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# Angiographic results after percutaneous coronary interventions in ostial versus distal left main lesions

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ABSTRACT

*Purpose:* We sought to evaluate angiographic outcomes in ostial and distal LM lesions.
*Methods:* 176 patients with LM disease undergoing PCI were retrospectively included in this study. 9 months of angiographic and 12 months of clinical follow-up was obtained. Quantitative coronary analysis (QCA) was performed for all lesions, using an 11-segment model. Clinical endpoint measure was a composite endpoint of cardiac death, myocardial infarction and target lesion revascularization (TLR).
*Results:* During 12 months follow up after successful PCI, the composite endpoint occurred more frequently in distal LM bifurcation lesions mainly driven by elevated TLR rates (14.1% in distal LM disease vs. 5.6% in ostial/midshaft LM disease, P = 0.20). Concordantly angiographic binary restenosis (8.2% compared to 0.0%) and late lumen loss (LLL, 0.42 ± 0.97 vs. 0.28 ± 0.34 mm) were increased in distal LM bifurcation lesions compared to ostial LM lesions. In distal lesions highest values for LLL were observed in segments adjacent to the bifurcation (0.37 ± 1.13 mm and 0.37 ± 0.73 mm). On cox proportional regression analysis the angiographic parameter LLL in a bifurcation segment (P = 0.03, HR 1.68 [1.1–2.7]) as well as presence of diabetes mellitus as a clinical parameter (P = 0.046, HR 2.77 [1.0–7.5]) were independent correlates for occurrence of MACE in distal LM bifurcations lesions.
*Conclusion:* PCI of ostial LM in accomplished with low LLL (0.28 ± 0.34 mm) and binary restenosis rates. In distal left main lesions highest rates for LLL and binary restenosis were observed in segments nearest to the bifurcation and rather focused on the main vessel (0.42 ± 0.97 mm).



## 1. Introduction

Nowadays, percutaneous coronary intervention (PCI) of left main (LM) coronary artery disease, using drug-eluting stents (DES), is associated with appropriate clinical results for the safety composite of death, myocardial infarction (MI) and stroke at long-term follow-up [1,2]. Therefore, recent guidelines indicate that PCI is a suitable alternative to coronary artery bypass graft (CABG) in LM coronary artery disease with less complex coronary anatomy, resulting in a class I level A recommendation for patients with low SYNTAX score (0−22) and a class IIa level A recommendation for patients with intermediate SYNTAX score (23−32) [3].

Due to the anatomical complexity, distal LM lesions result in higher SYNTAX scores than ostial and midshaft LM lesions and consequently in lower levels of evidence for revascularization with PCI [3]. Previous studies have reported that PCI of lesions not involving the distal LM has better outcomes than PCI of distal LM lesions, largely because of a lower need for repeat revascularization [4]. However, limited data are available regarding angiographic outcomes after PCI with DES implantation at different LM segments.

The aim of the present study was to evaluate angiographic and clinical outcomes in ostial/midshaft and distal lesions in LM coronary artery disease after percutaneous coronary intervention.

## 2. Methods

176 patients with LM coronary artery disease of low or intermediate anatomical complexity and prohibitive surgical risk, undergoing percutaneous coronary intervention at our center between 2010 and 2014, were retrospectively included in the present study. Based on lesion location, the population was divided into two groups: the group with an ostial or midshaft and the group with a distal LM coronary artery disease. Pre-procedural parameters, procedural data and post-procedural

*Abbreviations:* DES, drug-eluting stents; MI, myocardial infarction; PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft; SYNTAX, SYNergy between PCI with TAXUS and Cardiac Surgery; LM, left main; MACE, major adverse cardiac events; TLR, target lesion revascularization; ARC, Academic Research Consortium; QCA, quantitative coronary angiography analysis; MLD, minimal lumen diameter; LLL, late lumen loss; EuroSCORE, European System for Cardiac Operative Risk Evaluation.

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clinical and angiographic outcomes were evaluated for both groups. All patients gave written informed consent and were clinically followed up for at least one year after intervention. The study was approved by the local ethics committee and has been performed in accordance with the ethical standards laid down in the Declaration of Helsinki.

