ORIGINAL ARTICLE

Factors determining the frequency of optical coherence tomography and intravascular ultrasound use in patients treated with percutaneous coronary interventions in recent years: Analysis based on a large national registry

Rafał Januszek[1], Zbigniew Siudak[2], Krzysztof Piotr Malinowski[3, 4], Wojciech Wańha[5], Sławomir Surowiec[1], Grzegorz Heba[1], Artur Pawlik[1], Tomasz Kameczura[6], Wojciech Wojakowski[5], Miłosz Jaguszewski[7], Agnieszka Kołodziej[2], Leszek Bryniarski[1, 8], Krzysztof Bartuś[9], Andrzej Surdacki[1, 8], Sławomir Dobrzycki[10], Jacek Legutko[11], Stanisław Bartuś[1, 8]

[1]Department of Cardiology and Cardiovascular Interventions, University Hospital, Kraków, Poland
[2]Faculty of Medicine and Health Sciences, Jan Kochanowski University, Kielce, Poland
[3]Jagiellonian University Medical College, Faculty of Medicine, Department of Bioinformatics and Telemedicine, Kraków, Poland
[4]Jagiellonian University Medical College, Center for Digital Medicine and Robotics, Kraków, Poland
[5]Department of Cardiology and Structural Heart Diseases, Medical University of Silesia, Katowice, Poland
[6]Chair of Electroradiology, Faculty of Medicine, University of Rzeszow, Rzeszów, Poland
[7]1st Department of Cardiology, Medical University of Gdansk, Gdańsk, Poland
[8]Institute of Cardiology, Jagiellonian University Medical College, Kraków, Poland
[9]Department of Cardiovascular Surgery and Transplantology, Jagiellonian University Medical College, John Paul II Hospital, Kraków, Poland
[10]Department of Invasive Cardiology, Medical University of Bialystok, Białystok, Poland
[11]Department of Interventional Cardiology, Institute of Cardiology, Jagiellonian University Medical College, John Paul II Hospital, Kraków, Poland

Editorial
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Correspondence to:
Rafał Januszek, MD, PhD,
Department of Cardiology and Cardiovascular Interventions,
University Hospital in Krakow,
Jakubowskiego 2, 30–688 Kraków,
Poland,
phone: +48 12 400 22 50,
e-mail: jaanraf@interia.pl

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ABSTRACT

Background: Intravascular ultrasound (IVUS) and optical coherence tomography (OCT) have demonstrated improvement in the clinical outcome of patients undergoing percutaneous coronary intervention (PCI).

Aims: We aimed to examine the frequency of implementing OCT and IVUS during coronary angiography (CA) and PCI in everyday practice in Poland. Factors related to the more common choice of these imaging techniques were determined.

Methods: Data from the Polish National Registry of Percutaneous Coronary Interventions (ORPKI) were procured for analysis. Between January 2014 and December 2021, we extracted data on 1 452 135 CAs, 11 710 using IVUS (0.8%) and 1471 with OCT (0.1%) and 838 297 PCIs, 15 436 with IVUS (1.8%) and 1680 with OCT (0.2%). We assessed the determining factors for applying IVUS and OCT via multiple regression logistics models.

Results: The frequency of applying IVUS during CAs and PCIs increased significantly between the years 2014 and 2021. In 2021, it reached 1.54% for CAs and 4.42% for PCIs, while for OCT, there was a rise regarding the CA group, namely 0.13% in 2021, and, in the PCI group, 0.43%. Age was one of the factors significantly associated with the frequency of using IVUS/OCT during CA/PCI, which was confirmed by multivariate analysis (Odds ratio: 0.981 for IVUS and 0.973 for OCT use with PCI).

Conclusion: The frequency at which IVUS and OCT were used has undergone a significant increase in previous years. This increase can be largely attributed to the current reimbursement policies. Further improvement is required for this frequency to be at a satisfactory level.

Key words: coronary angiography, frequency of use, intravascular ultrasound, optical coherence tomography, percutaneous coronary intervention

WHAT'S NEW?

Intravascular ultrasound (IVUS) and optical coherence tomography (OCT) improve outcomes for patients treated with percutaneous coronary interventions (PCIs). In the current study, we assessed the frequency of OCT and IVUS use during coronary angiography (CA) and PCI. Data for this analysis were obtained from the Polish National Registry of Percutaneous Coronary Interventions (ORPKI) and included 1 452 135 CAs (0.8% IVUS, 0.1% OCT), and 838 297 PCIs (1.8% IVUS, 0.2% OCT). The frequency of using intravascular coronary imaging techniques increased significantly between 2014 and 2021. This resulted mainly from the favorable reimbursement policy. Location of culprit lesion, age, year of PCI, dissemination of coronary stenoses, or prior coronary interventions were found, among others, to be significantly related to the frequency of OCT/IVUS use during PCI and CA. The frequency of intracoronary imaging techniques has significantly increased in recent years; however, for this to be satisfactory, more improvement is needed.

