Original article

Coronary Angiography Optimized by Optical Coherence Tomography in Patients with Coronary Artery Disease

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Abstract

Aim: This study aimed to examine whether there is a difference in the clinical findings of lesions obtained by coronary angiography and OCT, and to examine the association of OCT findings in decision-making regarding additional optimization of PCI.

Respondents and methods: The research was conducted as a cross-sectional study using historical data. The study included patients who underwent OCT at the Department of Cardiovascular Diseases of the Osijek Clinical Hospital Center from 2021 to 2023.

Results: The research involved 62 patients, with a median age of 67. The most common location of the lesion was the LAD, in 52 (84%) cases. Thirty-nine respondents (63%) required additional optimization. Three (5%) patients were recommended for cardiosurgical consultation based on OCT. There was a significant increase in the length of the LAD (Wilcoxon test, $P < 0.001$), LCx (Wilcoxon test, $P < 0.001$), and RCA (Wilcoxon test, $P = 0.006$) as measured by OCT compared to coronary angiography. Regarding proximal width, the values for the LAD (Wilcoxon test, $P < 0.001$) and RCA (Wilcoxon test, $P = 0.03$) were significantly higher.

Conclusion: The research demonstrated the important role of OCT in clinical practice, particularly in the detailed assessment of coronary artery lesions, management of PCI, and assessment of additional optimization in patients with coronary disease.

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Introduction

Coronary artery disease is a chronic progressive condition characterized by an inflammatory process in the arterial wall and the formation of atherosclerotic plaque in the walls of coronary arteries. Invasive diagnostic methods used to confirm the diagnosis and evaluate coronary disease include coronary angiography, near-infrared spectroscopy (NIRS), and newer intravascular imaging techniques such as intravascular ultrasound (IVUS) and optical coherence tomography (OCT) (1). Coronary angiography is currently the gold standard for diagnosing coronary artery disease and guiding percutaneous coronary interventions (PCI). However, angiography provides a two-dimensional view of the lumen of blood vessels, which has certain limitations in assessing vessel wall pathology and lumen stenosis (2).

OCT is an intravascular imaging technique that allows visualization of the structure of coronary artery walls and plaque composition (3). In coronary angiography, OCT has Class 1A recommendations for certain applications, particularly in complex lesions and acute coronary syndromes, including cases involving the left main stem, true bifurcations, and elongated lesions (4). OCT images can reveal almost histological details and changes in the structure of the coronary artery wall (Figure 1.) (5).