Treatment strategy was to cover the stenotic segment with one or more stents. High-pressure implantation with at least 14 atm was mandatory to ensure a proper alignment of stent struts at the vessel wall and to avoid any residual stenosis. Dual antiplatelet therapy was prescribed for at least 12 months. Patients were routinely scheduled for 9 months angiographic follow-up. Furthermore, 12 months clinical follow-up was completed for all patients in outpatient visits. Primary point of interest was the occurrence of major adverse cardiac events (MACE), defined as the composite of cardiac death, any myocardial infarction and target lesion revascularization (TLR). Definite stent thrombosis was defined according to the ARC criteria [5]. Quantitative coronary angiography analysis (QCA) of the index procedure and the angiographic follow-up were performed with the current Cardiovascular Angiography Analysis System (CAAS 11.7, Pie Medical Imaging, Maastricht, The Netherlands), using the conventional single-vessel mode for ostial/midshaft lesions and the dedicated bifurcation algorithm for distal bifurcation lesions of the LM coronary artery [6]. Minimal lumen diameter (MLD) was measured in multiple projections, recording the results from the worst view. Late lumen loss (LLL) was defined as the difference between MLD post PCI and MLD at angiographic follow-up. LM bifurcation lesions were assessed according to the Medina classification [7].

### 2.1. Statistical analysis

Categorical parameters are presented as counts and percentages. Comparisons of proportions were carried out using the $\chi^2$-test. Continuous variables are presented as mean ± one standard deviation. Continuous variables for two groups were compared with the unpaired *U* test. Time-to-event analyses for one-year follow-up were performed using Kaplan-Meier estimates and were compared with the log-rank test. Kaplan-Meier survival curves were generated for time-to-event outcomes.

Multivariate Cox proportional-hazards regression (full-model) analysis was performed for probable influential variables ($P < 0.20$) of univariate analysis. A two-sided P-value <0.05 was considered to indicate statistical significance. All statistical analyses were performed using the Statistica software version 7.1 (Stat Soft, Inc., Tulsa, Oklahoma, USA) and MedCalc Software 17.9.2 (MedCalc Software bvba, Ostend, Belgium).

## 3. Results

Out of the 176 patients with LM coronary artery disease 19.3% of patients presented with ostial/midshaft lesions (N = 34) and 80.7% with distal lesions (N = 142 patients).

Baseline characteristics, including the logistic EuroSCORE were comparable for both groups (Table 1). As expected, the SYNTAX score was significantly higher in the distal LM group compared to the ostial/midshaft LM coronary artery disease group (28.5 ± 7.3 vs. 23.7 ± 7.6, $P < 0.01$). Lesion characteristics and procedural data are displayed in Table 2. Ostial/midshaft LM lesions were predominantly treated with a single stent strategy (stents per lesion: 1.0 ± 0.2). Medina classifications of distal LM lesions are also shown in Table 2. In distal left main lesions, single stent strategy was used in 40.1% and two-stent strategy was applied in 59.9%. T-stenting was the leading technique in case of two-stent strategy (80.0%). Final kissing technique was performed in 62.7% in total and in 69.4% in case of side brunch stenting (see Table 3).

Clinical follow up after 12 months was completed for all 176 patients. Primary point of interest (MACE) was 5.6% in ostial/midshaft LM disease vs. 14.1% in distal left main disease, P = 0.20, Fig. 1). The combined endpoint was mainly driven by elevated TLR in distal left main disease lesions compared to ostial/midshaft LM disease lesions (14.1% vs. 5.6%, P = 0.15). Risk for target vessel related cardiac death (2.9% vs. 0.7%, P = 0.28) and target vessel related myocardial infarction were comparable in both groups (2.9% in ostial lesions and 4.9 in distal lesions, P = 0.59). Detailed data about clinical follow-up are shown in Table 4. Despite slightly lowered TLR rates (12.2%, N = 7) in those cases single stent strategy was performed, all in all there were no statistically significant difference observed, neither between the single or multiple stent strategy nor among any other utilized bifurcation treatment strategies (P = 0,83), including performance of final kissing (P = 0.82).

