Enhanced Stent Imaging System Guided Percutaneous Coronary Intervention İs Linked to Optimize Stent Placement

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Abstract

Purpose: Stent under-expansion utmost importance for restenosis, also one of the strongest predictors of Stent Thrombosis is stent under-expansion. Thus, it remains uncertain whether Enhanced stent imaging (CLEARstent) guidance improved stent under-expansion.Our aim to assess the using Enhanced stent imaging (ESI) on stent under-expansion, after percutaneous coronary intervention (PCI, with using CLEARstent technology.

Methods: This cross-sectional observational based on single center study. The subjects who applied to our cardiology clinic with stable angina or acute coronary syndrome, from March 2020 to September 2020 were recruited. A total of 164 patients who underwent post-PCI clear stent in the study group and age sex matched 77 control patients were included in the study. Post-procedural minimal lumen diameter (MLD) was calculated with quantitative coronary angiography module.

Results: Approximately one third of the study population was in X-ray guided PCI group and two third of which was involved in ESI guided PCI group (32% and 68%, respectively, p=0.22). The patients in ESI guided PCI group, median age was 61 (54-69) years and 76.8% (n=126) of whom were male.The patients in ESI guided PCI group have higher minimal lumen area when compared to X-ray guided PCI group (2.88 (2.58-2.99) vs 2.55 (2.34-2.63), p<0.001).

Conclusion: Our study addresses that use of ESI system with intend to optimize stent placement results in better procedural outcome expressed by MLD.

Introduction

Coronary angiography (CAG) and percutaneous coronary intervention (PCI) have been pivotal diagnostic and therapeutic tools for patients suffering from coronary artery disease (CAD). Coronary stent under-expansion is not only important preventable factor of in-stent restenosis (ISR), but also related to stent thrombosis (ST) (1-3). ST is a serious PCI complication, which has a huge adverse impact on survival with the mortality rate of 23% along with stroke, major bleeding, emergency PCI and so on (4). One of the strongest predictors of ST is stent underexpansion, which increases the relative risk approximately 13 times. (5). Although evolving the interventional techniques, the contemporary rate of ISR for PCI is approximately 10% and under expansion of the coronary stent is still an independent determinant of ISR causing proved ischemia (6,7). Therefore, performing an appropriate coronary stent deployment in a PCI procedure is crucial. It has been noted that, intravascular ultrasound (IVUS) guided PCI is associated with lower rates of major adverse cardiovascular events than angiography-guided stent implantation (8).

Enhanced stent imaging (ESI) is a novel software based angiographic imaging modality that improves coronary stent visualization and provides advantages regarding quantitative analysis of stent dimension (9). Although IVUS is the gold standard technique for the assessment of adequate stent expansion, correlation of minimum stent diameter is higher between IVUS and ESI when compared to IVUS and quantitative coronary angiogram (QCA) and ESI and QCA. For this reason, ESI is a potential alternative imaging tool for the assessment of stent deployment in clinical practice with some advantages such as easy to apply, cost-effective, requiring less trained personnel and no need to additional equipment (10,11).

As it has favorable practical features, we aimed to find out whether ESI achieves better procedural success in terms of minimal lumen diameter (MLD) calculated by QCA when compared to conventional PCI.

Patients And Methods

Study population

We conducted a cross-sectional study. All patients who were hospitalized with stable angina or acute coronary syndrome were included for the study population. Patients younger than eighteen years old and/or patients who were not hospitalized were excluded from the study population. Exclusion criteria included; treatment with thrombolytic drugs in the previous 24 h, contraindications for dual antiplatelet therapy (active gastrointestinal bleeding, recent hemorrhagic stroke, allergy to aspirin), cardiogenic shock and previous CABG. In the present study, subjects who applied to our cardiology clinic, from March 2020 to September 2020 were recruited. A total of 164 patients who underwent post PCI ESI in the study group and age sex matched 77 control patients were included in the study.

Data collection

All data were obtained from hospital digital health record systems, including the “Health Management System module” specific data (obtain symptoms, biomarkers, medications, and clinical outcomes during index hospitalization).

Procedure

Conventional stent implantations were performed with angiograms in two orthogonal projections. Whether to post-dilate the stent based on the poststent angiogram was decision of the operator. ESI images and documenting the operator’s decision whether the ESI images changed the decision to postdilatation the stent. This decision was made by the operator discretion. An example of an ESI is shown in Figure-1.The decision for the postdilatation was made by the nine experinced interventional cardiologist who were working together in the same clinic for a long time.All patients undergoing angioplasty received a loading dose of aspirin 300 mg and either clopidogrel 600 mg or ticagrelor 180 mg or 60 mg prasugrel prior to the procedure. All patients then received regular 75 mg aspirin and 75 mg clopidogrel or 10 mg prasugrel or 180 mg ticagrelor daily maintenance therapy. Drug eluting stent were implanted for all patients.