INTRODUCTION

The usefulness of intravascular imaging — optical coherence tomography (OCT) and intravascular ultrasound (IVUS) — in patients undergoing percutaneous coronary interventions (PCIs) has been demonstrated in several studies [1, 2]. The utility of modern software for improving OCT use has also been confirmed by our team in a recently published article [3, 4]. Analyses of trends in the use of intravascular imaging techniques in large populations are less frequently published. In an older study, the frequency of IVUS and OCT use was assessed in the United States between 2007 and 2013, with over 4 million PCIs analyzed. A decline was observed in the frequency of PCI use, with the IVUS-guided PCIs constant ranging from 5% in 2007 to 6.5% in 2013 [5]. Elgendy et al. [5] revealed a lower frequency of IVUS application in rural regions compared to urban areas, regardless of the teaching center location. They also observed an exponential increase in the frequency of OCT-guided PCI, albeit it was still at a low level by the end of observation — approximately 1% in 2013. The decrease in PCI frequency was attributed to the higher incidence of applying functional measurements of stenoses, mainly fractional flow reserve assessment [5]. In a US-based study, the frequency of IVUS use was calculated, totaling approximately 20%. However, that study involved a selected group of patients, mainly, those with borderline stenoses [6]. In the US, other studies on the frequency of IVUS and OCT use were also carried out in certain subgroups, e.g. in a group of patients with ST-segment elevation myocardial infarction (STEMI), further demonstrating an increase in the frequency of IVUS- and OCT-guided PCIs. Nonetheless, this turned out to be statistically significant, reaching 5.1% in 2016, but only in the case of IVUS. With regard to OCT-guided PCI, its frequency totaled 0.2% [7].

Our study aimed to investigate the frequency of OCT and IVUS use during diagnostics of coronary angiography (CA) and PCI between 2014 and 2021 as well as local barriers to the implementation of OCT and IVUS in everyday practice in Poland. We further aimed to evaluate factors associated with the more frequent application of these imaging techniques.

METHODS

Materials

This retrospective analysis was performed on prospectively collected data. Data for conducting the current study were obtained from the Polish National Registry of Percutaneous Coronary Interventions (ORPKI). The registry has been described in previously published articles [8, 9]. Data were collected from the registry between January 2014 and December 2021. From this period, we extracted data on all patients undergoing CAs (1452135), for which IVUS was used in 11710 (0.8%) and OCT in 1471 (0.1%). During the analyzed period, there were 838 297 PCIs, and all those patients were included in the analysis (15 436 using IVUS [1.8%] and 1680 using OCT [0.2%]). During the investigated period, there were 162 active catheterization laboratories, and all of them potentially had equipment for IVUS use, while 38 laboratories potentially had equipment for OCT use; the most up-to-date software (Ultreon™ 1.0 Software) has been installed in 9 laboratories so far [3, 4]. Technical aspects of the procedure, such as the choice of access site (femoral or radial sheath), catheter or guidewire size, choice and type of intravascular imaging device, etc. were at the operator's discretion. Patients were qualified for CA and PCI as well as intravascular imaging according to current European guidelines [10–13]. All data on concomitant diseases, medical history, treatment, and the hemodynamic procedure itself were entered based on medical records on an ongoing basis by the operators performing the procedure or other qualified and trained persons/laboratory employees, such as technicians. The protocol complied with the 1964 Declaration of Helsinki, and all participants provided their written informed consent for the percutaneous procedure. Due to the retrospective nature and anonymization of the collected data and registry, approval of the Bioethics Committee was not required.

Statistical analysis

Continuous variables were presented as means and standard deviations, and medians and interquartile ranges, where applicable. Normality was assessed via the Shapiro-Wilk or

Kolmogorov-Smirnov tests with the Lilliefors correction for variables equaling more than 2000 observations. Equality of variance was evaluated using Levene's test. Differences between the 2 groups were compared using Student's or Welch's t-tests, depending on the equality of variance for normally distributed variables. Categorical variables were compared with Pearson's χ^2 or Fisher's exact tests if 20% of cells had an expected count of less than 5 (Monte Carlo simulation for Fisher's test using tables of higher dimensions than 2 × 2). The Cochrane Armitage trend test was used for comparison between frequencies of IVUS, OCT, or both in the following years. All baseline/demographic characteristics were adopted as potential factors related to the use/choice of intravascular imaging (IVUS or OCT) during CA or PCI in univariable logistic regression models. Variables with a *P*-value <0.2 or those of clinical significance were included in the multivariable model. Final multivariable logistic regression models were constructed using minimization of the Akaike Information Criterion to find predictors regarding the use/choice of intravascular imaging (IVUS or OCT) during CA or PCI. Statistical analysis was performed using the R version 4.1.1 (R Foundation for Statistical Computing, Vienna, Austria, 2021), with the 'rms' package, version 6.2–0.

RESULTS

Current trends in the frequency of IVUS and OCT use during CA and PCI

The frequency of IVUS use during DCAs and PCIs increased in the following years of the analyzed period (2014–2021). In 2014, it totaled 0.54% for CAs and 0.67% for PCIs, and in 2021, it reached 1.54% for CAs (*P* <0.001) and 4.42% for PCIs (*P* <0.001) (Figures 1A, B).

Considering OCT frequency, there was a significant change during the analyzed period, with a slight in-

