Intravascular ultrasound-guided percutaneous coronary intervention for patients with unprotected left main coronary artery lesions

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Background   In percutaneous coronary intervention (PCI) procedures for patients with unprotected left main coronary artery (ULMCA) lesions, intravascular ultrasonography (IVUS) guidance has shown potential for enhancing clinical outcomes. However, studies confirming its superiority to conventional angiographic-guided PCI remain few. This study aimed to assess if IVUS-guided PCI for patients with unprotected LMCA stenosis improves clinical outcomes compared to angiographic-guided PCI.

Methods   This randomized clinical study enrolled 181 patients with ULMCA lesions scheduled for drug-eluting stent implantation. Patients were split into 90 in the IVUS-guided group and 91 in the conventional group. Procedural characteristics, clinical outcomes, and the incidence of major adverse cardiovascular event (MACE) were evaluated for all patients. The risk reduction associated with IVUS-guided PCI was evaluated using a multivariate Cox regression analysis.

Results   Patients who underwent IVUS demonstrated significantly higher pre-dilatation before stenting (88.9% vs. 72.5%, $P = 0.005$), post-dilatation balloon diameter (4.46 ± 0.48 vs. 4.21 ± 0.49, $P < 0.001$), stent diameter (3.9 ± 0.4 vs. 3.7 ± 0.3, $P = 0.002$), and pressure for post dilatation (18 ± 3 vs. 16 ± 2, $P = 0.001$). Regarding 12-month outcomes, patients who underwent IVUS demonstrated significantly lower MACE (3.3% vs. 18.7%, $P < 0.001$) than those who underwent the conventional method. Multivariate Cox regression analysis revealed that IVUS was related to 84.4% risk reduction of 1-year MACE (HR = 0.156, 95% CI = 0.044–0.556, $P = 0.004$).

Conclusion   Compared to angiographic-guided PCI, IVUS-guided PCI resulted in improved clinical results and a markedly reduced risk of MACE in patients with ULMCA lesions. *Coron Artery Dis* XXX: XXXX–XXXX Copyright © 2024 Wolters Kluwer Health, Inc. All rights reserved.

Introduction

Coronary artery disease (CAD) is a significant global health concern, especially when the left main coronary artery (LMCA) is affected. Interventional cardiologists face significant challenges when treating unprotected LMCA lesions, as they must make key revascularization technique decisions [1].

Percutaneous coronary intervention (PCI) has revolutionized CAD treatment. Patients with unprotected LMCA lesions are especially challenging to treat due to the vital role of LMCA in supplying blood to the major areas of the heart [2].

Conventional angiographic guidance has been the standard for determining lesion severity and performing PCI operations. However, modern methods such as intravascular ultrasonography (IVUS) provide detailed, real-time imaging of coronary arteries, allowing precise evaluation of lesion features, vessel size, and plaque burden [3].

IVUS has improved the precision of lesion diagnosis and optimized stent deployment in complicated coronary lesions by simplifying lesion evaluation and ensuring optimal stent expansion during the percutaneous intervention. In left main (LM) PCI employing a drug-eluting stent (DES), the utilization of IVUS may improve its effectiveness [4,5].

Numerous observational studies demonstrated that MACE-free survival at 2 to 3 years was better in the IVUS group, as was stent thrombosis (ST) incidence [6–8].

Patients with ULMCA lesions experience many vascular diseases and are susceptible to various risk factors. However, there is a lack of randomized controlled research demonstrating IVUS therapeutic advantages for this patient population [9,10]. Consequently, this trial investigated whether IVUS-guided PCI improves clinical outcomes for patients with ULMCA stenosis compared to angiographic-guided PCI.

Methods

Study design

This randomized clinical trial was performed at Benha University Hospital and the National Heart Institute on 181 patients with ULMCA lesions identified by visual examination as at least 50% LMCA stenosis.

Inclusion criteria were patients with ULMCA lesions aged between 18 and 75 years and planned for receiving implantation. The exclusion criteria included patients with the following conditions: (1) Those with acute myocardial infarction (AMI) within the past 24 h; (2) individuals in a state of cardiogenic shock; (3) patients with bleeding high-risk factors; (4) Individuals with hepatic or renal failure or carcinoma; and (5) those with severe mitral or valve disease requiring surgery in the next six months.

Of note, the term 'unprotected' LM total occlusion in the study refers to LMCA lesions without a bypass graft. Total occlusions are 'unprotected' unless they have a prior surgical bypass, though they may be physiologically 'protected' by collateral circulation from the RCA. This distinction is key for the study's inclusion criteria and patient population characteristics.

Methods

Patients were randomized in a 1:1 fashion using the closed envelope method into two main groups: Group 1: underwent ULMCA PCI under IVUS guidance and was labeled as the IVUS-guided group. Group 2: underwent ULMCA PCI without IVUS assessment and was designated the control group.

