecular weight heparin (LMWH), and earlier PCI. The risk of allergic reaction was reduced by active smoking, renal disease, chronic obstructive pulmonary disease, UFH, and performing coronary angiography only (Table 3).

Among perioperative factors, the use of drug-eluting balloons decreased the risk of allergic reaction, and the amount of contrast and radiation increased the risk of allergic reaction (Table 4). Based on multivariable regression analysis of selected variables, we found that independently the risk of allergic reaction was increased by LMWH (25-fold increase in risk), GPI IIb/IIIa (2-fold increase in risk), previous PCI (1.5-fold increase in risk), each 1000 mGy of radiation (29% increase in risk) and each 100 ml of contrast (20% increase in risk) and. Independently, the risk of allergic reaction was reduced by factors such as active smoking, diabetes (21% decrease in risk), and UFH (50% decrease in risk) (Figure 1). The distribution of the variables used in the regression analysis is shown in Supplementary material, *Table S1*.

Table 3. Clinical and periprocedural factors affecting incidence allergic reaction

Variables	Univariable	
	OR (95% CI)	*P*-value
Male sex	0.93 (0.83–1.04)	0.21
Age, years	1 (0.99–1)	0.24
Weight, kg	1 (1–1)	0.49
Diabetes	0.87 (0.75–1)	0.06
Previous stroke	1.14 (0.83–1.57)	0.42
Previous myocardial infarction	1.27 (1.12–1.44)	<0.001
Previous PCI	1.37 (1.22–1.55)	<0.001
Previous CABG	0.89 (0.68–1.16)	0.37
Smoking status (active)	0.8 (0.68–0.94)	0.01
Arterial hypertension	0.96 (0.85–1.09)	0.56
Kidney disease	0.68 (0.5–0.92)	0.01
COPD	0.46 (0.27–0.78)	0.003
ACS (yes/no)	1.29 (1.15–1.45)	<0.001
UFH during angiogram	0.67 (0.52–0.87)	0.003
LMWH during angiogram	0.53 (0.2–1.41)	0.21
Cardiac arrest at baseline	1.24 (0.62–2.48)	0.55
Direct transport to cathlab	0.64 (0.41–0.99)	0.045
UFH	0.34 (0.3–0.39)	<0.001
LMWH	49.18 (43.85–55.15)	<0.001
GPI IIb/IIIa	4.46 (3.79–5.24)	<0.001
Killip IV vs. Killip I	1.09 (0.57–2.11)	0.79
Thrombolysis during angiogram	11.67 (1.63–83.46)	0.01
Angiography	0.33 (0.29–0.37)	<0.001
PCI	2.74 (2.4–3.12)	<0.001
CTO	0.94 (0.7–1.25)	0.67
Bifurcation lesion	1.18 (0.96–1.45)	0.12
DES	1.18 (0.97–1.44)	0.11
BVS	1.25 (0.56–2.8)	0.58
BMS	0.73 (0.44–1.19)	0.21
Implanted stent (any)	1.15 (0.92–1.42)	0.22
DEB	0.43 (0.2–0.9)	0.03
TIMI 0-1 PRE	0.93 (0.8–1.07)	0.31
TIMI 3 POST	0.89 (0.68–1.16)	0.38
Contrast per 100 ml	1.53 (1.46–1.6)	<0.001
Radiation per 1000 mGy	1.5 (1.46–1.55)	<0.001

Abbreviations: ACS, acute coronary syndrome; BMS, bare metal stent; BVS, bioresorbable vascular scaffold; CABG, coronary artery bypass grafting; COPD, chronic obstructive pulmonary disease; CTO, chronic total occlusion; DEB, drug-eluting balloon; DES, drug-eluting stent; GPI IIb/IIIa, IIb/IIIa glycoprotein inhibitor; LMWH, low molecular weight heparin; PCI, percutaneous coronary intervention; UFH, unfractionated heparin; TIMI, thrombolysis in myocardial infarction