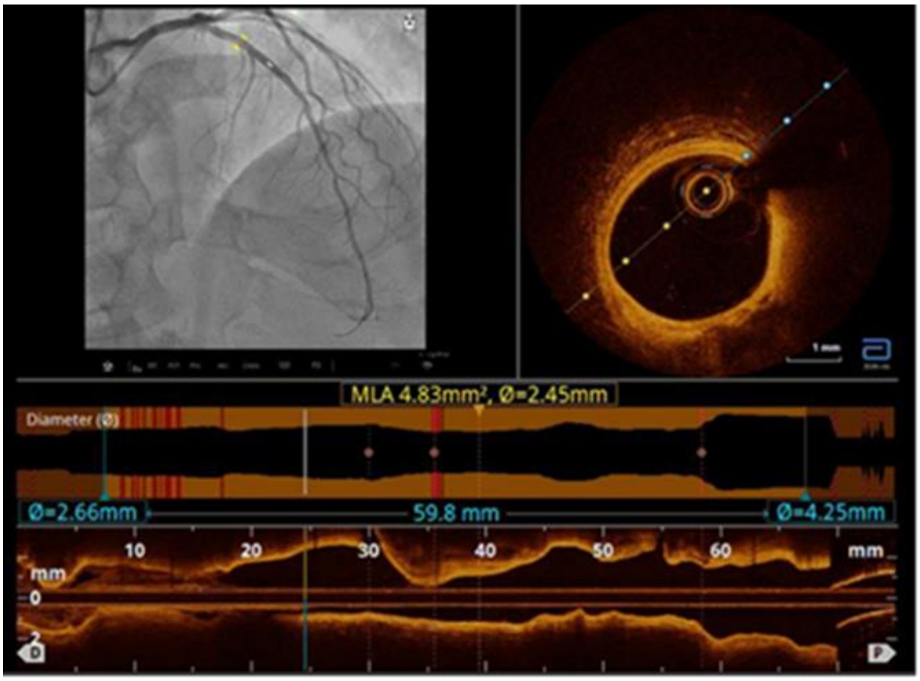

Figure 1. OCT Imaging Display.The image in the upper right shows a cross-section of the artery at the corresponding location. In the upper left corner of the image, there is a representation of the coronary angiography of the same artery. The lower part of the image presents a longitudinal section of the coronary artery (photographed by the author).

In clinical practice, OCT is useful for assessing lesion severity, plaque instability, optimizing PCI, and analyzing inadequately positioned stents (6).

Recent studies confirm the advantages of intracoronary imaging over coronary angiography during PCI (7). OCT, with its high-resolution capabilities, accurately identifies features of plaque instability. By recognizing these plaques, treatment strategies can be implemented to reduce potential future adverse effects (8). Detailed characterization of lesion morphology and accurate measurement of vessel size by OCT can improve procedural outcomes, guide interventional strategies, and help detect suboptimally positioned stents that may not be identified through coronary angiography (9). The most common reasons for additional optimization after OCT imaging include stent malapposition, inadequate stent expansion, and dissection at the stent edge.

Patients and Methods

This research recived the approval from the appropriate ethics committee. The study was structured as a cross-sectional study using historical dana. It included patients who underwent coronary angiography optimized with OCT at the Department of Cardiovascular Diseases, Clinical Hospital Center Osijek, from 2021 to 2023. Data collection was conducted under the supervision and permission of the mentor, using data stored in the hospital information system. The following data were collected: general information about the participant (age, gender), cardiovascular risk factors (arterial hypertension, dyslipidemia, diabetes mellitus, atrial fibrillation, cardiomyopathy, chronic kidney insufficiency, history of acute myocardial infarction, prior cardiac surgery, valvular disease, smoking). Pharmacological therapy (acetylsalicylic acid, clopidogrel, prasugrel, ticagrelor, warfarin, direct oral anticoagulants, statins, ezetimibe, beta-blockers, calcium channel blockers, renin-angiotensin system medications, amiodarone), echocardiographic characteristics, indication for coronary angiography, characteristics of the performed coronary angiography, characteristics of optical coherence tomography and recommendation for cardiac surgical consultation. Categorical data are presented as absolute and relative frequencies. Differences in categorical variables were tested using Fisher's exact test. The normality of distribution for numerical variables was assessed using the Shapiro-Wilk test. Numerical data are described by the median and interquartile range. Differences in numerical variables between two measurements were analyzed using the Wilcoxon test (with the reported Hodges-Lehmann median difference and 95% confidence interval for the difference). All p-values are two-tailed. The significance level was set at alpha (α) = 0.05. Statistical analysis was performed using MedCalc® Statistical Software version 22.018 (MedCalc Software Ltd, Ostend, Belgium; https://www.medcalc.org; 2024).

Results

The study included 62 participants, 55 (89%) male and 7 (11%) female, with a median age of 67 (range 40-87 years). Among the risk factors, 74% participants had arterial hypertension, 53% had dyslipidemia, and 63% participants had previously undergone PCI. The most common therapies were acetylsalicylic acid (ASA) or beta-blockers. (Table 1). Thirty-six participants (58%) had an ejection fraction greater than 50%, while eight (13%) had an ejection fraction less than 40%. Impaired contractility was observed in 42 participants (68%), and the highest number of participans had Stage I diastolic dysfunction (52%).

The indication for coronary angiography was chronic coronary syndrome in 42 participants (68%), while 13 (8%) had an ST-segment elevation myocardial infarction. In 49 cases (79%), access was via the right radial artery. Multivessel disease was present in 30 cases (48%); triple-vessel disease in 7 (11%), and dual-vessel disease in 23 (37%).

Multiple lesions were found in 9 participants (14%), while 7 (11%) had one vessel with multiple lesions. In 55 cases (89%), there was a single vessel with a single lesion.