The study was approved by the Ethics Committee at Benha Faculty of Medicine. All patients who participated gave their informed written permission.

All patients' demographic, clinical, and laboratory data were collected, including age, gender, and cardiovascular risk factors, such as hypertension, diabetes, cigarette smoking, lipid abnormalities, and peripheral arterial disease. In addition, ejection fraction was assessed using Simpson's conventional echocardiographic method, and electrocardiography was done using 12-lead ECG to evaluate the ischemic and arrhythmic changes. Also, serum creatinine was evaluated.

Angiographic characteristics were assessed for all patients. All interventional operations were carried out following the existing standards by five experienced main interventionists. These interventionists selected two-stent procedures for patients with LM bifurcation lesions in the distal LM segment. Using intra-aortic balloon pump, glycoprotein IIb/IIIa inhibitors, specific types of DES, and predilation were left to their discretion. Postdilation with noncompliant balloons (≥18 atm pressure) was advised for all stents, particularly those with inadequate expansion or stent malapposition verified by IVUS and angiography. Successful PCI was defined as achieving thrombolysis in myocardial infarction (TIMI grade 3 flow) and less than 10% residual stenosis.

Before PCI procedures, all patients received 100 mg aspirin and P2Y12 inhibitors (300 mg clopidogrel or 180 mg ticagrelor). For surgical anticoagulation, unfractionated heparin was administered. Post-PCI, patients were prescribed lifelong aspirin (100 mg/day) and P2Y12 inhibitors (clopidogrel 75 mg/day or ticagrelor 90 mg twice/day) for at least 12 months. Additional use of aldosterone antagonists or angiotensin-converting enzyme inhibitors, statins, and beta-blockers was consistent with current secondary prevention recommendations.

Methodology of IVUS

IVUS requires the placement of the catheter at a distance of at least 10 mm beyond the distal end of the lesion. The IVUS catheter was automatically retracted until it reached the LMCA ostium at a 0.5 mm/s rate. During this procedure, pictures were recorded utilizing imaging equipment outfitted with a 40 MHz mechanical transducer manufactured by Boston Scientific or Volcano Therapeutics, USA. Minimal lumen diameter and area, lipid plaque load, and reference lumen area were measured to assess relevant lesions and guide the decision for stent installation.

IVUS was done after PCI to assess the optimum performance of the implanted stents. A successful PCI treatment guided by IVUS was described as obtaining a stent lumen cross-sectional area of at least $6.9 \, mm^2$, assuring entire stent apposition and expansion, and observing no dissection [9].

Study endpoints

The primary outcome of the study was to assess the MACEs occurrence through a follow-up period of 1 year. MACEs were assessed in a hierarchical fashion to avoid double-counting. MACEs encompassed myocardial infarction, target vessel revascularization (TVR), and cardiac death. As for safety assessment, the focus was on evaluating ST risk. In cases where a clear non-cardiac cause was ruled out, death resulting from cardiac factors was considered. TVR referred to any subsequent revascularization procedure performed on the treated lesion or vessel, irrespective of whether it involved PCI or coronary artery bypass grafting (CABG). ST was defined and classified based on the timing of occurrence according to the Academic Research Consortium: early (within 0−30 days following PCI), late (between 31 and 360 days), and very late (> 360 days) [9].

Clinical follow-up was done at 1, 6, and 12 months. Coronary angiography was repeated 1 year later or sooner depending on clinical indications. All incidents were evaluated by a cardiologist blinded to the research. Of

note, the current study did not collect information on vessel sizes.

Sample size calculation

G*power version 3.1.9.2 software was used to calculate sample size, according to a prior study by Andell *et al.* that examined the impact of IVUS guidance in patients undergoing stenting for ULMCA lesions [8]. The study reported a primary composite endpoint in 13.8% of the IVUS group compared to 29.3% in the No IVUS group. The computed sample size was 172 patients (86 patients per group). Alpha and power were adjusted to be 0.05 and 0.80, respectively.

Statistical analysis

SPSS 28 (IBM, Armonk, New York, USA) was utilized for data management and statistical analysis. Using the Kolmogorov–Smirnov test and direct data visualization approaches, the normality of quantitative data was established. According to normality, means and standard deviations or medians and ranges were used to represent the quantitative data. We utilized percentages and numbers to summarize categorical data. For normally and non-normally distributed quantitative variables, the independent t-test or Mann–Whitney U test was used, respectively, to compare quantitative data across groups. To compare categorical data, the Chi-square or Fisher's exact test, if applicable, was utilized. A Kaplan–Meier analysis of the time to MACE was conducted. Using the log-rank test, comparisons were made between Kaplan–Meier curves. Using a multivariate Cox regression model, the risk of MACE was assessed. Hazard ratios with 95% confidence intervals were calculated. Every statistical test generated two results. P values less than 0.05 were considered statistically significant.