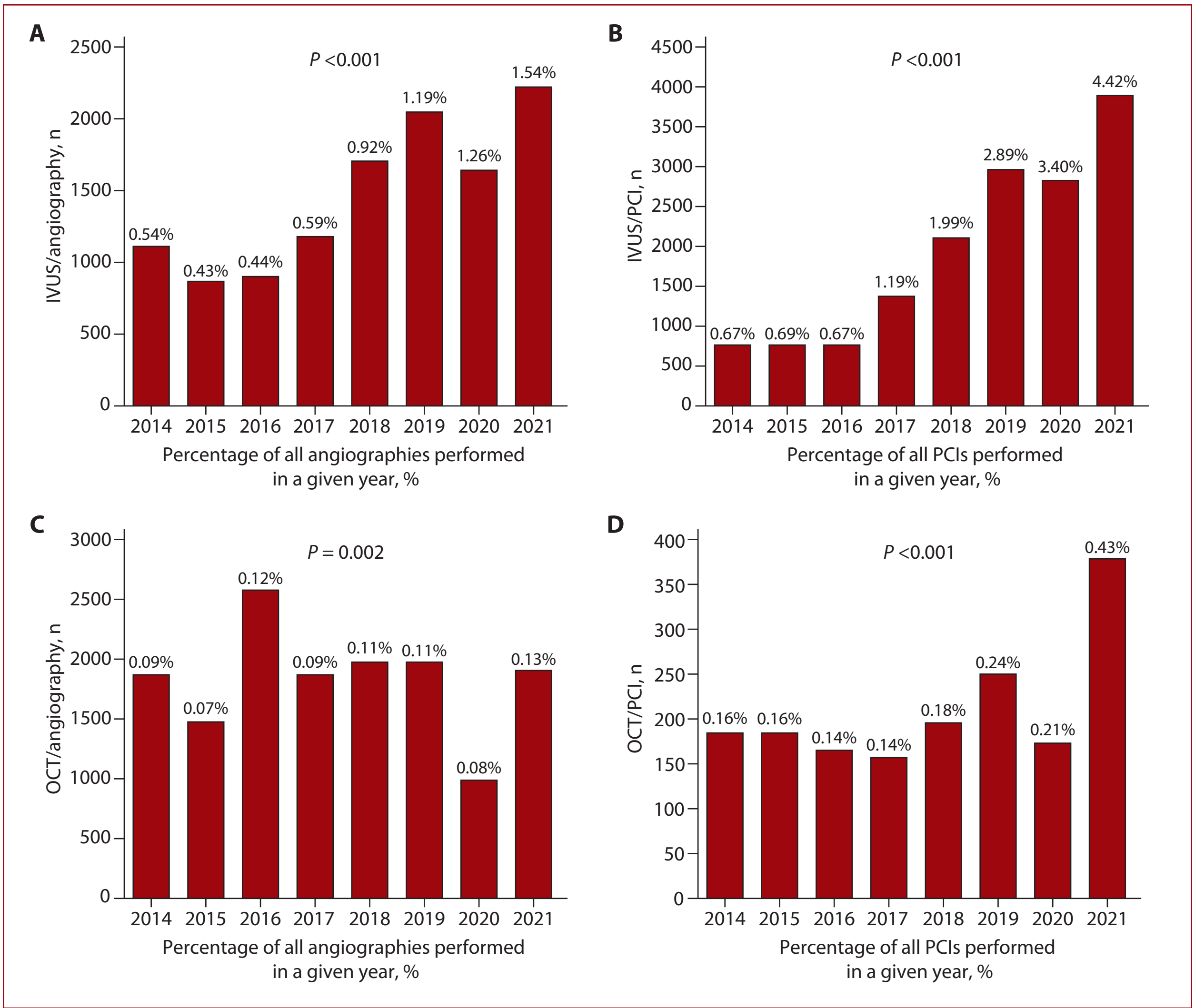

Figure 1. A. Frequency of intravascular ultrasound use during coronary angiography diagnostics in the analyzed period (2014–2021). **B.** Frequency of intravascular ultrasound use during percutaneous coronary interventions in the analyzed period (2014–2021). **C.** Frequency of optical coherence tomography use during coronary angiography diagnostics in the analyzed period (2014–2021). **D.** Frequency of optical coherence tomography use during percutaneous coronary interventions in the analyzed period (2014–2021)

Abbreviations: IVUS, intravascular ultrasound; OCT, optical coherence tomography; PCI, percutaneous coronary intervention

Table 1. Clinical characteristics of patients undergoing angiogram — IVUS/OCT during angiography

Selected indices	Total	Non-IVUS	IVUS	*P*-value	Non-OCT	OCT	*P*-value
IVUS/OCT during angiography							
	n = 1452135	n = 1440425	n = 11710		n = 1450664	n = 1471	
Age, years	66.7 (10.8)	66.8 (10.8)	66.3 (10.2)	<0.001	66.8 (10.8)	63.1 (10.6)	<0.001
Sex, male	902888 (62.5%)	894426 (62.4%)	8462 (72.5%)	<0.001	901835 (62.4%)	1053 (71.7%)	<0.001
Diabetes mellitus	315588 (21.7%)	312916 (21.7%)	2672 (22.8%)	<0.005	315292 (21.7%)	296 (20.1%)	0.13
Prior stroke	43179 (2.97%)	42879 (2.98%)	300 (2.56%)	<0.01	43157 (2.97%)	22 (1.5%)	<0.001
Prior MI	319530 (22%)	314925 (21.9%)	4605 (39.3%)	<0.001	318928 (22%)	602 (40.9%)	<0.001
Prior PCI	379108 (26.1%)	373309 (25.9%)	5799 (49.5%)	<0.001	378168 (26.1%)	940 (63.9%)	<0.001
Prior CABG	80476 (5.54%)	79912 (5.55%)	564 (4.82%)	<0.001	80413 (5.54%)	63 (4.28%)	<0.05
Active smoking	254279 (17.51%)	252046 (17.5%)	2233 (19.1%)	<0.001	254053 (17.5%)	226 (15.4%)	<0.05
Arterial hypertension	1004763 (69.2%)	996425 (69.2%)	8338 (71.2%)	<0.001	1003813 (69.2%)	950 (64.6%)	<0.001
Kidney disease	77060 (5.31%)	76298 (5.3%)	762 (6.51%)	<0.001	77005 (5.31%)	55 (3.74%)	<0.01
COPD	37245 (2.56%)	36876 (2.56%)	369 (3.15%)	<0.001	37217 (2.57%)	28 (1.9%)	0.09
IVUS/OCT during PCI							
	n = 838297	n = 822861	n = 15436		n = 836617	n = 1680	
Age, years	67.3 (10.7)	67.3 (10.7)	67.1 (10.6)	<0.05	67.3 (10.7)	64.4 (10.7)	<0.001
Sex, male	570623 (68.3%)	559372 (68.2%)	11251 (73%)	<0.001	569405 (68.3%)	1218 (72.6%)	<0.001
Diabetes mellitus	198876 (23.7%)	194881 (23.7%)	3995 (25.8%)	<0.001	198539 (23.7%)	337 (20%)	<0.001
Prior stroke	26492 (3.16%)	26015 (3.16%)	477 (3.08%)	0.6	26455 (3.16%)	37 (2.2%)	0.01
Prior MI	263224 (31.4%)	256298 (31.12%)	6926 (44.8%)	<0.001	262627 (31.4%)	597 (35.4%)	<0.001
Prior PCI	322386 (38.4%)	314298 (38.16%)	8088 (52.3%)	<0.001	321485 (38.4%)	901 (53.5%)	<0.001
Prior CABG	50422 (6.01%)	49180 (5.97%)	1242 (8.03%)	<0.001	50346 (6.01%)	76 (4.51%)	0.007
Active smoking	168632 (20.1%)	165565 (20.1%)	3067 (19.8%)	0.4	168374 (20.1%)	258 (15.3%)	<0.001
Arterial hypertension	588630 (70.1%)	577596 (70.1%)	11034 (71.3%)	<0.005	587605 (70.2%)	1025 (60.8%)	<0.001
Kidney disease	47624 (5.68%)	46373 (5.63%)	1251 (8.09%)	<0.001	47556 (5.68%)	68 (4.04%)	<0.005
COPD	20176 (2.4%)	19680 (2.39%)	496 (3.21%)	<0.001	20140 (2.14%)	36 (2.1%)	0.47