Enhanced Stent Imaging Procedure

The Clearstent is image processing software system (Siemens Healthcare, Munih, Germany) and designed as an add on conventional X-ray angiographic systems. After stent deployment and balloon deflation, an ESI is produced from a minimum of 20 cine frames over 3 sec using the radiopaque markers of the delivery balloon as an anchor to align the stent across all frames. The Clearstent system automatically grabs the cine images to create a still image of the stent with enhanced edges and the associated region of interest. Stent visibility was assessed using both standard angiography and ESI. Following the procedure, ESI diameter measurements were obtained independent of and blinded to the QCA measurements.

Outcome variables measurements

Post-procedurel minimal lumen diameter was calculated with quantitative coronary angiography module. QCA analysis was performed using a validated semi-automated QCA software (Siemens Healthcare, Munih, Germany) Frames for QCA analysis were selected from fully-opacified angiograms that provided optimal visualization of the lesion/treated segment with the least degree of foreshortening. Calibration was performed with the use of the contrast-filled guiding catheter as the reference. Post-PCI diameters of the stented segments as well as the diameters at the proximal and distal stent edges were obtained. QCA measurements were obtained independent of and blinded to the ESI measurements.

Statistics

Continuous variables distribution assessed by histogram and Shapiro-Wilks's test. Numerical variables were represented with median and interquartile ranges or mean and standard deviations, for comparison t-test or Mann-Whitney-U test were used. Categorical variables were expressed as percentages and number and for comparison chi-square test was used.

Main candidate predictor and adjustment variables

The predictors for the primary outcome ought to be literally plausible, and their relationships with minimal stent diameter should be demonstrated in previous studies (12,13). We considered all candidate predictors that we included in the model under these principles. The main candidate predictor, ESI usage was included in the model. Adjustment variables were determined as age, pre-dilation, classification, post-dilation, lesion type, stent diameter, stent balloon ATM post-clear stent extra-balloon usage.

Statistical modeling

To examine the relationship between minimal lumen-diameter and clear-stent, we used the ordinary least square regression model. The associations between candidate predictors and minimal lumen diameter were quantified by the adjusted Beta coefficient with a 95% confidence interval (CI). We did not remove any of these predictors based on statistical significance. For analyses, R-software version 4.01 (Vienna, Austria) with “rms” and “desctool” packages were used.

Results

Throughout the study period, a total of 241 patients were recruited to either X-ray guided PCI group or ESI guided PCI group. Approximately one third of the study population was in X-ray guided PCI group and two third of which was involved in ESI guided PCI group (32% and 68%, respectively, p=0.22). The patients in ESI guided PCI group, median age was 61 (54-69) years and 76.8% (n=126) of whom were male. More than half of patients were represented with acute coronary syndrome in both groups. Baseline clinic, laboratory and procedure related factors analysis between x-ray guided and ESI guided groups were summarized in Table-1. Post-dilatation rate before ESI did not different between two groups (figure-2). Procedural characteristics such as fluoroscopy time, radiation exposure, stent diameter and stent length were similar in both groups whereas stent thrombosis rates were lower in ESI guided PCI group than in X-ray guided PCI (0.6% vs. 3.8%, respectively, p=0.06) (Table-2).

The patients in ESI with extra-balloon group has higher minimal lumen area when compared to without extra-balloon use group (2.88 (2.58-2.99) vs 2.55 (2.34-2.63), p<0.001). (Table-3)

The ordinary least square regression model for the study endpoint which was minimal lumen diameter (MLD), concluded that stent diameter, post-dilation, ESI implementation, use of extra-balloons post ESI were predictors of MLD (Table-4). Although, age did not show a statistically significance regarding study endpoint, there was an inverse relationship between age and MLD (figure-3).

Discussion

This study revealed that stent diameter, post-dilation, extra balloon usage after ‘ClearStent Live’ system (Siemens Healthcare, Munich, Germany) and additional stent deployment by the help of ClearStent implementation associated with better stent expansion which was quantitated by minimal stent diameter.

As conventional angiography-guided PCI relies on two-dimensional projections, assessing the appropriateness of stent placement can be difficult using this method alone. Therefore, there has been compelling requirement of more complex and practical imaging modalities for PCI guidance.