The most common lesion location for OCT was the left anterior descending coronary artery (LAD) in 52 cases (84%).

The longest lesion was recorded in the LAD, ranging from 19.8 to 30 mm (median 25 mm). The largest proximal width was found in the LAD, ranging from 2.6 to 3.5 mm (median 3 mm). The highest percentage of stenosis was recorded in the LCx, ranging from 47.5 to 82.5% (median 75%).

Table 1. Distribution of participants according to risk factors and pharmacotherapy

	Number of patients (%)
RISK FACTORS	
Hypertension	46 (74)
Dyslipidemia	33 (53)
Diabetes Mellitus	15 (24)
Atrial fibrillation	12 (19)
Cardiomyopathy	23 (37)
Chronic kidney disease (CKD)	4 (6)
History of AMI	31 (50)
Underwent PCI	39 (63)
Underwent CABG	1 (2)
Valvular heart disease	16 (26)
Smoker	8 (13)
Pharmacotherapy	
Acetylsalicylis acid	58 (93)
Clopidogrel	7 (11)
Prasugrel	12 (19)
Ticagrelor	34 (55)
Warfarin	1 (2)
DOAC´s	11 (18)
Statins	61 (98)
Ezetimibe	6 (10)
Beta-blockers	58 (93)
Calcium channel blockers	24 (39)
ACE inhibitors/ ARB	54 (87)
ARNI	1 (2)
Moxonidine	3 (5)
Amiodarone	1 (2)

In 6 participants (10%), the lesion was located ostially, and in 6 (10%), in the bifurcation area. OCT was performed on the LAD in 45 participants (73%), while the fewest OCT procedures were conducted on the left main coronary artery (LMCA). According to lesion morphology, 29 participants (46%) had calcifications, and 19 (30%) had a lipid plaque. The length of the LAD lesion measured by OCT ranged from 27.6 to 41.1 mm (median 33.1 mm). The LCx lesion ranged from 24 to 34.4 mm (median 27.3 mm). The minimal lumen area (MLA) of the LAD ranged from 1.4 to 3.5 mm^2 (median 2.4 mm^2). The proximal width of the LAD ranges from 3 to 3.7 mm (median 3.44 mm). The proximal width of the LCx ranges from 2.4 to 3.9 mm (median 3.46 mm). Malapposition of the LAD was observed in 23 participants (37%), LCx in 6 (10%), and RCA in 4 (6%). Adequate expansion of the LAD was seen in 10 participants (16%), inadequate expansion of the LCx in 2 (3%), and RCA in 3 (5%) (Table 2).

Table 2. Distribution of participants according to OCT results after PCI

	Number of patients (%)
Disection of the LAD	4 (6)
Apposition of the LAD	
good	13 (21)
malapposition	23 (37)
Apposition of the Lcx	
good	3 (5)
malapposition	6 (10)
Apposition of the RCA	
good	3 (5)
malapposition	4 (6)
Expansion of the LAD	
adequate	26 (42)
inadequate	10 (16)
Expansion of the LCx	
adequate	7 (11)
inadequate	2 (3)
Expansion of the RCA	
adequate	4 (6)
inadequate	3 (5)

The MSA for the LAD ranges from 5.4 to 7.7 mm^2 (median 6.81 mm^2) and for the LCx from 4.2 to 8.1 mm^2 (median 5.65 mm^2). Thirty-nine participants (63%) required additional optimization. Stent malapposition was noted in 33 participants (53%) (Table 3).

Table 3. Distribution of participants according to the reason for additional optimization

	Number of patients (%)
Additional optimization	39 (63)
Dilation	40 (64)
dissection at the edge of the stent	4 (6)
stent malapposition	33 (53)
inadequate stent expansion	15 (24)
restenosis in the stent	1 (2)
Stent placement	3 (5)
OMT	10 (16)

Three patients (5%) were referred for cardiothoracic surgery consult. There was a significant increase in the length of the LAD (Wilcoxon test, P < 0.001), LCx (Wilcoxon test, P < 0.001), and RCA (Wilcoxon test, P = 0.006) measured by OCT compared to coronary angiography. Proximal width values were significantly higher values for the LAD (Wilcoxon test, P < 0.001) and RCA (Wilcoxon test, P = 0.03), with no significant differences for the LMCA and LCx (Table 4).