Data are presented as mean (SD) for continuous variables and as absolute numbers (n) and percentages (%)

Abbreviations: ACS, acute coronary syndrome; CABG, coronary artery bypass grafting; COPD, chronic obstructive pulmonary disease; MI, myocardial infarction; NS, not significant; other — see Figure 1

crease in the CA group from 0.09% in 2014 to 0.13% in 2021 (*P* = 0.002), and more explicitly, for PCIs, from 0.16% in 2014 to 0.43% in 2021 (*P* <0.001) (Figures 1C, D).

Considering the frequency of the assessed intravascular imaging methods (IVUS and OCT), there was a distinct increase in the CA group from 0.61% in 2014 to 1.66% in 2021 (*P* <0.001), and from 0.81% in 2014 to 4.83% in 2021 in the PCI group (*P* <0.001) (Supplementary material, *Figure S1A, B*).

General characteristics at baseline

Patients undergoing IVUS/OCT-assisted CA were younger, and more often male. They more frequently suffered from concomitant diseases and had also undergone past coronary revascularization procedures more often. A similar relationship was observed in the group of patients treated with PCI with IVUS/OCT support (Table 1).

Clinical presentation and state before CA and PCI

CA with intracoronary imaging was more often applied in patients with stable angina and in those with lower Killip class grades. Patients with ACSs were more frequently found in the group treated with PCI assisted by IVUS or OCT. Their clinical state was more often severe, and this was demonstrated by higher mean Killip class grade, and the percentage share of patients with higher Killip class grades (Table 2).

Vascular access and coronary angiography

Femoral vascular access was more frequently chosen for patients undergoing CA with the use of IVUS/OCT. Intravascular imaging was also more often used in patients with left main coronary artery (LMCA) disease, independently of the presence of coronary stenosis in other arteries (Table 3). Moreover, mean radiation exposure and contrast dose were higher in patients diagnosed with IVUS/OCT (Table 3). Similar relationships were noted for patients treated with IVUS/OCT-assisted PCI (Table 3). Both IVUS and OCT were more often used in PCIs performed on the patent coronary arteries assessed by TIMI score (Table 3). This did not remain consistent with chronic total occlusion (CTO) PCI, where OCT was more often applied in CTO PCIs compared to non-CTO PCIs. An opposite correlation was found for OCT PCI with IVUS. Bifurcation lesions were more often treated with the use of intra-arterial imaging techniques (IVUS/OCT) when compared to non-bifurcation lesions (Table 3).

Frequency of intravascular imaging in selected PCI scenarios

Considering the frequency of IVUS use in patients treated with PCI in CTO lesions, its application was noted in 837 patients (1.66%), while for OCT, in 145 (0.28%); whereas PCI within bifurcation was assisted by IVUS in 4145 patients (5.02%) and by OCT in 264 (0.31%). Patients

Table 2. Clinical characteristics of patients undergoing angiogram — IVUS/OCT during angiography and PCI