In early 1990’s, Tobis et al. first showed that IVUS, which acquire cross sectional image of coronary arterial wall and get preliminary knowledge about atherosclerotic plaque composition, could be utilized in vivo (14). After IVUS was started to be used widely in clinical practice, follow-up adverse cardiovascular outcomes showed a decreasing trend (15,16). Optical coherence tomography (OCT) is another adjunctive imaging method which provides valuable information about coronary wall cross-sectional structure and atherosclerotic plaque architecture (17). Studies have showed that, similar to IVUS, OCT guided coronary intervention may lead better results than PCI guided by angiography alone (18,19). Although these favorable clinical results of IVUS and OCT, both imaging techniques have some disadvantages. Resolution or penetration challenges, limited tissue characterization, additional contrast media requirement, interpretation difficulties, and cost constitute of some restrictions of these modalities regarding routine clinical use (20).

Enhanced stent imaging techniques such as ClearStent (Siemens Healthcare, Munich, Germany) or StentBoost (Philips Medical Systems Nederland BV, Best, The Netherlands) are novel, software based, motion-compassed imaging techniques that provides enhanced visibility of deployed stent. In addition, this new innovative technology promises a practical and cost-effective clinical use. Emerging clinical studies investigating the impact of ESI to cardiology practice revealed that, ESI guided PCI is associated with lower rates of stent restenosis, target lesion revascularization in follow-up term and major adverse cardiovascular events compared with no use of ESI (21,22). Our study demonstrated that enhanced visualization of deployed coronary stent was associated with better post-interventional result measured as MLD. It can be deduced that ESI guided PCI provides better clinical outcome by means of better visualization of stent characteristics such as deployment status, which help needing for further post-dilation and stent strut fracture assessment (9,22).

Besides its positive contributions, ESI related fluoroscopy time and radiation exposure can be expected to be higher than standard PCI, but the flouroscopy time and radiation exposure of ESI-guided coronary procedures are comparable to that of conventional angiography-guided PCI (22,23). In our study, fluoroscopy time and radiation exposure dose were compatible to the studies in literature (22,23).

Different commercial ESI systems such as StentViz (GE Healthcare), StentBoost (Philips Medical Systems, Netherlands), ClearStent (Siemens Healthcare, Germany), and StentOptimizer (Paieon, Israel) are currently available in market. By virtue of its improved imaging quality, ESI system can be used in different procedural scenarios such as assessing stent under-expansion, stent strut disruption, implantation a second stent in overlap, ostial lesion stenting, bifurcation stenting and side branch preservation (24-27).

Considering the emerging technology, ESI systems promise to be auxiliary tools that can guide the operator in both simple and complex PCI procedures, with features such as cost effectiveness, availability, and procedural and clinically satisfactory results.

Limitation

Our study had some limitations. One of which, our study sample size was relatively small. This study was designed in an observational fashion. Another limitation was study endpoint which was minimal lumen diameter was quantified with QCA, beside we could not compare with IVUS. Although we included all variables in regression model, however, due to nature of regression model unmeasured confounders may remain which related minimal lumen area. On the other hand, as IVUS and OCT provide structural information such as plaque characteristic or vascular wall anatomy, ESI shouldn't be considered as a substitute of those modalities.

Conclusion

Our study addresses that use of ESI system with intend to optimize stent placement results in better procedural outcome expressed by MLD. In the era of complex intracoronary imaging modalities such as IVUS and OCT, ESI systems seem to be a good alternative. Although there are publications in the literature that show favorable results, it should be stated that this subject needs further research in randomized, controlled manner.

Declarations

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Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by İlhanİlkerAvcı, Gönül Zeren, Mustafa AzmiSungur, BarışŞimşek, Mehmet Fatih Yılmaz, Fatma Can,UfukGürkan, Ali Karagöz and İbrahim HalilTanboğa. The first draft of the manuscript was written by İlhanİlkerAvcı, Aylin Sungur, and Can YücelKarabay. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Ethics approval

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee ofHaydarpaşaNumune Training and Research Hospital (2021/106).

Consent to participate

Informed consent was obtained from all individual participants included in the study.

References

1. Kang SJ, Mintz GS, Park DW, et al. Mechanisms of in-stent restenosis after drug-eluting stent implantation: intravascular ultrasound analysis. CircCardiovascInterv. 2011;4(1):9-14.