Here's how we censored the Kaplan–Meier curves in our study: (1) event occurrence: For each study participant, we tracked the occurrence of MACE events over the specified follow-up period, which was 12 months in our study. (2) Censored data: If a participant experienced a MACE event during the follow-up period, their event was recorded at the time it occurred on the Kaplan–Meier curve, and this event was not censored. (3) Censoring: For participants who did not experience a MACE event by the end of the follow-up period or were lost to follow-up before the event occurred, we censored their data at the last known follow-up time. In other words, their data

Fig. 1
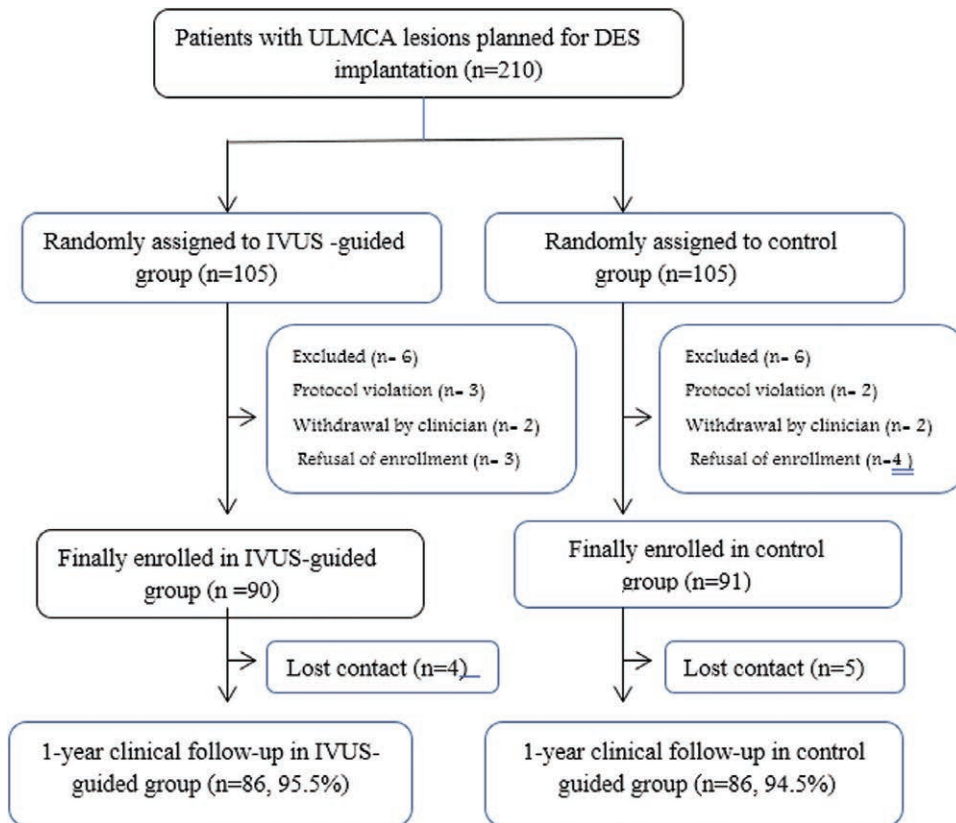
CONSORT flowchart of the studied patients.

point on the Kaplan−Meier curve represents the time at which they were last observed without experiencing a MACE event.

The Kaplan−Meier curves in our study were constructed using these principles, and censored data points were appropriately incorporated to provide a comprehensive representation of event-free survival over time.

Results

In this study, 210 patients were scheduled for DES implantation. These patients were randomized into the IVUS and the control groups. Ultimately, 90 patients were enrolled in the IVUS group, while the control group consisted of 91. All allocated patients were followed up for 1 year. Four and five patients were lost to follow-up in the IVUS and control groups, respectively (Fig. 1).

Baseline characteristics

All baseline demographic and general characteristics demonstrated insignificant differences between the studied groups(Table 1).

Lesion characteristics

No significant differences were observed regarding all lesion characteristics between the studied groups (Table 2).

Procedural characteristics

The IVUS group demonstrated significantly higher pre-dilatation before stenting (88.9% vs. 72.5%, $P = 0.005$), post-dilatation balloon diameter (4.46 ± 0.48 vs. 4.21 ± 0.49, $P < 0.001$), stent diameter (3.9 ± 0.4 vs. 3.7 ± 0.3, $P = 0.002$), pressure for post dilatation (18 ± 3 vs. 16 ± 2, $P = 0.001$), procedural cost (79 444.4 ± 13480 vs. 52 527.5 ± 7830.6 LE, $P < 0.001$) than the control group. Trans-radial approach, total stent number, total stent length, the technique used for PCI, IABP use, GP2b/3a use, TIMI-3 flow in the main vessel, TIMI-3 flow in the side branch, and procedural time demonstrated no significant differences between the study groups (Table 3).