Selected indices	Total	Non-IVUS	IVUS	*P*-value	Non-OCT	OCT	*P*-value
IVUS/OCT during angiography							
	n = 1452135	n = 1440425	n = 11710		n = 1450664	n = 1471	
Clinical presentation							
Acute heart failure	3857 (0.27%)	3814 (0.26%)	43 (0.37%)		3856 (0.27%)	1 (0.07%)	
Cardiac arrest	11282 (0.78%)	11203 (0.78%)	79 (0.67%)		11278 (0.78%)	4 (0.27%)	
Chronic heart failure	21733 (1.5%)	21532 (1.49)	201 (1.72)		21728 (1.5%)	5 (0.34%)	
Congenital heart defect	44227 (3.05%)	44094 (3.06%)	133 (1.14%)		44220 (3.05%)	7 (0.48%)	
NSTEMI	194124 (13.4%)	193030 (13.4%)	1094 (9.34%)	<0.001	194029 (13.4%)	95 (6.46%)	<0.001
Other	27690 (1.91%)	27411 (1.9%)	279 (2.38%)		27670 (1.91%)	20 (1.36%)	
Stable angina	555056 (38.2%)	548611 (38.1%)	6445 (55%)		554237 (38.2%)	819 (55.7%)	
STEMI	167223 (11.5%)	166668 (11.6%)	555 (4.74%)		167131 (11.5%)	92 (6.25%)	
Unstable angina	427000 (29.4%)	424119 (29.4%)	2881 (24.6%)		426572 (29.4%)	428 (29.1%)	
ACS	788347 (54.3%)	783817 (54.4%)	4530 (38.7%)	<0.001	787732 (54.3%)	615 (41.8%)	<0.001
Killip class							
I	1075723 (92.8%)	1067049 (92.8%)	8674 (94.2%)		1074596 (92.8%)	1,127 (96.3%)	
II	57160 (4.93%)	56778 (4.94%)	382 (4.15%)	<0.001	57127 (4.93%)	33 (2.82%)	<0.001
III	13934 (1.2%)	13844 (1.2%)	90 (0.98%)		13926 (1.2%)	8 (0.68%)	
IV	12530 (1.08%)	12468 (1.08%)	62 (0.67%)		12528 (1.08%)	2 (0.17%)	
Killip class IV	12530 (1.08%)	12468 (1.08%)	62 (0.67%)	<0.001	12528 (1.08%)	2 (0.17%)	0.003
Hypothermia at baseline	360 (0.02%)	360 (0.02%)	0 (0%)	0.08	360 (0.02%)	0 (0%)	0.39
Direct transport	53343 (3.67%)	53151 (3.69%)	192 (1.64%)	<0.001	53325 (3.68%)	18 (1.22%)	<0.001
IVUS/OCT during PCI							
	n = 838297	n = 822861	n = 15436		n = 836617	n = 1680	
Clinical presentation							
Acute heart failure	1515 (0.18%)	1454 (0.18%)	61 (0.39%)		1510 (0.18%)	5 (0.3%)	
Cardiac arrest	5952 (0.71%)	5816 (0.71%)	136 (0.88%)		5946 (0.71%)	6 (0.36%)	
Chronic heart failure	6068 (0.72%)	5827 (0.71%)	241 (1.56%)		6053 (0.72%)	15 (0.89%)	
Congenital heart defect	1403 (0.17%)	1386 (0.17%)	17 (0.11%)		1401 (0.17%)	2 (0.12%)	
NSTEMI	162988 (19.4%)	160574 (19.5%)	2414 (15.6%)	<0.001	162816 (19.4%)	172 (10.2%)	<0.001
Other	5828 (0.69%)	5530 (0.67%)	298 (1.93%)		5821 (0.7%)	7 (0.42%)	
Stable angina	246938 (29.4%)	240016 (29.1%)	6922 (44.7%)		246149 (29.4%)	789 (46.8%)	
STEMI	186324 (22.2%)	184288 (22.4%)	2036 (13.2%)		186004 (22.2%)	320 (19%)	
Unstable angina	222145 (26.5%)	218803 (26.6%)	3342 (21.6%)		221776 (26.5%)	369 (21.9%)	
ACS	571457 (68.1%)	563665 (68.4%)	7792 (50.4%)	<0.001	570596 (68.1%)	861 (51.1%)	<0.001
Killip class							
I	480641 (90.1%)	475207 (90.1%)	5434 (89.6%)		479863 (90.1%)	778 (97%)	
II	34419 (6.45%)	34031 (6.45%)	388 (6.4%)	<0.05	34401 (6.5%)	18 (2.24%)	<0.001
III	9140 (1.71%)	9038 (1.71%)	102 (1.68%)		9137 (1.71%)	3 (0.37%)	
IV	9401 (1.76%)	9262 (1.76%)	139 (2.29%)		9398 (1.76%)	3 (0.37%)	
Hypothermia at baseline	324 (0.05%)	323 (0.05%)	1 (0.01%)	0.14	324 (0.05%)	0 (0%)	0.49
Direct transport	48505 (7.41%)	48111 (7.44%)	394 (5.02%)	<0.001	48464 (7.41%)	41 (4.42%)	<0.001

Data are presented as absolute numbers (n) and percentages (%)

Abbreviations: NSTEMI, non-ST segment elevation myocardial infarction; other — see Figure 1 and Table 1

with multivessel disease (MVD) were treated with PCI and IVUS in 2624 cases (0.85%), while OCT was implemented in 317 (0.1%). PCI within the LMCA with or without concomitant MVD was assisted by IVUS in 2480 patients (5.33%) and by OCT in 93 (0.2%).

Periprocedural complications

In patients undergoing CA with the use of OCT or IVUS, a higher dissection frequency was observed. In the case of IVUS itself, more strokes and puncture-site bleedings were noted, whereas fewer deaths and cardiac arrests were observed (Table 4). Myocardial infarctions, puncture-site bleedings, and coronary artery perforations were among the more frequently occurring complications during PCIs. This was found by analyzing PCI procedures in the IVUS group. The overall periprocedural complication rate was higher in the IVUS group compared to non-IVUS. Allergic reactions, cardiac arrests, and deaths were less frequently noted in the IVUS group. For PCI procedures with OCT use, fewer differences were observed in periprocedural complications between the OCT and non-OCT group, while cardiac arrest occurred less frequently in the OCT group compared to the non-OCT PCI group (Table 4).