Table 4. Differences in length and proximal width measured by coronary angiography and OCT

	Median (interquartile range)		Difference (95% confidence interval)	*P**
	Coronary angiography	OCT		
Lenght (mm)				
LMCA	18,5 (14 – 23)	15,2 (14,4 – 16,0)	-3,3 (-)	-
LAD	25 (19,8 – 30)	33,1 (27,6 – 40,8)	7,4 (4,8 – 11,2)	**<0,001**
LCx	20 (19 – 23,5)	27,3 (24,2 – 33,5)	6,8 (4,2 – 11,7)	**<0,001**
RCA	18 (14,5 – 20,8)	28,1 (19,8 – 29,9)	6,6 (2,4 – 12,8)	**0,006**
Proximal width (mm)				
LMCA	5,0 (4 – 6)	4,2 (4,2 – 4,3)	-0,79 (-)	-
LAD	3 (2,7 – 3,5)	3,4 (3,0 – 3,7)	0,33 (0,23 – 0,5)	**<0,001**
LCx	3 (2,5 – 3,5)	3,5 (2,5 – 3,9)	0,18 (-0,25 – 1,1)	0,47
RCA	2,7 (2,5 – 3,6)	2,9 (2,8 – 4,0)	0,31 (0,05 – 0,54)	**0,03**

*Wilcoxon test

Significantly higher values were observed for the LAD (Wilcoxon test, P < 0.001), LCx (Wilcoxon test, P = 0.004), and RCA (Wilcoxon test, P = 0.03) for minimum stent area (MSA) compared to minimum lumen diameter (MLD) (Table 5). Diastolic dysfunction was present in 88% of participants, with 57% classified as grade I. There was no significant difference regarding the need for additional optimization (Table 6).

Table 5. Differences in LMCA, LAD, LCx, and RCA regarding MLA and MSA

	Median (interquartile range)		Difference (95% confidence interval)	P*
	MLA	MSA		
LMCA	2,6 (n = 1)	12,5 (n = 1)	-	-
LAD	1,9 (1,4 – 2,9)	6,8 (5,4 – 7,6)	4,4 (3,7 – 5,1)	**<0,001**
LCx	2,1 (1,6 – 2,8)	5,7 (4,2 – 7,6)	3,9 (2,6 – 5,6)	**0,004**
RCA	2,6 (2 – 3,6)	5,7 (3,8 – 8,6)	3,4 (0,32 – 7,4)	**0,03**

*Wilcoxon test

Table 6. Distribution of participants according to diastolic dysfunction in relation to additional optimization

	Number (%) of patients with additional optimization.			P^*
	No	Yes	Total	
Diastolic dysfunction	17 (81)	35 (92)	52 (88)	0,23
Degree of dysfunction				
Without	4 (20)	3 (8)	7 (13)	0,59
I degree	10 (50)	22 (61)	32 (57)	
II degree	6 (30)	10 (28)	16 (28)	
III degree	0	1 (3)	1 (2)	

* Fisher's exact test

Discussion

The prevalence of coronary artery disease increases with age. According to NHANES (National Health and Nutrition Examination Survey) data, the prevalence is higher in men than in women. Risk factors such as arterial hypertension, dyslipidemia, diabetes, renal dysfunction, and smoking are often present in older patients (10). In a study of 418 patients undergoing coronary angiography with OCT, the median age was 65, with significant risk factors: arterial hypertension in 72%, dyslipidemia in 76%, and diabetes in 37% (11). In this study, 63 patients were analyzed, with a median age of 67 years; 74% had arterial hypertension, 53% had dyslipidemia, and 24% had diabetes.

The first line of treatment for chronic coronary syndrome is pharmacological therapy, except in cases involving lesions on the LMCA or severe left ventricular dysfunction, where myocardial revascularization improves outcomes. If symptoms persist despite therapy, ori f pharmacological treatment is not tolerated, current guidelines support non-invasive or invasive diagnostic procedures to identify ischemic lesions and refer patients for revascularization (12). In the ILUMEN I study, the indication for coronary angiography with OCT was chronic coronary syndrome in 63% of patients (13). In this study, the most common indication was also chronic coronary syndrome, present in 68% of patients.