Clinical outcomes

No substantial changes were observed between the study groups concerning hospital outcomes, including myocardial infarction, ST, mortality, target lesion revascularization, and CABG. Regarding 12-month outcomes, patients who underwent IVUS demonstrated significantly lower MACE (3.3% vs. 18.7%, $P < 0.001$) than those who underwent the conventional method (Table 4).

Kaplan−Meier analysis for time to MACE

Kaplan−Meier analysis compared the time to MACE according to the method used. At six months, MACE rates were 2.3% and 8.1% for the IVUS and conventional groups, respectively. At 12 months, the rates were 3.5% for the IVUS group and 20.1% for the conventional group. The median time to MACE was not reached in both groups. The log-rank test demonstrated that the two curves differed significantly ($P < 0.001$) (Fig. 2).

Prediction of the instantaneous risk of MACE

Multivariate Cox regression analysis was done to predict the instantaneous MACE risk. It revealed that IVUS was related to 84.4% risk reduction of 1-year MACE (HR = 0.156, 95% CI = 0.044−0.556, $P = 0.004$), controlling for age, BMI, gender, hypertension, heart rate, diabetes, dyslipidemia, and smoking (Table 5).

Discussion

IVUS may overcome coronary angiography intrinsic limitations for lesion evaluation and stent placement. IVUS improves results in individuals with stable or complicated CAD, although evidence on IVUS-guided PCI efficacy in ULMCA lesions patients is limited.

This study primary result was that IVUS guidance might reduce adverse outcomes in patients following ULMCA treatment. We observed that IVUS-assisted patients had MACE-decreased incidences. This favorable outcome was mostly a consequence of the reduced TVR rate. IVUS may verify the existence of severe LM illness and influence stent size detection. Moreover, IVUS allows identifying PCI problems and the requirement for post-dilatation.

Table 1   Baseline characteristics of the studied patients

	Total (n = 181)	IVUS (n = 90)	Conventional (n = 91)	*P*-value
Age (years)	62 ± 9	63 ± 9	61 ± 9	0.162
Gender				
Males	129 (71.3)	66 (73.3)	63 (69.2)	0.542
Females	52 (28.7)	24 (26.7)	28 (30.8)	
BMI (kg/m²)	27.47 ± 2.94	27.15 ± 3.03	27.78 ± 2.83	0.151
SBP (mmHg)	128 ± 16	128 ± 16	128 ± 16	0.99
DBP (mmHg)	73 ± 8	73 ± 8	73 ± 7	0.682
Heart rate (bpm)	82 ± 11	81 ± 11	83 ± 11	0.253
Hypertension	129 (71.3)	68 (75.6)	61 (67)	0.205
Diabetes	119 (65.7)	56 (62.2)	63 (69.2)	0.32
Dyslipidemia	125 (69.1)	67 (74.4)	58 (63.7)	0.119
Current smoker	102 (56.4)	52 (57.8)	50 (54.9)	0.701
Peripheral artery disease	21 (11.6)	10 (11.1)	11 (12.1)	0.837
Prior stroke	6 (3.3)	2 (2.2)	4 (4.4)	0.682
Prior myocardial infarction	29 (16)	16 (17.8)	13 (14.3)	0.522
Prior PCI	59 (32.6)	33 (36.7)	26 (28.6)	0.245
Prior CABG	2 (1.1)	1 (1.1)	1 (1.09)	1
Creatinine (mg/dl)	1 (0.5–3.3)	1 (0.6–3.3)	1.1 (0.5–2.8)	0.074
eGFR (ml/min/1.73 m²)	78 (9–204)	81 (9–204)	75 (32–187)	0.574
LVEF (%)	55 ± 9	55 ± 9	54 ± 8	0.571
Silent ischemia presentation	5 (2.8)	3 (3.3)	2 (2.2)	0.682
CCS presentation	99 (54.7)	51 (56.7)	48 (52.7)	0.596
Post-ACS Presentation	77 (42.5)	36 (40)	41 (45.1)	0.492

Data were presented as median (range), mean ± SD, frequency (%).
ACS, acute coronary syndrome; CABG, coronary artery bypass graft; CCS, chronic coronary syndrome; e-GFR, estimated glomerular filtration rate; LVEF, left ventricular ejection fraction; PCI, percutaneous coronary intervention.

In the present work, patients who underwent IVUS demonstrated significantly higher pre-dilatation before stenting (88.9% vs. 72.5%, $P = 0.005$), stent diameter (3.9 ± 0.4 vs. 3.7 ± 0.3, $P = 0.002$), post-dilatation balloon diameter (4.46 ± 0.48 vs. 4.21 ± 0.49, $P < 0.001$), and pressure for post dilatation (18 ± 3 vs. 16 ± 2, $P = 0.001$). The study notes that the average postdilation pressure in the angiography-guided group was 16 atm, below the recommended ≥ 18 atm. This deviation may be due to factors like operator discretion, vessel characteristics, and complications. Operators might have chosen lower pressures based on clinical judgment and case specifics, explaining the observed mean pressure. This variation highlights the real-world scenario where decisions are tailored to each patient's condition, emphasizing the need to consider these nuances in interpreting study results.