2. Rathore S, Terashima M, Katoh O, et al. Predictors of angiographic restenosis after drug eluting stents in the coronary arteries: contemporary practice in real world patients. EuroIntervention. 2009;5(3):349-354.
3. Fujii K, Carlier SG, Mintz GS, et al. Stent underexpansion and residual reference segment stenosis are related to stent thrombosis after sirolimus-eluting stent implantation: an intravascular ultrasound study. J Am CollCardiol. 2005;45(7):995-998.
4. Batchelor R, Dinh D, Brennan A, et al. Incidence, Predictors and Clinical Outcomes of Stent Thrombosis Following Percutaneous Coronary Intervention in Contemporary Practice. Heart Lung Circ. 2020;29(10):1433-1439.
5. D'Ascenzo F, Bollati M, Clementi F, et al. Incidence and predictors of coronary stent thrombosis: evidence from an international collaborative meta-analysis including 30 studies, 221,066 patients, and 4276 thromboses. Int J Cardiol. 2013;167(2):575-584.
6. Moussa ID, Mohananey D, Saucedo J, et al. Trends and Outcomes of Restenosis After Coronary Stent Implantation in the United States. J Am CollCardiol. 2020;76(13):1521-1531.
7. Kang SJ, Cho YR, Park GM, et al. Predictors for functionally significant in-stent restenosis: an integrated analysis using coronary angiography, IVUS, and myocardial perfusion imaging. JACC Cardiovasc Imaging. 2013;6(11):1183-1190.
8. Jang JS, Song YJ, Kang W, et al. Intravascular ultrasound-guided implantation of drug-eluting stents to improve outcome: a meta-analysis. JACC CardiovascInterv. 2014;7(3):233-243.
9. Sanidas EA, Maehara A, Barkama R, et al. Enhanced stent imaging improves the diagnosis of stent underexpansion and optimizes stent deployment. Catheter CardiovascInterv. 2013;81(3):438-445.
10. Rogers RK, Michaels AD. Enhanced x-ray visualization of coronary stents: clinical aspects. CardiolClin. 2009;27(3):467-475.
11. Mishell JM, Vakharia KT, Ports TA, Yeghiazarians Y, Michaels AD. Determination of adequate coronary stent expansion using StentBoost, a novel fluoroscopic image processing technique. Catheter CardiovascInterv. 2007;69(1):84-93.
12. Cura F, Albertal M, Candiello A, et al. StentBoost Visualization for the Evaluation of Coronary Stent Expansion During Percutaneous Coronary Interventions. CardiolTher. 2013;2(2):171-180.
13. Stone GW, St Goar FG, Hodgson JM, et al. Analysis of the relation between stent implantation pressure and expansion. Optimal Stent Implantation (OSTI) Investigators. Am J Cardiol. 1999;83(9):1397-A8.
14. Tobis JM, Mallery J, Mahon D, et al. Intravascular ultrasound imaging of human coronary arteries in vivo. Analysis of tissue characterizations with comparison to in vitro histological specimens. Circulation. 1991;83(3):913-926.
15. Hong SJ, Kim BK, Shin DH, et al. Effect of Intravascular Ultrasound-Guided vs Angiography-Guided Everolimus-Eluting Stent Implantation: The IVUS-XPL Randomized Clinical Trial [published correction appears in JAMA. 2016 Feb 2;315(5):518. Kim, Yonghoon [corrected to Kim, Yong Hoon]]. JAMA. 2015;314(20):2155-2163.