In the Light Lab study, the most common vascular access method was via the the right radial artery (62%). Multi-vessel disease was present in 12% of cases; multiple lesions in 0.5%, a single vessel with multiple lesions in 13%, and a single vessel with one lesion in 76% (14). In this study, 79% had right radial access, and 48% had multivessel disease.

Multiple lesions were present in 14% of patients, with 11% having one vessel affected by multiple lesions, and 89% with a single vessel with one lesion.

Complex coronary lesions pose challenges during PCI guided by coronary angiography. These include bifurcation lesions, ostial lesions, chronic total occlusions (CTO), left main coronary artery (LMCA) lesions, and in-stent restenosis (ISR). OCT has proven effective in guiding PCI for such complex lesions (15). Bifurcation lesions are the most common complex coronary lesions, reported in up to 20% of all PCIs. OCT enables accurate determination of the main branch and side branch positions, crucial for procedural strategy (16). CTOs are present in about 20% of patients undergoing coronary angiography; OCT is used to confirm correct guidewire placement (17, 18). For ISR, optimizing treatment and considering re-implantation is critical. Inadequate expansion of the old stent, the amount of calcium, and the presence of multiple layers of older stents are significant determinants of the new stent's inadequate expansion. Inadequate expansion of the new stent is associated with unfavorable long-term outcomes, making optimization as vital as de novo stent implantation. In one study, ISR (17%), bifurcation lesions (9%), and CTO (3%) were present in a minority of all lesions (19). In this study, 10% of patients had ostial lesions, and 10% had lesions located in bifurcation areas. Additionally, 14% of patients had ISR.

Based on pathological and angiographic data, atherosclerotic changes are more common in the left coronary artery, especially in the LAD branch (20). In the Light Lab study, 50% of lesions were in the LAD, 29% in the RCA, and 15% in the LCx (21). In this study, the most common lesion location was the LAD (84%), with lesions in the LCx in 32% and RCA in 39%.

Calcified lesions are associated with advanced atherosclerosis and a higher frequency of inadequate stent expansion (22). Studies like HORIZONS-AMI and ACUITY have shown that calcified lesions are linked to ISR within one year (23). In a study utilizing OCT, calcification was the most common morphological finding (56%) (24). In this study, 46% had calcification.

The results indicate a significant increase in lesion length in the LAD, LCx, and RCA measured by OCT compared to coronary angiography. Proximal diameter values for the LAD and RCA were also significantly higher.

In the ILUMEN III study, there was no significant difference in lesion length and proximal diameter measured by OCT versus coronary angiography (25).

These findings can be explained as follows: the most proximal and distal segments determine reference diameter values for lesion length on coronary angiography, which are visually estimated. OCT allows precise visualization of plaque location and type, leading to more accurate lesion length measurement. According to current protocols, it is recommended to find the largest lumen using OCT to avoid high-risk zones for thrombosis and restenosis, which can result in greater lesion lenght and larger proximal diameter measurments compared to coronary angiography.

There were significantly higher values for LAD, LCx and RCA in terms of minimum stent area (MSA) compared to minimum lumen area (MLA). MLA represents the vessel's minimal lumen area before PCI; the goal is to achieve adequate stent expansion and the target MSA. MSA denotes the minimal lumen area after atent deployment. Studies confirm that MSA is the most critical indicator of thrombosis and restenosis risk (26). The COCOA study confirmed that OCT-guided PCI results in a larger MSA compared to coronary angiography-guided PCI (27). The leading causes of acute stent thrombosis are inadequate expansion and stent malposition. The PESTO study confirmed that these factors can mostly be identified by OCT, particularly in proximal segments, such as the LMCA or proximal LAD. The incidence of stent malposition is higher after interventions on complex lesions like bifurcation lesions. Therefore, intravascular imaging is recommended for complex procedures (28). Stent malposition is more common after interventions on complex lesions like birfucations, so intravascular imaging is recommended for complex procedures.