The observed 16 atm post-dilation pressure in the angiography-guided group, below the recommended ≥ 18 atm, is due to (1) operator judgment: cardiologists adjust pressure based on patient-specific anatomy and lesion characteristics, (2) patient variability: factors like vessel size and calcification influence pressure choice, (3) balloon type: different balloons require varying pressures for stent expansion; and (4) safety concerns: lower pressures may be chosen in complex cases to minimize risks. This variation reflects a balance between achieving optimal stent expansion and ensuring patient safety.

In line with the current study, Tan *et al.* reported that the IVUS group had a higher post-dilation than the conventional group. In contrast, no change was observed in stent diameter [11].

In the current study, regarding 12-month outcomes, patients who underwent IVUS demonstrated significantly lower MACE (3.3% vs. 18.7%, $P < 0.001$) than those who underwent the conventional method. Also, the Kaplan–Meier analysis compared the time to MACE according to the method used. MACE rates were lower in the IVUS groups at six months (2.3% vs. 8.1%) and at 12 months (3.5% vs. 20.1%) compared to the conventional group. Finally, multivariate Cox regression analysis was done to predict the risk of MACE. It revealed that IVUS was

Table 2   Lesion characteristics in the studied patients

	Total (n = 181)	IVUS (n = 90)	Conventional (n = 91)	*P*-value
Multivessel stenting	112 (61.9)	53 (58.9)	59 (64.8)	0.410
LAD	176 (97.2)	86 (95.6)	90 (98.9)	0.211
LCX	102 (56.4)	47 (52.2)	55 (60.4)	0.265
RCA	32 (17.7)	15 (16.7)	17 (18.7)	0.722
LM lesion location				
Ostial	17 (9.4)	8 (8.9)	9 (9.9)	0.787
Mid-shaft	25 (13.8)	14 (15.6)	11 (12.1)	
Distal	139 (76.8)	68 (75.6)	71 (78)	
Calcification	76 (42)	41 (45.6)	35 (38.5)	0.334
Medina class				
1-1-1	91 (50.3)	47 (52.2)	44 (48.4)	0.767
1-1-0	71 (39.2)	32 (35.6)	39 (42.9)	
1-0-1	12 (6.6)	7 (7.8)	5 (5.5)	
1-1	1 (0.6)	1 (1.1)	0 (0)	
1-0-0	6 (3.3)	3 (3.3)	3 (3.3)	
1-0	0 (0)	0 (0)	0 (0)	
1	0 (0)	0 (0)	0 (0)	
TIMI flow below 3	136 (75.1)	69 (76.7)	67 (73.6)	0.636
LM total occlusion	34 (18.8)	16 (17.8)	18 (19.8)	0.730
Syntax score (points)	27 ± 6.4	27.6 ± 6	26.4 ± 6.8	0.192
Syntax score category				
0–22	51 (28.2)	19 (21.1)	32 (35.2)	0.103
23–32	95 (52.5)	51 (56.7)	44 (48.4)	
More than 32	35 (19.3)	20 (22.2)	15 (16.5)	

Data were presented as frequency (%), mean ± SD.
LAD, left anterior descending; LCX, left circumflex artery; LM, left main coronary; RCA, right coronary artery.

Table 3   Procedural characteristics of the studied patients

	Total (n = 181)	IVUS (n = 90)	Conventional (n = 91)	*P*-value
Trans-radial approach	84 (46.4)	42 (46.7)	42 (46.2)	0.945
Pre-dilatation before stenting	146 (80.7)	80 (88.9)	66 (72.5)	**0.005**[a]
Total stent(s) number				
One	112 (61.9)	61 (67.8)	51 (56)	0.092
Two	68 (37.6)	28 (31.1)	40 (44)	
Three	1 (0.6)	1 (1.1)	0 (0)	
Total stent(s) length (mm)	33 (9–89)	33 (12–89)	36 (9–82)	0.139
Stent diameter (mm)	3.8 ± 0.4	3.9 ± 0.4	3.7 ± 0.3	**0.002**[a]
Technique used for PCI				
Culotte	2 (1.1)	1 (1.1)	1 (1.1)	0.196
T or provisional T-stenting	134 (74)	70 (77.8)	64 (70.3)	
V or SKS stenting	2 (1.1)	2 (2.2)	0 (0)	
DK crush	43 (23.8)	17 (18.9)	26 (28.6)	
Post-dilatation balloon diameter (mm)	4.33 ± 0.5	4.46 ± 0.48	4.21 ± 0.49	**<0.001**[a]
Pressure for post-dilatation (atm)	17 ± 3	18 ± 3	16 ± 2	**0.001**[a]
IABP use	4 (2.2)	3 (3.3)	1 (1.1)	0.368
GP2b/3a use	6 (3.3)	3 (3.3)	3 (3.3)	1
TIMI-3 flow in main vessel	180 (99.4)	90 (100)	90 (98.9)	1
TIMI-3 flow in side branch	177 (97.8)	88 (97.8)	89 (97.8)	1
Procedure cost (LE)	-	79 444.4 ± 13 480	52 527.5 ± 7830.6	**<0.001**[a]
Procedure time (minutes)	-	70 ± 19	68 ± 19	0.479