DISCUSSION

Our study showed a declining incidence of allergic reactions during invasive ACS treatment. The incidence of allergic reactions was 0.02% during the 176 487 coronary angiography and PCI procedures performed in 2022. This study did not include a breakdown of the etiology of these reactions, therefore, the reported frequency refers to reactions to contrast agents and drugs together. Our multivariable logistic regression analysis showed that GPI IIb/IIIa, LMWH, previous PCI, contrast dose, and x-ray dose were independent predictors of allergic reaction occurrence. According to recent data, the incidence of immediate allergic reactions to non-ionic iodine contrast agents is 0.02%–1%, and late reactions are 1%–3% [17–19]. In patients with a history of radiocontrast allergy, the risk of recurrence is 16%–35% [20]. Contrast reactions in most cases (29%) are rash-like skin reactions, while anaphylaxis occurs in about 8.6% of patients [21]. Confirmed methods for managing patients with a history of allergic reactions to contrast are to routinely check for a history of such reactions, use skin tests, avoid triggers, and premedicate [22]. Recommended protocols for managing patients with a history of allergic reaction to contrast help prevent complications in predisposed individuals [23].

Dery et al. [24], in a study involving 1342 patients, showed that re-administration of abciximab was associated with a very low incidence of allergic reaction (5 patients) and did not require interruption of the drug infusion. In contrast, Masood et al. [23], in a study involving 37 patients receiving eptifibatide, reported allergic reactions in 3 patients (10.75%). These reactions can be characterized as anaphylaxis and require urgent interventions [26, 27]. The incidence of allergic reactions during the use of tirofiban is very rare, but anaphylactic reactions and rash can occur even during the first exposure (similar to apixaban) [28].

In our study, the strongest predictor of allergic reaction was the use of LMWH. In the available literature, cutaneous allergic reactions as adverse reactions to this group of drugs occur with a frequency of 7.5% to 39.5% [29–31].