Table 3. Vascular access and coronary angiography — IVUS/OCT during angiography and PCI

Selected indices	Total	Non-IVUS	IVUS	*P*-value	Non-OCT	OCT	*P*-value
IVUS/OCT during angiography							
	n = 1452135	n = 1440425	n = 11710		n = 1450664	n = 1471	
Vascular access							
Femoral	251269 (17.3%)	248939 (17.3%)	2330 (19.9%)	<0.001	250980 (17.3%)	289 (19.6%)	<0.005
Other	11852 (0.82%)	11753 (0.82%)	99 (0.85%)		11849 (0.82%)	3 (0.2%)	
Radial	1188368 (81.9%)	1179093 (81.9%)	9275 (79.2%)		1187189 (81.9%)	1179 (80.1%)	
Coronary angiography							
MVD	438077 (30.2%)	435862 (30.3%)	2215 (18.9%)		437831 (30.2%)	246 (16.7%)	
MVD + LMCA	105351 (7.26%)	101970 (7.08%)	3381 (28.9%)		105247 (7.26%)	104 (7.07%)	
No atherosclerosis	391333 (27%)	388841 (27%)	2492 (21.3%)	<0.001	390853 (27%)	480 (32.6%)	<0.001
Separate LMCA	4227 (0.29%)	3706 (0.26%)	521 (4.45%)		4214 (0.29%)	13 (0.88%)	
SVD	369889 (25.5%)	367044 (25.5%)	2845 (24.3%)		369392 (25.5%)	497 (33.8%)	
No significant stenoses	142304 (9.81%)	142055 (9.87%)	249 (2.13%)		142173 (9.81%)	131 (8.9%)	
Contrast amount, ml	100 (60, 150)	100 (60, 150)	130 (100, 200)	<0.001	100 (60, 150)	150 (100, 200)	<0.001
Radiation exposure, Gy	0.41 (0.21, 0.8)	0.41 (0.2, 0.8)	0.58 (0.31, 1.06)	<0.001	0.6 (0.33, 1.02)	0.4 (0.2, 0.8)	<0.001
IVUS/OCT during PCI							
	n = 838297	n = 822861	n = 15436		n = 836617	n = 1680	
Vascular access							
Femoral	181234 (21.6%)	176939 (21.5%)	4295 (27.8%)	<0.001	180722 (21.6%)	512 (30.5%)	<0.001
Other	7565 (0.9%)	7400 (0.9%)	165 (1.07%)		7562 (0.9%)	3 (0.18%)	
Radial	649337 (77.5%)	638346 (77.6%)	10991 (71.1%)		648173 (77.5%)	1164 (69.3%)	
TIMI before PCI							
0	159706 (19.9%)	158120 (20.1%)	1586 (10.4%)		159434 (19.9%)	272 (16.3%)	
1	107055 (13.3%)	105752 (13.4%)	1303 (8.6%)	<0.001	106951 (13.3%)	104 (6.24%)	<0.001
2	146593 (18.3%)	144446 (18.3%)	2147 (14.1%)		146407 (18.3%)	186 (11.2%)	
3	389261 (48.5%)	379119 (48.1%)	10142 (66.8%)		388156 (48.5%)	1105 (66.3%)	
Location of culprit lesion							
RCA	252917 (30.1%)	250921 (30.5%)	1996 (12.9%)	<0.001	252520 (30.1%)	397 (23.6%)	<0.001
LAD	305466 (36.4%)	296861 (36%)	8605 (55.6%)	<0.001	304569 (36.4%)	897 (53.2%)	<0.001
Cx	166055 (19.8%)	162485 (19.7%)	3570 (23.1%)	<0.001	165813 (19.8%)	242 (14.4%)	<0.001
LMCA	30046 (3.58%)	24516 (2.98%)	5530 (35.7%)	<0.001	29873 (3.57%)	173 (10.3%)	<0.001
Coronary angiography							
MVD	307543 (47%)	304919 (47.2%)	2624 (33.4%)		307226 (47%)	317 (34.2%)	
MVD + LMCA	44855 (6.86%)	42542 (6.58%)	2313 (29.5%)	<0.001	44767 (6.85%)	88 (9.48%)	<0.001
Separate LMCA	1609 (0.25%)	1442 (0.22%)	167 (2.13%)		1604 (0.25%)	5 (0.54%)	
SVD	299651 (45.8%)	296911 (45.9%)	2740 (34.9%)		299134 (45.8%)	517 (55.7%)	
Others	465 (0.07%)	460 (0.07%)	5 (0.07%)		464 (0.07%)	1 (0.11%)	
CTO	50361 (6%)	49524 (6.01%)	837 (5.41%)	<0.005	50216 (6%)	145 (8.61%)	<0.001
Bifurcation	82535 (9.84%)	78390 (9.52%)	4145 (26.8%)	<0.001	82271 (9.82%)	264 (15.7%)	<0.001
Aspiration thrombectomy	24698 (2.94%)	24440 (2.97%)	258 (1.67%)	<0.001	24661 (2.94%)	37 (2.2%)	0.06
Contrast amount, ml	150 (115, 200)	150 (110, 200)	190 (140, 250)	<0.001	150 (115, 200)	200 (150, 250)	<0.001
Radiation exposure, Gy	0.71 (0.39, 1.23)	0.71 (0.39, 1.23)	0.98 (0.55, 1.64)	<0.001	0.71 (0.39, 1,23)	0.93 (0.54, 1.54)	<0.001

Data are presented as medians and lower and upper quartiles for continuous variables and as absolute numbers (n) and percentages (%)

Abbreviations: CTO, chronic total occlusion; Cx, circumflex branch; LMCA, left main coronary artery; MVD, multi-vessel disease; NS, not significant; RCA, right coronary artery; SVD, single-vessel disease

Factors related to more frequent use of IVUS during CA and PCI

Generally considering CA, IVUS was more often implemented in younger patients, those with LMCA stenosis or a history of prior PCIs or chronic obstructive pulmonary disease (COPD), and in more recent years, patients exposed to more radiation and/or contrast (Supplementary material, *Table S1*).