16. Elgendy IY, Mahmoud AN, Elgendy AY, Bavry AA. Outcomes With Intravascular Ultrasound-Guided Stent Implantation: A Meta-Analysis of Randomized Trials in the Era of Drug-Eluting Stents. CircCardiovascInterv. 2016;9(4):e003700.
17. Low AF, Tearney GJ, Bouma BE, Jang IK. Technology Insight: optical coherence tomography–current status and future development. Nat ClinPractCardiovasc Med. 2006;3(3):154-172.
18. Meneveau N, Souteyrand G, Motreff P, et al. Optical Coherence Tomography to Optimize Results of Percutaneous Coronary Intervention in Patients with Non-ST-Elevation Acute Coronary Syndrome: Results of the Multicenter, Randomized DOCTORS Study (Does Optical Coherence Tomography Optimize Results of Stenting). Circulation. 2016;134(13):906-917.
19. Jones DA, Rathod KS, Koganti S, et al. Angiography Alone Versus Angiography Plus Optical Coherence Tomography to Guide Percutaneous Coronary Intervention: Outcomes From the Pan-London PCI Cohort. JACC CardiovascInterv. 2018;11(14):1313-1321.
20. Räber L, Mintz GS, Koskinas KC, et al. Clinical use of intracoronary imaging. Part 1: guidance and optimization of coronary interventions. An expert consensus document of the European Association of Percutaneous Cardiovascular Interventions [published correction appears in Eur Heart J. 2019 Jan 14;40(3):308]. Eur Heart J. 2018;39(35):3281-3300.3
21. Oh DJ, Choi CU, Kim S, et al. Effect of StentBoost imaging guided percutaneous coronary intervention on mid-term angiographic and clinical outcomes. Int J Cardiol. 2013;168(2):1479-1484.
22. McBeath KCC, Rathod KS, Cadd M, et al. Use of enhanced stent visualisation compared to angiography alone to guide percutaneous coronary intervention. Int J Cardiol. 2020;321:24-29.
23. Jin Z, Yang S, Jing L, Liu H. Impact of StentBoost subtract imaging on patient radiation exposure during percutaneous coronary intervention. Int J Cardiovasc Imaging. 2013;29(6):1207-1213.
24. Nazif TM, Weisz G, Moses JW. Clinical applications of a new Enhanced Stent Imaging technology. Catheter CardiovascInterv. 2013;82(7):1115-1122.
25. Eng MH, Klein AP, Wink O, Hansgen A, Carroll JD, Garcia JA. Enhanced stent visualization: a case series demonstrating practical applications during PCI. Int J Cardiol. 2010;141(1):e8-e16.
26. Biscaglia S, Tumscitz C, Tebaldi M, et al. Enhanced stent visualization systems during PCI: A case series and review of literature. J Cardiol Cases. 2015;12(1):1-5.
27. Figini F, Louvard Y, Sheiban I. Stent Enhancement during Percutaneous Coronary Intervention: Current Role, Technical Tips and Case Examples. *CardiovascRevasc Med*. 2020;21(1):137-143.

Tables

Table-1

Baseline Clinic laboratory and procedure related factors analysis between X-ray guided PCI and ESI guided PCI group.

Variables	Standard PCI, n:77	ESI guided PCI, n:164	p value
Age, years [IQR] (%)	60 (52, 69)	61 (54, 69)	0.22
Gender (Male) (%)	61 (79.2)	126 (76.8)	0.68
Hypertension (%)	33 (42.9)	84 (51.2)	0.23
Diabetes Mellitus (%)	15 (19.5)	55 (33.5)	0.03
Atrial fibrillation (%)	6 (7.8)	8 (4.9)	0.37
Smoking (%)	22 (28.6)	48 (29.3)	0.91
Clinical presentation			
STEMI (%)	5 (6.5)	11 (6.7)	0.63
NSTEMI (%)	36 (46.8)	87 (53)	
CCS (%)	36 (46.8)	66 (40.2)	
Hemoglobin (g/dl)	14.1 (13.3, 15.3)	13.9 (12.7, 15.1)	0.22
Platelet (10ˆ3/µl)	240 (216, 279)	241 (209, 284)	0.88
Creatinine (g/dl)	0.89 (0.80, 1.00)	0.87 (0.79, 1.00)	0.62
Low Density Lipoprotein (g/dl)	113 (80.5, 138)	111 (83.3, 138)	0.82
Ejection fraction (%)	55 (46.3, 60)	55 (45, 60)	0.49
Fluoroscopy duration (minutes)	20 (15, 29)	21 (16,30)	0.61
Radiation dose (millisievert)	600 (366, 1090)	791 (380, 1150)	0.12
Pre-dilatation (%)	62 (80.5)	133 (81.1)	0.92
Pre-dilatation balloon length (mm)	15 (12, 15)	15 (12, 20)	0.05
Pre-dilatation balloon diameter (mm)	2 (2, 2)	2 (2, 2.5)	0.20
Post-dilatation (%)	35 (45.5)	69 (42)	0.44
Post-dilatation balloon diameter (mm)	2.75 (2.75, 3)	2.78 (2.75, 3)	0.11
Stent diameter (mm)	3 (2.75, 3)	3 (2.75, 3)	0.14
Stent length (mm)	20 (16, 28)	24 (16, 32)	0.10
Stent balloon pressure (atm)	12 (12, 14)	14 (12, 14)	0.23

Minimal stent diameter (post-procedural) before extra balloon usage	2.55 (2.34, 2.55)	2.55 (2.34, 2.55)	0.76
Minimal stent diameter (post-procedural) post-extra balloon usage	2.55 (2.34, 2.68)	2.63 (2.41, 2.88)	0.163
Acetylsalicylic acid (%)	77(100)	164 (100)	-
P2Y12 inhibitors (%)			
Clopidogrel	55 (71.4)	117 (71.3)	0.92
Ticagrelor	12 (15.6)	28 (17.1)	
Prasugrel	10 (13)	19 (11.6)	
Continuous variables presented as median IQR 25-75 categoric variables presented as number and present, mm: millimeter, g:gram, dl:deciliter, µl: microliter, STEMI: ST elevation myocardial infarction, NSTEMI: non-ST-segment elevation myocardial infarction , CCS: chronic coronary syndrome, PCI: percutaneous coronary intervention, ESI: enhanced stent imaging.			