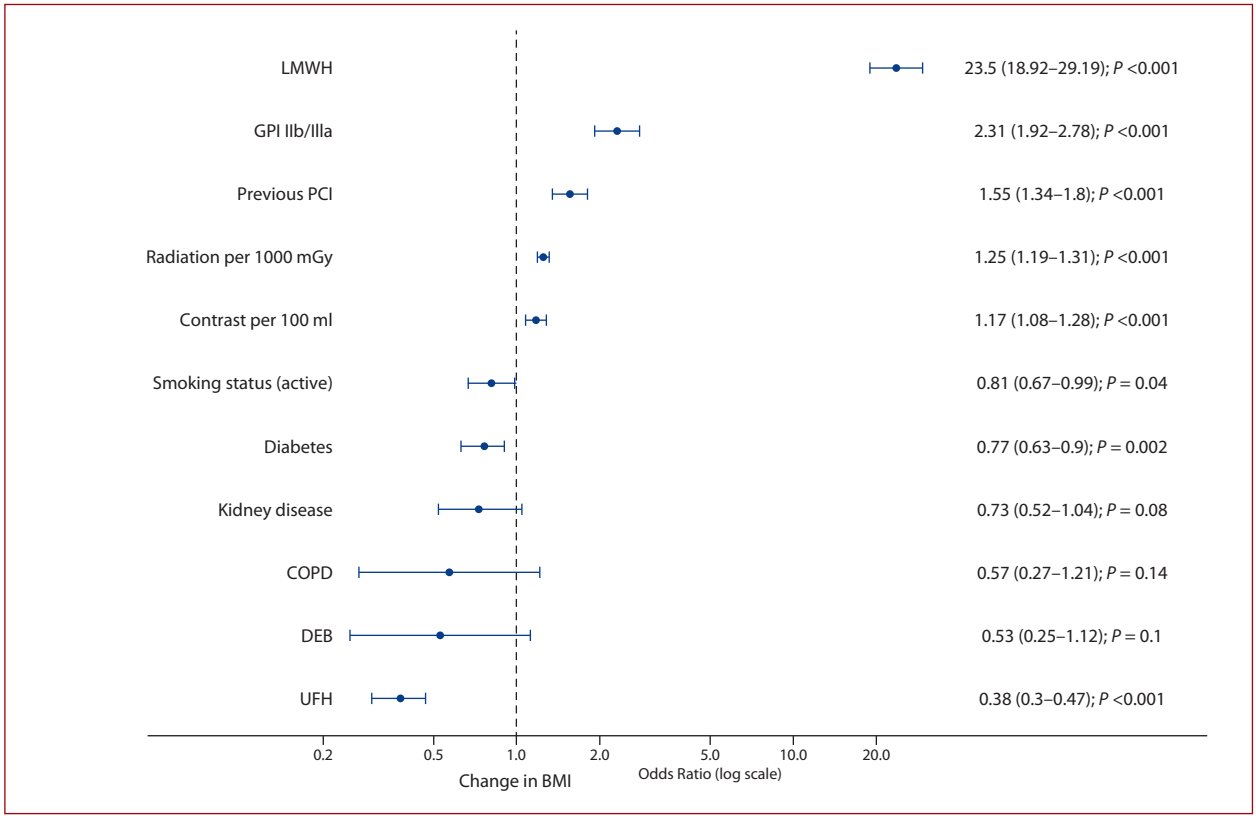


Figure 2. Independent predictors of allergic reactions during procedure adjusted to consecutive years

Abbreviations: COPD, chronic obstructive pulmonary disease; DEB, drug-eluting balloon; GPI IIb/IIIa, IIb/IIIa glycoprotein inhibitor; LMWH, low molecular weight heparin; UFH, unfractionated heparin

These reactions are most often delayed-type hypersensitivity reactions [30, 32] but can also appear immediately [33]. In addition, clinically, these reactions can manifest as pustulosis, urticaria, bullous eruptions, necrosis, and heparin-induced thrombocytopenia [34]. Of all LMWHs, nadroparin has the highest risk of late cutaneous reactions [35]. The association of the occurrence of allergic reaction with LMWH use may be due to the subcutaneous route of administration of the drug. So far, it has been established that the heparin molecule itself is not immunogenic, while it may be a hapten that gains immunogenicity when combined with previously unrecognized proteins after intradermal or subcutaneous administration [36].

Radiation does not cause allergic reactions but leads to direct damage to the skin [37]. Skin lesions can appear immediately after exposure and pathophysiologically are usually dermatitis with a rash or blistering eruptions [38]. An earlier study [9] and our results confirmed the effect of rentgen radiation on the occurrence of allergic reactions; however, the mechanism of this phenomenon has not been clarified. A possible reason is the dependence of the radiation dose on the duration of the procedure and, thus, the increased likelihood of revascularization with the drugs used during the procedure. Although Killip–Kimball class IV did not affect the onset of allergic reaction, it remains one of the strongest predictors of poor short- and long-term prognosis [39]. As Cazzola et al. [40] pointed out, the presence of a history of bronchial asthma may affect cardiovascular mortality; however, the registry presented here does not provide information on the prevalence of this disease or other allergic diseases in those undergoing coronary angiography and PCI. Currently, patients undergoing interventional cardiology procedures with a history of allergic reactions receive prophylactic antihistamines and corticosteroids, which significantly reduce the risk of recurrence of such reactions [41]. The above procedure, as well as the widespread use of low osmolality contrast agents, has significantly reduced the incidence of allergic reactions during contrast procedures [42]. If, despite adequate prophylaxis, a severe anaphylactic allergic reaction leading to shock develops, it is advisable to administer epinephrine by the intramuscular or even intravenous route in patients with severe hypotension [43].

Each predictor directly or indirectly influences the occurrence of allergic reactions. The results of this study can be used in direct clinical practice when performing invasive cardiac procedures. However, the study has some limitations. This is a multi-center national registry. Observation for allergic reaction included the duration of the patient's stay in the hemodynamics laboratory. The registry does not provide accurate information on the symptoms of an allergic reaction, type of allergic reaction, severity of the course, number of deaths due to an allergic reaction

or treatment of allergic reactions, as well as the type of LMWH or GPI IIb/IIIa that were used during the treatments.

CONCLUSIONS

The overall incidence of acute allergic reactions in the cath lab is low and decreased significantly between 2014 and 2022. The decrease in frequency did not depend on age or sex. Independent strong predictors of allergic reaction were the use of GPI IIb/IIIa, LMWH, high dose of contrast agent, and radiation. To reduce the risk of allergic reaction, one should consider avoiding these treatments if possible and minimizing contrast and radiation doses.