Data were presented as median (range), mean ± SD, frequency (%).
IABP, intra-aortic balloon pump; PCI, percutaneous coronary intervention.
[a]Significant *P*-value.

associated with 84.4% risk reduction of 1-year MACE. The current study notes that five interventionists often used two-stent procedures for distal LM lesions, but this varied; 77% of cases had these lesions, and 62% received single-stent interventions. IVUS-guided PCI, used in 68% of cases, suggests more precise and potentially safer strategies, emphasizing IVUS's importance in optimizing PCI.

Groenland et al.'s meta-analysis, with 838 902 patients, showed IVUS-guided PCI significantly reduced all-cause mortality and MACE compared to angiography-guided PCI [12]. Hannan et al. also found lower mortality and TVR rates in IVUS-guided PCI patients.

Studies comparing IVUS and angiography for PCI, including Darmoch et al.'s meta-analysis [4] and the ULTIMATE trial [13] by Ge et al., reveal IVUS's superiority. IVUS-guided procedures notably decrease CVD mortality, myocardial infarction, ST, target lesion revascularization, and target vessel failure, particularly reducing ST and TVR. Andell et al'.s observational study [8] on ULMCA PCI patients showed that IVUS guidance led to larger stent diameters and significantly lower rates of composite endpoints (including all-cause death, restenosis, or ST) and all-cause mortality, even after adjusting for confounders. Tan et al. found no differences in myocardial infarction and mortality between groups, but the IVUS-assisted group showed a lower 2-year MACE rate compared to controls (13.1% vs. 29.3%) [11]. Mentias et al. [14] found that IVUS-assisted PCI lowered the risk of death, myocardial infarction, and repeated revascularization. Choi et al. also reported reduced risks of cardiac mortality, all-cause death, myocardial infarction, ST, and target lesion revascularization with IVUS-assisted PCI in complicated lesions [15]. Hernandez et al. found that the IVUS group had better survival without cardiac mortality, infarction, and TVR, and IVUS independently indicated fewer adverse reactions, especially in patients with distal LM affection [16].

Table 4   Clinical outcomes of the studied patients

	Total (n = 181)	IVUS (n = 90)	Conventional (n = 91)	P-value
In-hospital				
Mortality	2 (1.1)	0 (0)	2 (2.2)	0.497
Myocardial infarction	4 (2.2)	0 (0)	4 (4.4)	0.121
TVR	2 (1.1)	0 (0)	2 (2.2)	0.497
Stent thrombosis	2 (1.1)	0 (0)	2 (2.2)	0.497
CABG	1 (0.6)	0 (0)	1 (1.1)	1
12 months				
MACE	20 (11)	3 (3.3)	17 (18.7)	<0.001[a]
Type of MACE				
Mortality	2 (10)	0 (0)	2 (11.8)	1
Myocardial infarction	3 (15)	0 (0)	3 (17.6)	
TVR	13 (65)	3 (100)	10 (58.8)	
Stent thrombosis	2 (10)	0 (0)	2 (11.8)	

Data were presented as frequency (%).
CABG, coronary artery bypass graft; MACE, major adverse cardiac event; TVR, target vessel revascularization.
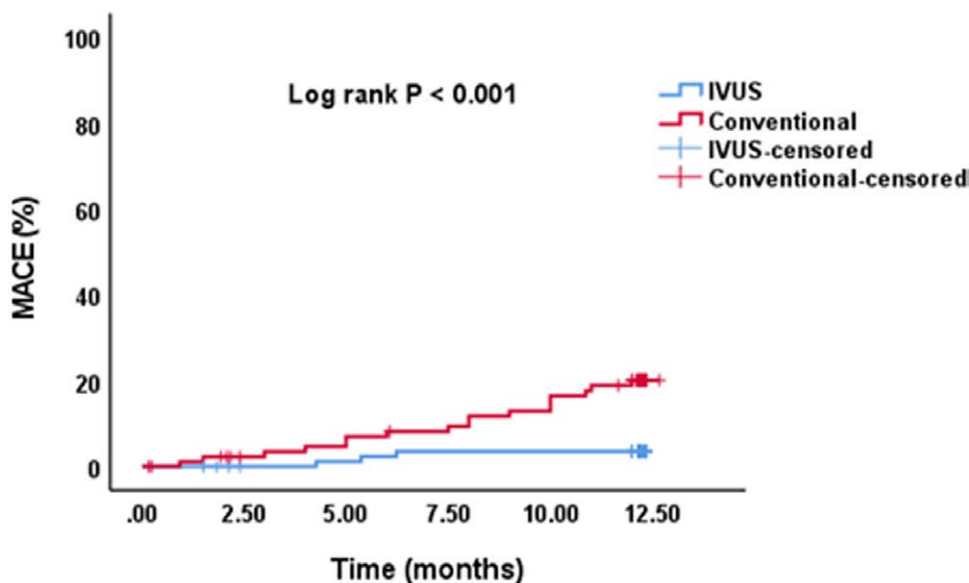[a]Significant P value.