Table-2

Procedure related variables between ESI versus X-ray guided PCI.

Variables	Standard PCI, n:77	ESI guided PCI, n:164	p value
Stent thrombosis (%)	3 (3.8)	1 (0.6)	0.06
IRA			
LMCA	-	3 (1.8)	
LAD (%)	31 (40.2)	80 (48.8)	0.34
CX (%)	23 (29.9)	42 (25.6)	
RCA (%)	23 (29.9)	39 (23.8)	
Lesion type			0.005
A (%)	12 (15.6)	32 (19.5)	
B (%)	40 (51.9)	50 (30.5)	
C (%)	25 (32.5)	82 (50)	
Calcific lesion (%)	6 (7.8)	32 (19.5)	0.02
Post-ESI extra balloon	-	39	-
Post-ESI extra stent usage	-	6	-
Continuous variables presented as median IQR 25-75 categoric variables presented as number and percent, PCI: percutaneous coronary intervention, IRA: infarct-related artery, LMCA: left main coronary artery, LAD: left anterior descending coronary artery, CX: circumflex artery , RCA: right coronary artery. ESI: enhanced stent imaging.			

Table-3

Comparison of patients with and without post dilatation in group ESI.

Variables	ESI baloon usage n: 39	ESI no balloon usage n:125	p value
Age, years [IQR] (%)	57 (49-69)	62 (56-69)	0.15
Gender (Male) (%)	30 (76.9)	96 (76.8)	0.98
Hypertension (%)	23 (59)	61 (48.8)	0.26
Diabetes Mellitus (%)	15 (38.5)	40 (32)	0.45
Clinical presentation			0.84
STEMI (%)	2 (5.1)	9 (7.2)	
NSTEMI (%)	22 (56.4)	65 (52)	
CCS (%)	15 (38.5)	51 (40.8)	
Minimal stent diameter (post-procedural) before extra balloon use (mm)	2.55 (2.34-2.58)	2.55 (2.34-2.63)	0.71
Minimal stent diameter (post-procedural) post-extra balloon use (mm)	2.88 (2.58-2.99)	2.55 (2.34-2.63)	<0.001
STEMI: ST elevation myocardial infarction, NSTEMI: non-ST-segment elevation myocardial infarction , CCS: chronic coronary syndrome, mm:milimeter. ESI: enhanced stent imaging			

Table-4

Associated variables with final minimal lumen diameter according to multivariable ordinary least square regression.

Variables	ß-coefficient	95% CI	p value
Age, per each year	-0.001	-0.002, 0.001	0.56
Calcific lesion, yes/no	-0.02	-0.06, 0.01	0.21
Stent diameter, per each mm increase	0.85	0.81, 0.88	<0.001
Lesion type			
Type B vs. A	0.02	-0.01, 0.06	0.24
Type C vs. A	0.003	-0.03, 0.04	0.87
Pre-dilatation yes/no	0.03	-0.01, 0.06	0.16
Stent balloon atm,	0.003	-0.004, 0.009	0.51
Post-dilatation, yes/no	0.12	0.09, 0.15	<0.001
Extra balloon usage (after ESI)	0.98	0.61, 1.35	<0.001
ESI usage, yes/no	0.05	0.01, 0.10	0.001
ESI: enhanced stent imaging, mm: millimeter.			