Supplementary material

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

Article information

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REFERENCES

1. Grant SW, Kendall S, Goodwin AT, et al. Trends and outcomes for cardiac surgery in the United Kingdom from 2002 to 2016. JTCVS Open. 2021; 7: 259–269, doi: 10.1016/j.xjon.2021.02.001, indexed in Pubmed: 36003724.
2. Kataruka A, Maynard CC, Kearney KE, et al. Temporal trends in percutaneous coronary intervention and coronary artery bypass grafting: Insights from the Washington cardiac care outcomes assessment program. J Am Heart Assoc. 2020; 9(11): e015317, doi: 10.1161/JAHA.119.015317, indexed in Pubmed: 32456522.
3. Blumenfeld O, Na'amnih W, Shapira-Daniels A, et al. Trends in coronary revascularization and ischemic heart disease-related mortality in Israel. J Am Heart Assoc. 2017; 6(2): e004734, doi: 10.1161/JAHA.116.004734, indexed in Pubmed: 28213569.
4. Shawon MdS, Falster MO, Hsu B, et al. Trends and outcomes for percutaneous coronary intervention and coronary artery bypass graft surgery in New South Wales from 2008 to 2019. Am J Cardiol. 2023; 187: 110–118, doi: 10.1016/j.amjcard.2022.10.047, indexed in Pubmed: 36459733.
5. Alkhouli M, Alqahtani F, Kalra A, et al. Trends in characteristics and outcomes of patients undergoing coronary revascularization in the United States, 2003–2016. JAMA Netw Open. 2020; 3(2): e1921326, doi: 10.1001/jamanetworkopen.2019.21326, indexed in Pubmed: 32058558.
6. Cacciatore S, Spadafora L, Bernardi M, et al. Management of coronary artery disease in older adults: Recent advances and gaps in evidence. J Clin Med. 2023; 12(16): 5233, doi: 10.3390/jcm12165233, indexed in Pubmed: 37629275.
7. Nairooz R, Parzynski CS, Curtis JP, et al. Contemporary trends, predictors and outcomes of perforation during percutaneous coronary intervention (from the NCDR cath PCI registry). Am J Cardiol. 2020; 130: 37–45, doi: 10.1016/j.amjcard.2020.06.014, indexed in Pubmed: 32665131.
8. Masoudi FA, Ponirakis A, de Lemos JA, et al. Executive summary: trends in U.S. cardiovascular care: 2016 report from 4 ACC national cardiovascular data registries. J Am Coll Cardiol. 2017; 69(11): 1424–1426, doi: 10.1016/j.jacc.2016.12.004, indexed in Pubmed: 28025066.
9. Siudak Z, Wysocka-Dubielecka K, Malinowski K, et al. Psoriasis is an independent predictor of increased risk of allergic reaction during percutaneous coronary interventions. Big data analysis from the Polish National PCI Registry (ORPKI). Cardiol J. 2020; 27(3): 278–284, doi: 10.5603/CJ.a2018.0076, indexed in Pubmed: 30155870.
10. Hofmeier KS. Hypersensitivity reactions to modern antiplatelet and anticoagulant drugs. Allergo J Int. 2015; 24(2): 58–66, doi: 10.1007/s40629-015-0048-2, indexed in Pubmed: 26120548.
11. Montone RA, Sabato V, Sgueglia GA, et al. Inflammatory mechanisms of adverse reactions to drug-eluting stents. Curr Vasc Pharmacol. 2013; 11(4): 392–398, doi: 10.2174/1570161111311040003, indexed in Pubmed: 23905634.
12. Juergens CP, Khaing AMi, McIntyre GJ, et al. Adverse reactions of low osmolar non-ionic and ionic contrast media when used together or separately during percutaneous coronary intervention. Heart Lung Circ. 2005; 14(3): 172–177, doi: 10.1016/j.hlc.2005.06.013, indexed in Pubmed: 16352273.
13. Brockow K, Sánchez-Borges M. Hypersensitivity to contrast media and dyes. Immunol Allergy Clin North Am. 2014; 34(3): 547–564, doi: 10.1016/j.iac.2014.04.002, indexed in Pubmed: 25017677.