In our study, physicians managing patients were aware of the study arm (IVUS-guided or control) when deciding on early coronary angiography, based on their clinical judgment. Although the cardiologist evaluating incidents during follow-up was blinded to reduce bias, treating physicians were not blinded to treatment assignments,

Fig. 2

Kaplan–Meier analysis for time to MACE occurrence.

Table 5 Multivariate Cox regression analysis to predict the risk of MACE

	HR (95% CI)	*P*-value
IVUS method	0.156 (0.044–0.556)	**0.004**[a]
Age (years)	1.023 (0.963–1.087)	0.466
Gender	0.807 (0.259–2.518)	0.712
BMI (kg/m²)	0.962 (0.797–1.16)	0.681
Heart rate (bpm)	1.031 (0.991–1.074)	0.134
Hypertension	1.783 (0.61–5.208)	0.291
Diabetes	0.758 (0.277–2.073)	0.589
Dyslipidemia	0.351 (0.135–0.913)	0.032
Current smoker	1.337 (0.456–3.917)	0.596

95% CI, 95% confidence interval; HR, hazard ratio.
[a]Significant as *P*-value less than 0.05.

mirroring real-world practice where decisions are made with full knowledge of the patient's condition and treatment plan.

On Cox proportional hazard analysis, Tan *et al.* documented that IVUS guidance was an independent determinant of MACE-free survival [11]. According to some studies in the era of bare metal stents (BMS) and the age of DES, IVUS guidance was demonstrated to minimize the incidence of significant adverse cardiac reactions in ULMCA patients [16–18].

IVUS-assisted BMS implantation was related to restenosis, revascularization, and lower MACE incidence, according to a meta-analysis of 2972 patients. However, there were no substantial improvements in mortality and myocardial infarction [17].

Nine hundred seventy-five patients with ULMCA lesions underwent PCI under the supervision of IVUS or angiography alone in the MAIN-COMPARE trial. In 145 comparable pairs of patients, the 3-year incidence of overall mortality was lower in the IVUS-guided group (4.7% vs. 16%; *P* = 0.048), with survival curves deviating after the second year [19].

Our study compared outcomes between patients with routine IVUS guidance and those without, avoiding crossover between the two groups. We acknowledge the significance of researching selective IVUS use for specific clinical indications, a topic our study didn't address but warrants future investigation for optimal clinical application.

This research study has some limitations, including the small sample size and the relatively short follow-up duration of 1 year, limiting the assessment of long-term outcomes.

Conclusion

The present investigation indicated that IVUS usage in patients with ULMCA was safe, and it was associated with 84.4% risk reduction of 1-year MACE. The IVUS-guided group showed significantly reduced risk and lower MACE rates at 12 months. Moreover, the IVUS guidance allowed for more optimized procedural

characteristics, including better larger stent diameter, pre-dilatation, and improved post-dilatation parameters. Therefore, IVUS usage during ULMCA treatments with DES may enhance clinical results for patients.

References

1 Dąbrowski EJ, Kożuch M, Dobrzycki S. Left main coronary artery disease-current management and future perspectives. *J Clin Med* 2022; **11**:5745.

2 Lawton JS, Tamis-Holland JE, Bangalore S, Bates ER, Beckie TM, Bischoff JM, *et al.* 2021 ACC/AHA/SCAI guideline for coronary artery revascularization: executive summary: a report of the American College of Cardiology/American Heart Association Joint Committee on clinical practice guidelines. *Circulation* 2022; **145**:e4–e17.

3 Ayman R, Shaheen SM, Sabet SS, Abdellatif YA. Percutaneous coronary artery intervention in unprotected left main coronary artery disease: one-year outcome Egyptian registry. *Egypt Heart J* 2022; **74**:63.

4 Darmoch F, Alraies MC, Al-Khadra Y, Moussa Pacha H, Pinto DS, Osborn EA. Intravascular ultrasound imaging-guided versus coronary angiography-guided percutaneous coronary intervention: a systematic review and meta-analysis. *J Am Heart Assoc* 2020; **9**:e013678.