Stent malposition, inadequate stent expansion, thrombus protrusion, edge dissection, and residual plaque at the stent margins detected by OCT are known risk indicators for adverse cardiovascular events (29). In the ILUMEN I study, OCT after PCI identified stent malposition in 15%, inadequate expansion in 8%, and edge dissection in 3%. Achieving adequate stent expansion is a key objective of PCI (30). In this study, LAD malposition was observed in 37%, LCx in 10%, and RCA in 6%. Inadequate LAD expansion was present in 16%, LCx in 3% and RCA in 5%. When dissection, malposition, or inadequate stent expansion are detected by OCT, additional optimization is required. Malposition and inadequate expansion necessitate further balloon dilation, while stent dissection may require additional stenting (31). In the CLI-OPCI study, 35% of patients needed further optimization after OCT imaging, with 23% undergoing dilation (32). In this study, 63% required additional optimization, with 64% receiving dilation.

Triple vessel disease, complex double vessel disease, significant LMCA stenosis, and LAD stenosis >50% or LCx stenosis >70% are key anatomical indications for CABG. The SYNTAX score assesses coronary artery disease complexity and guide revascularization decisions (PCI vs. CABG) (33). In this study, OCT was used for three patients to evaluate lesion significance, leading to a surgical consult, highlighting OCT's role in assessing lesions for CABG.

Diastolic function is often the first cardiac function impaired in coronary artery disease. Subclinical atherosclerosis may affect diastolic function without significantly impacting systolic function. One study indicated a link between diastolic dysfunction and increased calcification progression (34). This study compared diastolic dysfunction with additional optimization aiming to determine whether patients with diastolic dysfunction require additional optimization more frequently. The results showed no significant differences regarding the need for additional optimization.

It is important to nothe the study's limitations: the sample size is small, it is a cross-sectional study, and data were collected from a single center. These factors may impact the generalizability of the findings.

Conclusion

Based on the conducted research and the obtained results, the following conclusions can be drawn:

- The clinical findings of lesion length and proximal width of the blood vessel obtained via OCT significantly from those obtained through coronary angiography.
- OCT significantly influences decision-making regarding additional optimization of PCI.
- OCT is important for further assessment of lesion significance in multivessel coronary disease intended for surgical treatment
- A significant association between diastolic dysfunction and a higher incidence of inadequate PCI requiring additional intervention based on OCT was not confirmed.

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Koronarografija optimizirana optičkom koherentnom tomografijom u pacijenata s koronarnom bolesti

Sažetak

Cilj: Ciljevi ovoga istraživanja bili su ispitati postoji li razlika u kliničkom nalazu lezije dobivene koronarografijom i OCT-om i ispitati povezanost nalaza OCT-a prilikom odlučivanja o dodatnoj optimizaciji PCI-a.

Ispitanici i metode: Istraživanje je provedeno kao presječna studija s povijesnim podacima. Uključeni su pacijenti podvrgnuti OCT-u na Zavodu za bolesti srca i krvnih žila KBC-a Osijek od 2021. do 2023. godine.

Rezultati: Istraživanje je uključilo 62 pacijenta, medijana dobi od 67 godina. Najčešća lokacija lezije bio je LAD, u 52 (84%) slučaja, dok je 39 pacijenata (63%) trebalo dodatno optimizaciju. Tri (5%) pacijenta dobila su preporuku za kardiokirurški konzilij na temelju OCT-a. Zabilježeno je značajno produljenje LAD-a (Wilcoxon test, $P < 0.001$), LCx (Wilcoxon test, $P < 0.001$), i RCA (Wilcoxon test, $P = 0.006$) mjereno OCT-om u usporedbi s koronarografijom. S obzirom na prosječnu širinu, vrijednosti LAD-a (Wilcoxon test, $P < 0.001$) i RCA (Wilcoxon test, $P = 0.03$) bile su značajno više.

Zaključak: Istraživanje je pokazalo važnost OCT-a u kliničkoj praksi, posebice u detaljnoj procjeni lezija na koronarnim arterijama, upravljanju PCI-om, i procjenu dodatne optimizacije kod pacijenata s koronarnom bolesti.