14. Siudak Z, Hawranek M, Kleczyński P, et al. Interventional cardiology in Poland in 2022. Annual summary report of the Association of Cardiovascular Interventions of the Polish Cardiac Society (AISN PTK) and Jagiellonian University Medical College. Postepy Kardiol Interwencyjnej. 2023; 19(2): 82–85, doi: 10.5114/aic.2023.129205, indexed in Pubmed: 37465633.
15. Mello BH, Oliveira GB, Ramos RF, et al. Validation of the Killip–Kimball classification and late mortality after acute myocardial infarction. Arq Bras Cardiol. 2014; 103(2): 107–117, doi: 10.5935/abc.20140091, indexed in Pubmed: 25014060.
16. Antman EM, Cohen M, Bernink PJ, et al. The TIMI risk score for unstable angina/non-ST elevation MI: A method for prognostication and therapeutic decision making. JAMA. 2000; 284(7): 835–842, doi: 10.1001/jama.284.7.835, indexed in Pubmed: 10938172.
17. Brockow K, Christiansen C, Kanny G, et al. Management of hypersensitivity reactions to iodinated contrast media. Allergy. 2005; 60(2): 150–158, doi: 10.1111/j.1398-9995.2005.00745.x, indexed in Pubmed: 15647034.
18. Park C, Bae Y, Choi S, et al. Incidence, clinical manifestations, and outcome of adverse reactions to intravenous radio-contrast media following computed tomography (Ct) in general population. Ann Allergy Asthma Immunol. 2009; 103: A44.
19. Hosoya T, Yamaguchi K, Akutsu T, et al. Delayed adverse reactions to iodinated contrast media and their risk factors. Radiat Med. 2000; 18(1): 39–45, indexed in Pubmed: 10852654.
20. Aykan AÇ, Altıntaş Aykan D, Katırcıbaşı MT, et al. Management of radio-contrast allergy in radio-contrast allergic patients undergoing coronary angiography and intervention. Kardiologiia. 2020; 60(10): 62–65, doi: 10.18087/cardio.2020.10.n1117, indexed in Pubmed: 33228507.
21. Huang J, Bagsic S, Simon R. Characterizing overlapping radiocontrast media, shellfish, and iodine allergies. Ann Allergy Asthma Immunol. 2022; 129(5): S17, doi: 10.1016/j.anai.2022.08.550.
22. Kang HR, Jeong J, Brockow K. Diagnosis and prevention of hypersensitivity reactions to iodinated contrast media. Allergy Asthma Immunol Res. 2022; 14(4): 348–360, doi: 10.4168/aair.2022.14.4.348, indexed in Pubmed: 35837820.
23. Nittner-Marszalska M, Bochenek G, Bodzenta-Łukaszyk A, et al. Hypersensitivity to iodine contrast media. Guidelines of the Section of Drug Hypersensitivity of the Polish Society of Allergology. Alergologia Polska - Pol J Allergol. 2018; 5(1): 51–57, doi: 10.5114/pja.2018.74450.
24. Dery JP, Braden GA, Lincoff AM, et al. Final results of the ReoPro readministration registry. Am J Cardiol. 2004; 93(8): 979–984, doi: 10.1016/j.amjcard.2003.12.051, indexed in Pubmed: 15081439.
25. Masood F, Hashmi S, Chaus A, et al. Complications and management of eptifibatide-induced thrombocytopenia. Ann Pharmacother. 2021; 55(12): 1467–1473, doi: 10.1177/10600280211006645, indexed in Pubmed: 33813877.
26. Tcheng JE, Kereiakes DJ, Lincoff AM, et al. Abciximab readministration: Results of the ReoPro Readministration registry. Circulation. 2001; 104(8): 870–875, doi: 10.1161/hc3301.094533, indexed in Pubmed: 11514371.
27. Hawkins C, Gatenby P, McGill D. Severe hypotension complicating primary angioplasty: Allergy to abciximab. Allergy. 2003; 58(7): 688–689, doi: 10.1034/j.1398-9995.2003.00190.x, indexed in Pubmed: 12823141.