5 Malaiapan Y, Leung M, White AJ. The role of intravascular ultrasound in percutaneous coronary intervention of complex coronary lesions. *Cardiovasc Diagn Ther* 2020; **10**:1371–1388.

6 Youn YJ, Yoon J, Lee JW, Ahn SG, Ahn MS, Kim JY, *et al.* Intravascular ultrasound-guided primary percutaneous coronary intervention with drug-eluting stent implantation in patients with ST-segment elevation myocardial infarction. *Clin Cardiol* 2011; **34**:706–713.

7 Wang S, Liang C, Wang Y, Sun S, Wang Y, Suo M, *et al.* The long-term clinical outcomes of intravascular ultrasound-guided versus angiography-guided coronary drug eluting stent implantation in long de novo coronary lesions: a systematic review and meta-analysis. *Front Cardiovasc Med* 2022; **9**:944143.

8 Andell P, Karlsson S, Mohammad MA, Götberg M, James S, Jensen J, *et al.* Intravascular ultrasound guidance is associated with better outcome in patients undergoing unprotected left main coronary artery stenting compared with angiography guidance alone. *Circ Cardiovasc Interv* 2017; **10**:e004813.

9 Liu XM, Yang ZM, Liu XK, Zhang Q, Liu CQ, Han QL, *et al.* Intravascular ultrasound-guided drug-eluting stent implantation for patients with unprotected left main coronary artery lesions: a single-center randomized trial. *Anatol J Cardiol* 2019; **21**:83–90.

10 Kumar NP, Roy S, Rajendran M, Shafeeq A. Percutaneous coronary intervention in unprotected left main coronary artery stenosis: Mid-term outcomes of a single-center observational study. *Indian Heart J* 2022; **74**:96–104.

11 Tan Q, Wang Q, Liu D, Zhang S, Zhang Y, Li Y. Intravascular ultrasound-guided unprotected left main coronary artery stenting in the elderly. *Saudi Med J* 2015; **36**:549–553.

12 Groenland FTW, Neleman T, Kakar H, Scoccia A, Ziedses des Plantes AC, Clephas PRD, *et al.* Intravascular ultrasound-guided versus coronary angiography-guided percutaneous coronary intervention in patients with acute myocardial infarction: a systematic review and meta-analysis. *Int J Cardiol* 2022; **353**:35–42.

13 Ge Z, Gao XF, Kan J, Kong XQ, Zuo GF, Ye F, *et al.* Comparison of one-month versus twelve-month dual antiplatelet therapy after implantation of drug-eluting stents guided by either intravascular ultrasound or angiography in patients with acute coronary syndrome: rationale and design of prospective, multicenter, randomized, controlled IVUS-ACS and ULTIMATE-DAPT trial. *Am Heart J* 2021; **236**:49–58.

14 Mentias A, Sarrazin MV, Saad M, Panaich S, Kapadia S, Horwitz PA, *et al.* Long-term outcomes of coronary stenting with and without use of intravascular ultrasound. *JACC Cardiovasc Interv* 2020; **13**:1880–1890.

15 Choi KH, Song YB, Lee JM, Lee SY, Park TK, Yang JH, *et al.* Impact of intravascular ultrasound-guided percutaneous coronary intervention on long-term clinical outcomes in patients undergoing complex procedures. *JACC Cardiovasc Interv* 2019; **12**:607–620.

16   De la Torre Hernandez JM, Baz Alonso JA, Gómez Hospital JA, Alfonso Manterola F, Garcia Camarero T, Gimeno de Carlos F, *et al.*; IVUS-TRONCO-ICP Spanish study. Clinical impact of intravascular ultrasound guidance in drug-eluting stent implantation for unprotected left main coronary disease: pooled analysis at the patient-level of 4 registries. *JACC Cardiovasc Interv* 2014; **7**:244–254.

17   Parise H, Maehara A, Stone GW, Leon MB, Mintz GS. Meta-analysis of randomized studies comparing intravascular ultrasound versus angiographic guidance of percutaneous coronary intervention in pre-drug-eluting stent era. *Am J Cardiol* 2011; **107**:374–382.

18   Gao XF, Kan J, Zhang YJ, Zhang JJ, Tian NL, Ye F, *et al.* Comparison of one-year clinical outcomes between intravascular ultrasound-guided versus angiography-guided implantation of drug-eluting stents for left main lesions: a single-center analysis of a 1,016-patient cohort. *Patient Prefer Adherence* 2014; **8**:1299–1309.

19   Park SJ, Kim YH, Park DW, Lee SW, Kim WJ, Suh J, *et al.*; MAIN-COMPARE Investigators. Impact of intravascular ultrasound guidance on long-term mortality in stenting for unprotected left main coronary artery stenosis. *Circ Cardiovasc Interv* 2009; **2**:167–177.