IVUS use in patients treated with PCI was, in general, more frequent in younger patients with a history of prior myocardial infarction and PCI, PCIs complicated by coronary artery perforations, no-reflows and dissections, complex PCIs with the use of rotablation and bifurcated lesions, in cases using aspiration thrombectomy, PCI of the LMCA or left anterior descending coronary artery (LAD), use of a second antiplatelet drug, and more recent onset of PCI compared to previous cases. It was also connected with greater radiation exposure and contrast use. More comprehensive information is given in Supplementary material, *Table S2*. A more detailed presentation of factors associated with the increased use of IVUS in the group of patients undergoing CA and PCI is demonstrated in Supplementary material, *Table S1* and *Table S2*.

Table 4. Coronary angiography-related periprocedural complications

Selected indices	Total	Non-IVUS	IVUS	P-value	Non-OCT	OCT	P-value
IVUS/OCT during angiography							
	n = 1452135	n = 1440425	n = 11710		n = 1450664	n = 1471	
Stroke	219 (0.02%)	214 (0.01%)	5 (0.04%)	<0.05	218 (0.02%)	1 (0.07%)	0.22
Dissection	1001 (0.07%)	973 (0.07%)	28 (0.24%)	<0.001	998 (0.07%)	3 (0.2%)	<0.05
Puncture-site bleeding	495 (0.03%)	487 (0.03%)	8 (0.07%)	<0.05	495 (0.03%)	0 (0%)	0.49
Cardiac arrest	2778 (0.19%)	2766 (0.19%)	12 (0.1%)	<0.05	2778 (0.19%)	0 (0%)	0.09
Allergic reaction	385 (0.03%)	382 (0.03%)	3 (0.03%)	0.95	385 (0.03%)	0 (0%)	0.53
Death	3781 (0.26%)	3770 (0.26%)	11 (0.09%)	<0.001	3779 (0.26%)	2 (0.14%)	0.34
IVUS/OCT during PCI							
	n = 838297	n = 822861	n = 15436		n = 836617	n = 1680	
Cardiac arrest	3376 (0.4%)	3330 (0.4%)	46 (0.3%)	<0.05	3372 (0.4%)	4 (0.24%)	<0.001
Death	3422 (0.41%)	3397 (0.41%)	25 (0.16%)	<0.001	3419 (0.41%)	3 (0.18%)	0.13
Myocardial infarction	920 (0.11%)	871 (0.11%)	49 (0.32%)	<0.001	918 (0.11%)	2 (0.12%)	0.91
No-reflow	4821 (0.57%)	4727 (0.57%)	94 (0.61%)	0.58	4810 (0.57%)	11 (0.65%)	0.67
Puncture-site bleeding	827 (0.1%)	788 (0.1%)	39 (0.25%)	<0.001	826 (0.1%)	1 (0.06%)	0.6
Allergic reactions	779 (0.09%)	775 (0.09%)	4 (0.03%)	<0.005	778 (0.09%)	1 (0.06%)	0.65
CAP	1683 (0.2%)	1613 (0.2%)	70 (0.45%)	<0.001	1678 (0.2%)	5 (0.3%)	0.37
Any PCI complications or death	13946 (1.66%)	13665 (1.66%)	281 (1.82%)	0.12	13921 (1.66%)	25 (1.48%)	0.56
Any complications	16108 (1.92%)	15770 (1.91%)	338 (2.19%)	<0.05	16077 (1.92%)	31 (1.84%)	0.81

Data are presented as absolute numbers (n) and percentages (%)

Abbreviations: CAP, coronary artery perforation; other — see Figure 1 and Table 1

Factors related to more frequent use of OCT during CA and PCI

As in the IVUS group, OCT was generally more often used during CA in younger patients, in those with prior myocardial infarction, without significant stenoses, in males, and in patients with a more recent disease onset compared to previous cases (Supplementary material, *Table S3*).

Overall, younger age, prior PCI, rotablation, aspiration thrombectomy, PCI within chronic total occlusion, PCI within the LMCA, LAD, proximal right coronary artery (RCA) or saphenous vein graft (SvG), as well as more recent onset of PCI in comparison to previous ones, were among factors related to more frequent OCT implementation (Supplementary material, *Table S4*).

A more detailed presentation of factors concerning the increased use of OCT in the group of patients undergoing CA and PCI is shown in Supplementary material, *Tables S3* and *S4*.