28. Hofmeier KS. Hypersensitivity reactions to modern antiplatelet and anticoagulant drugs. Allergo J Int. 2015; 24(2): 58–66, doi: 10.1007/s40629-015-0048-2, indexed in Pubmed: 26120548.
29. Kaandorp SP, Goddijn M, van der Post JAM, et al. Aspirin plus heparin or aspirin alone in women with recurrent miscarriage. N Engl J Med. 2010; 362(17): 1586–1596, doi: 10.1056/NEJMoa1000641, indexed in Pubmed: 20335572.
30. Schindewolf M, Schwaner S, Wolter M, et al. Incidence and causes of heparin-induced skin lesions. CMAJ. 2009; 181(8): 477–481, doi: 10.1503/cmaj.081729, indexed in Pubmed: 19786468.
31. Schindewolf M, Gobst C, Kroll H, et al. High incidence of heparin-induced allergic delayed-type hypersensitivity reactions in pregnancy. J Allergy Clin Immunol. 2013; 132(1): 131–139, doi: 10.1016/j.jaci.2013.02.047, indexed in Pubmed: 23726261.
32. Schindewolf M, Kahle B, Lindhoff-Last E, et al. Heparin-induced skin lesions. Phlebologie. 2018; 39(1): 5–11, doi: 10.1055/s-0037-1622289.
33. Bircher AJ, Harr T, Hohenstein L, et al. Hypersensitivity reactions to anticoagulant drugs: Diagnosis and management options. Allergy. 2006; 61(12): 1432–1440, doi: 10.1111/j.1398-9995.2006.01227.x, indexed in Pubmed: 17073874.
34. Schindewolf M, Lindhoff-Last E, Ludwig R, et al. Heparin-induced skin lesions. Lancet. 2012; 380(9856): 1867–1879, doi: 10.1016/s0140-6736(12)60409-7, indexed in Pubmed: 22642893.
35. Schindewolf M, Recke A, Zillikens D, et al. Nadroparin carries a potentially high risk of inducing cutaneous delayed-type hypersensitivity responses. Contact Dermatitis. 2017; 77(1): 35–41, doi: 10.1111/cod.12764, indexed in Pubmed: 28294347.
36. Bircher AJ, Harr T, Hohenstein L, et al. Hypersensitivity reactions to anticoagulant drugs: diagnosis and management options. Allergy. 2006; 61(12): 1432–1440, doi: 10.1111/j.1398-9995.2006.01227.x, indexed in Pubmed: 17073874.
37. Yang X, Ren H, Guo X, et al. Radiation-induced skin injury: pathogenesis, treatment, and management. Aging (Albany NY). 2020; 12(22): 23379–23393, doi: 10.18632/aging.103932, indexed in Pubmed: 33202382.
38. Salvo N, Barnes E, van Draanen J, et al. Prophylaxis and management of acute radiation-induced skin reactions: A systematic review of the literature. Curr Oncol. 2010; 17(4): 94–112, doi: 10.3747/co.v17i4.493, indexed in Pubmed: 20697521.
39. Piątek Ł, Piątek K, Skrzypek M, et al. The impact of ECG at admission and a culprit lesion on 12-month outcomes in acute myocardial infarction — analysis based on the PL-ACS Registry. Medical Studies. 2023; 39(4): 327–333, doi: 10.5114/ms.2023.134083.
40. Cazzola M, Hanania NA, Rogliani P, et al. Cardiovascular disease in asthma patients: From mechanisms to therapeutic implications. Kardiol Pol. 2023; 81(3): 232–241, doi: 10.33963/KP.a2023.0038, indexed in Pubmed: 36739655.
41. Manda YR, Baradhi KM. Cardiac Catheterization Risks and Complications. [Updated 2023 Jun 5]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK531461/ (June 18, 2024).
42. Chiu TM, Chu SY. Hypersensitivity reactions to iodinated contrast media. Biomedicines. 2022; 10(5): 1036, doi: 10.3390/biomedicines10051036, indexed in Pubmed: 35625773.
43. Trooboff SW, Iribarne A. Acute adverse drug reactions following cardiac catheterization: Evidence-based guidance for providers and systems. J Thorac Dis. 2019; 11(7): 2680–2684, doi: 10.21037/jtd.2019.06.64, indexed in Pubmed: 31463092.