Figures

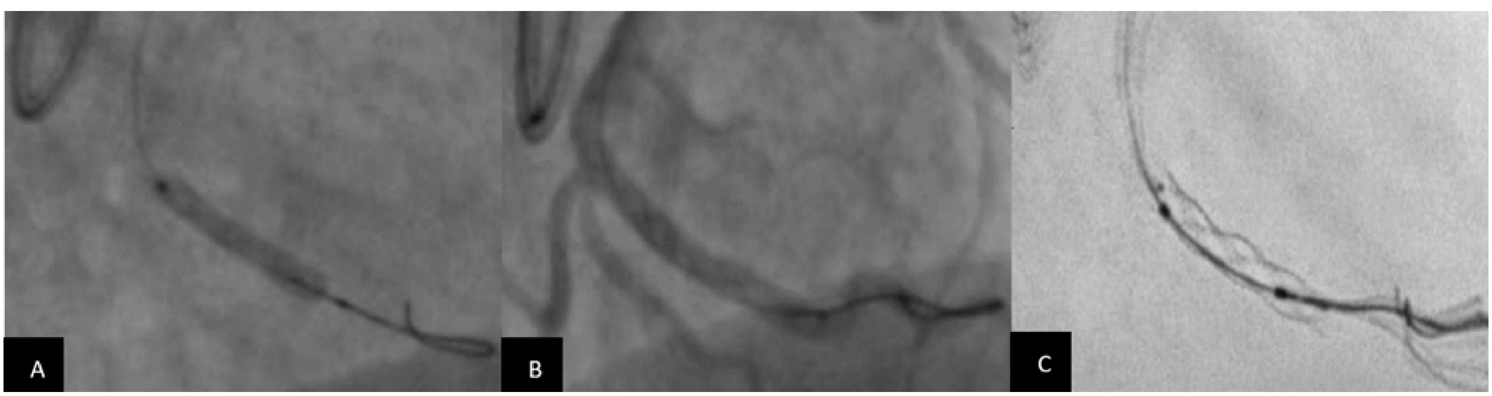

Figure 1

Legend not included with this version

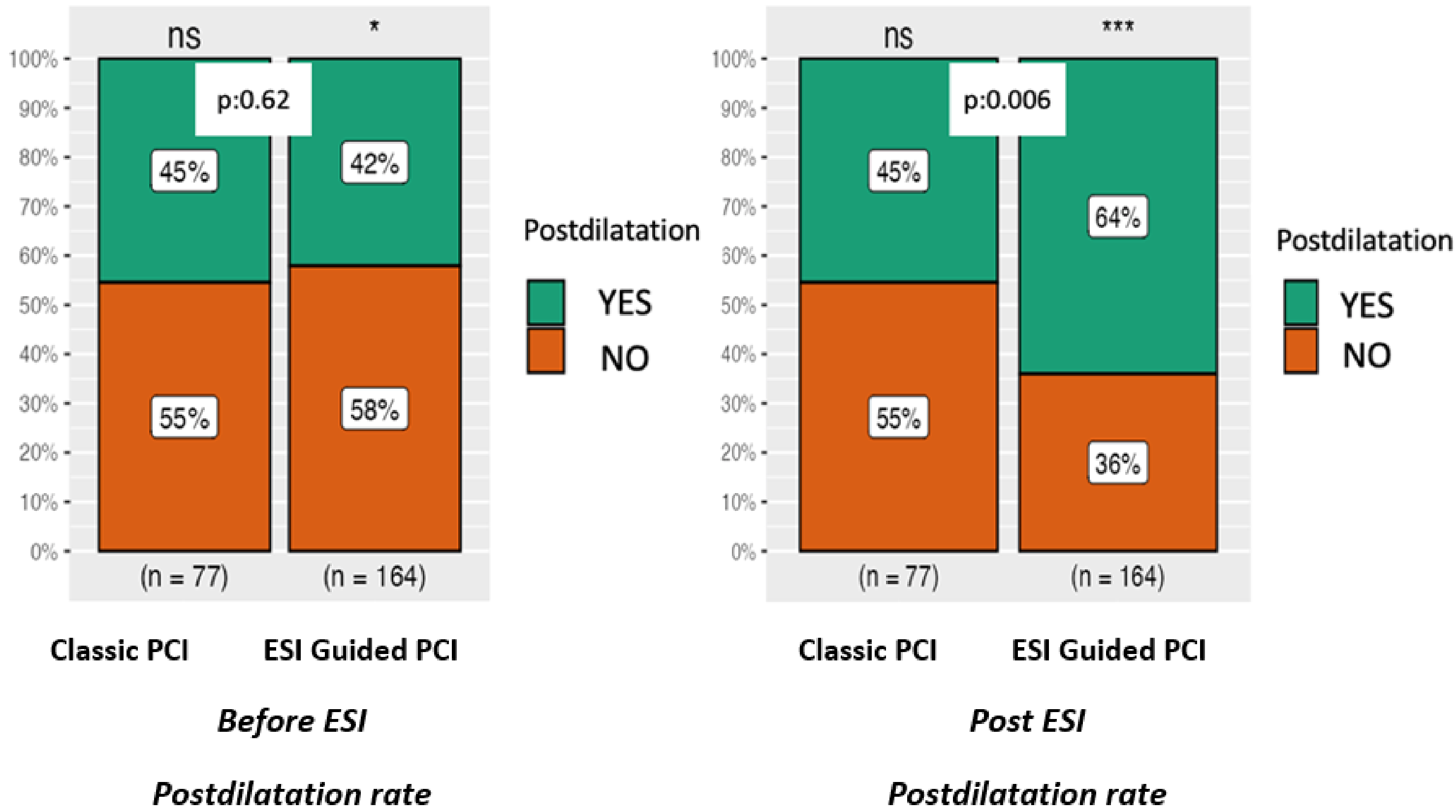
ns
*
p:0.62
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
45%
42%
55%
58%
(n = 77)
(n = 164)
Postdilatation
YES
NO
Classic PCI
ESI Guided PCI
Before ESI
Postdilatation rate
ns
***
p:0.006
45%
64%
55%
36%
(n = 77)
(n = 164)
Postdilatation
YES
NO
Classic PCI
ESI Guided PCI
Post ESI
Postdilatation rate