DISCUSSION

The main findings of the presented study are that the frequency of OCT and IVUS use as auxiliary tools in the assessment of stenosis pathology and severity in CA as well as PCI treatment outcomes have recently significantly improved in Poland. However, the frequency of IVUS and OCT application during CA and/or PCI is still low compared to other countries, in which their prevalence and frequency of use are close to the optimal and actual needs [14]. Based on the data from the US National Readmission Database, between 2010 and 2019, it was reported, for instance, that the rate of OCT-guided PCI was almost 0.6% and IVUS-guided PCI nearly 10% of all procedures, which is much higher than in our cohort of patients although our analysis came from a later period [14]. Similarly, in another trial conducted in the US on a group of over 3 million patients, as early as 2016, a higher frequency of IVUS- and OCT-guided PCI was found compared to Poland; the IVUS-guided PCI amounted to 6.6% and OCT-guided PCI to 0.3% [15]. In this study, very high variability between hospitals was demonstrated in terms of the frequency of applying intravascular imaging techniques, which ranged between <5 and >15%. Analyzing selected groups of patients in the current study, the frequency of applying intravascular imaging techniques in the case of PCI within the LMCA was calculated at just over 5%, whereas several international authorities recommend using intravascular imaging techniques in all such cases [16, 17]. For example, Swedish data indicate that 25% of patients had IVUS for LCA PCI and that long-term outcomes were significantly better with IVUS [18]. A much higher frequency of using intravascular imaging in the treatment of bifurcation lesions located in LMCA (80%) or non-LMCA patients (46%), in comparison to that observed by our team, was presented in a global survey published by Briliakis et al. [19].

Nonetheless, several mechanisms are currently being introduced to increase the frequency of applying intravascular imaging methods. These include cost reimbursement. This was initially introduced for IVUS use in selected treatment groups (LMCA and proximal LAD PCI), while in the latter period of OCT application, the incidence does not seem to be optimal despite the apparent increase. Currently, in Poland, IVUS and OCT are reimbursed in the case of assessing (1) the severity of LMCA stenosis; (2) significance of stenosis of the proximal segment of the

LAD (as part of qualification for revascularization); (3) significance of stenoses in patients with multi-vessel disease; and (4) controlling the result of LMCA angioplasty. This is done to evaluate the mechanism of stenosis and select the optimal treatment method in the event of stent failure (suspected poor outcome of stent implantation, stent thrombosis, stent restenosis), to determine the cause of myocardial infarction in the case of inconclusive coronary angiography, and in the diagnosis of vasculopathy after heart transplantation.

Other factors aimed at increasing the use of intravascular imaging methods include raising awareness of their benefits in the community of operators and interventional cardiologists training to become first operators. This is achieved by free courses, often financed by the Association of Cardiovascular Interventions (AISN), led by proctors recognized by interventional cardiologists in Europe and around the world.

Another major finding of the current study is the analysis of factors determining the more or less frequent use of intravascular imaging techniques when performing CA or PCI. Most factors defining the more frequent application of IVUS during CA or PCI seem to be obvious. They include, among others, patient age, year of surgery, location of culprit lesion, complexity of the procedure, significant atherosclerotic lesions in the coronary arteries, presence of comorbidities, prior coronary revascularizations (either surgical or percutaneous), the patient's clinical condition before the procedure, clinical manifestation of ischemic heart disease, presence of periprocedural complications, complexity of the procedure in terms of bifurcation occurrence or use of additional devices, e.g. rotablation to modify calcifications in the coronary arteries.

In the present study, it has been observed that the use of OCT or IVUS, regardless of percutaneous intervention type (CA or PCI), is associated with greater exposure to radiation and use of contrast. At first, when interpreting these test results, we assumed that the methods of intravascular imaging are associated with prolonged duration of the procedure or the amount of the administered contrast media — however, nothing could be further from the truth. Currently, the common trend is reducing the administered contrast during CA and PCI procedures [20]. In our opinion, the greater amount of contrast and exposure to radiation when using IVUS or OCT currently in Poland is rather related to increasingly frequent use of these imaging methods in more and more complex procedures. This seems to result from increasing access to and awareness of the usefullness of using these imaging methods [2]. Despite such observations in the previous period, the dominant view is that both of these endovascular diagnostic methods are intended for selected types of procedures and determined by their localization, e.g. the preferred method for imaging large vessels, such as the LMCA, is IVUS and not OCT [21, 22]. More frequent use of intravascular imaging methods in younger patients seems to be primarily associated with the fact that, in older patients, more advanced atherosclerotic lesions (including a more frequent occurrence of massive calcifications) by definition limit or remove the value of these tests due to the inability to cross over to the distal parts of the culprit artery with probes [23]. Nowadays, the use of endovascular imaging techniques in patients undergoing CTO PCI procedures is being increasingly discussed [24]. However, in this case, these methods mainly aim to assess the diameter of the vessel before stenting, after the guide wire has crossed the occlusion and reached the distal part of the target artery. IVUS use for proper selection of stent size in CTO PCI has been described in more than 30% of cases in recently published reports [25].

More frequent application of OCT in CA patients without significant stenosis, compared to those with MVD with or without LMCA disease, is certainly largely related to assessing the etiology of myocardial infarction with non-obstructive coronary arteries or ischemia with no obstructive arteries. For example, the presence of thin cup vulnerable plaques may cause threatening coronary incidents in the near future [26]. Also, intravascular imaging diagnostics of myocardial infarction without significant stenoses in the coronary arteries have gained popularity in recent years [27]. From the very beginning of introducing intravascular imaging techniques, their application in diagnosis of coronary complications related to percutaneous interventions of all kinds, as well as spontaneous coronary artery dissections, has been elaborated [28,29]. More frequent use of intravascular imaging techniques in patients with PCI and CA complications was reflected in the data in our study.

Furthermore, the results of previously published studies on IVUS- and OCT-guided PCI have shown a higher frequency of their use in men and younger patients compared to PCI without intravascular imaging [7]. We have obtained similar results in our analysis.

CONCLUSIONS

The frequency of IVUS and OCT use has significantly increased in recent years, which is mainly due to changes in the reimbursement policy. However, there is still much improvement needed to achieve a satisfactory level of usage.

Supplementary material

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

Article information

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