Figure 2

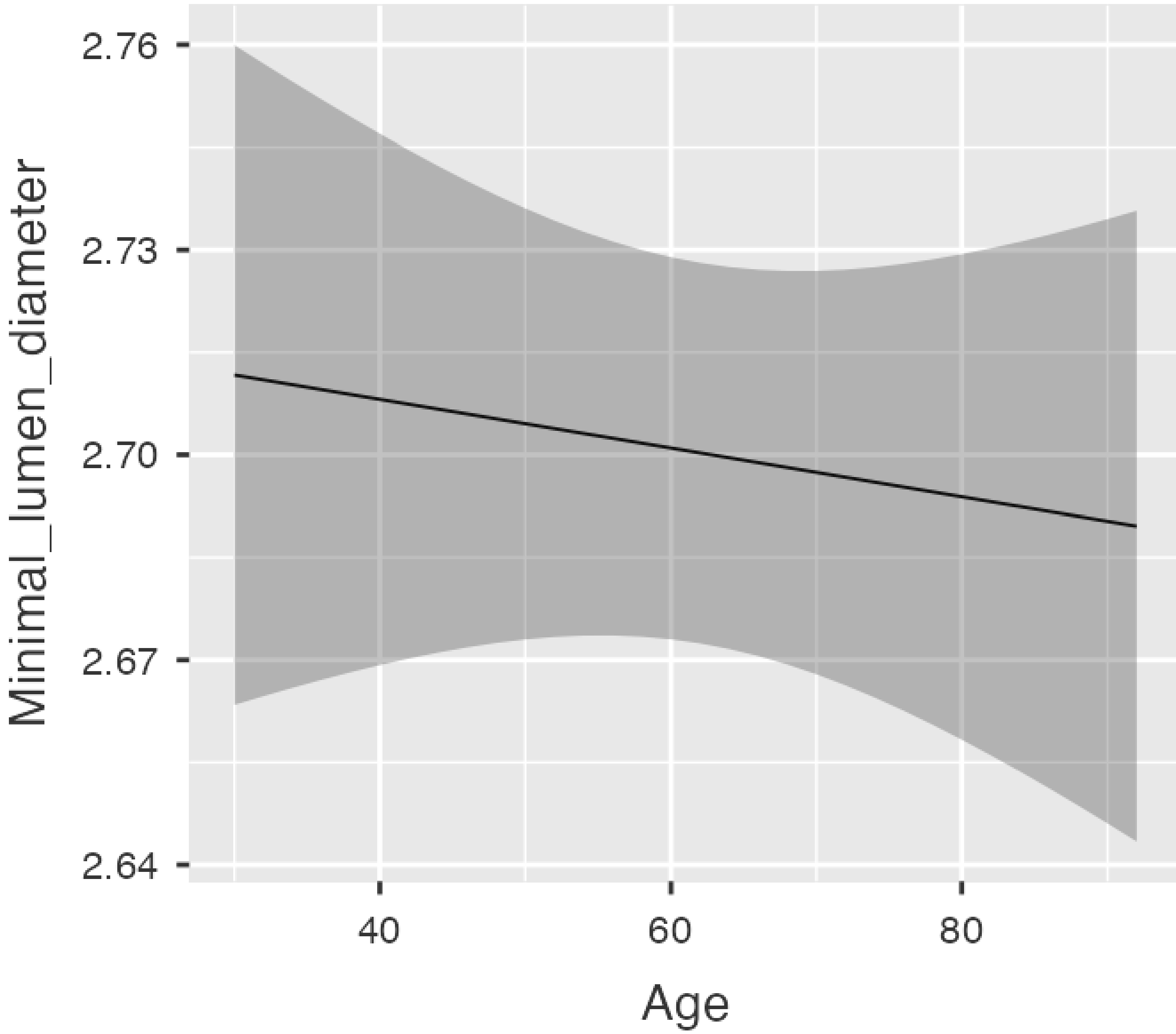

Figure 3