Angiographic follow-up rate was 48.3% and comparable for both groups (ostial and distal lesions). Angiographic measures of ostial/midshaft and distal LM disease lesions are presented in Tables 5 and 6. In ostial/midshaft LM disease late lumen loss (LLL) for total segment was 0.28 ± 0.34 mm, binary restenosis rate was 0.0%. For distal LM disease LLL in total was 0.42 ± 0.97 mm, with lowest values seen in

**Table 1**
Baseline clinical characteristics.

| | Total | Distal LMD | Proximal LMD | P-value |
|---|---|---|---|---|
| Number of patients | 176 | 142 | 34 | |
| Age (years) | 72.3 ± 10.6 | 72.3 ± 10.6 | 72.0 ± 11.0 | 0.83 |
| Sex (male) | 136 (77.3) | 113 (79.6) | 23 (67.7) | 0.15 |
| Hypertension | 151 (85.8) | 121 (85.2) | 30 (88.2) | 0.64 |
| Hyperlipidemia | 117 (66.5) | 97 (68.3) | 20 (58.8) | 0.30 |
| History of smoking | 51 (30.0) | 42 (29.6) | 9 (26.5) | 0.72 |
| Diabetes mellitus | 60 (34.1) | 50 (35.2) | 10 (29.4) | 0.52 |
| Renal insufficiency | 30 (17.0) | 25 (17.6) | 5 (14.7) | 0.68 |
| Body mass index (kg/m$^2$) | 27.1 ± 4.4 | 27.3 ± 4.6 | 26.9 ± 4.5 | 0.80 |
| Number of diseases vessels | 2.8 ± 0.5 | 2.8 ± 0.5 | 2.7 ± 0.5 | 0.29 |
| SYNTAX score | 27.6 ± 7.6 | 28.5 ± 7.3 | 23.7 ± 7.6 | <0.01 |
| EuroSCORE II | 6.4 ± 7.3 | 6.3 ± 7.3 | 5.7 ± 7.1 | 0.68 |
| Stable angina | 96 (54.5) | 78 (54.9) | 18 (52.9) | 0.83 |
| Unstable angina | 80 (45.5) | 64 (45.1) | 16 (47.1) | 0.83 |

Data are presented as mean ± SD or n (%). LMD = Left main disease.

**Table 2**
Lesion characteristics and procedural data.

| | Total | Distal LMD | Proximal LMD | P-value |
|---|---|---|---|---|
| Number of lesions | 176 | 142 | 34 | |
| Medina class | | | | |
| 1-1-1 | 63 (35.8) | 63 (44.4) | 0 (0.0) | <0.01 |
| 1-0-1 | 21 (11.9) | 21 (14.8) | 0 (0.0) | 0.02 |
| 0-1-1 | 1 (0.6) | 1 (0.7) | 0 (0.0) | 0.51 |
| Calcification | 14 (8.0) | 12 (8.5) | 2 (5.9) | 0.61 |
| Thrombus burden | 5 (2.8) | 4 (2.8) | 1 (5.9) | 0.97 |
| Total stent length (mm) | 27.8 ± 15.4 | 32.0 ± 13.7 | 10.6 ± 3.8 | <0.01 |
| Stents per lesion | 1.77 ± 1.03. | 1.97 ± 1.1 | 1.0 ± 0.2 | <0.01 |
| Maximal inflation pressure (atm) | 15.5 ± 3.4 | 15.6 ± 3.4 | 15.3 ± 3.6 | 0.68 |
| High pressure postdilatation | 148 (84.0) | 123 (86.6) | 25 (73.5) | 0.08 |

Data are presented as mean ± SD or n (%). LMD = left main disease.

**Table 3**
Bifurcation treatment strategy.

| Treatment strategy | No. (%) | Final kissing | TLR |
|---|---|---|---|
| Single stent strategy | 57 (40.1) | | 7 (12.2) |
| Multiple stent strategy | 85 (59.9) | 59 (69.4) | 13 (15.3) |
| T-stenting/reverse T | 68 (80.0) | 45 (66.2) | 11 (16.2) |
| Crush/mini crush | 7 (8.2) | 5 (71.4) | 1 (14.3) |
| Culotte | 3 (3.5) | 2 (66.7) | 0 (0.0) |
| V-stenting | 7 (8.2) | 7 (100.0) | 1 (14.3) |

TLR, target lesion revascularization.

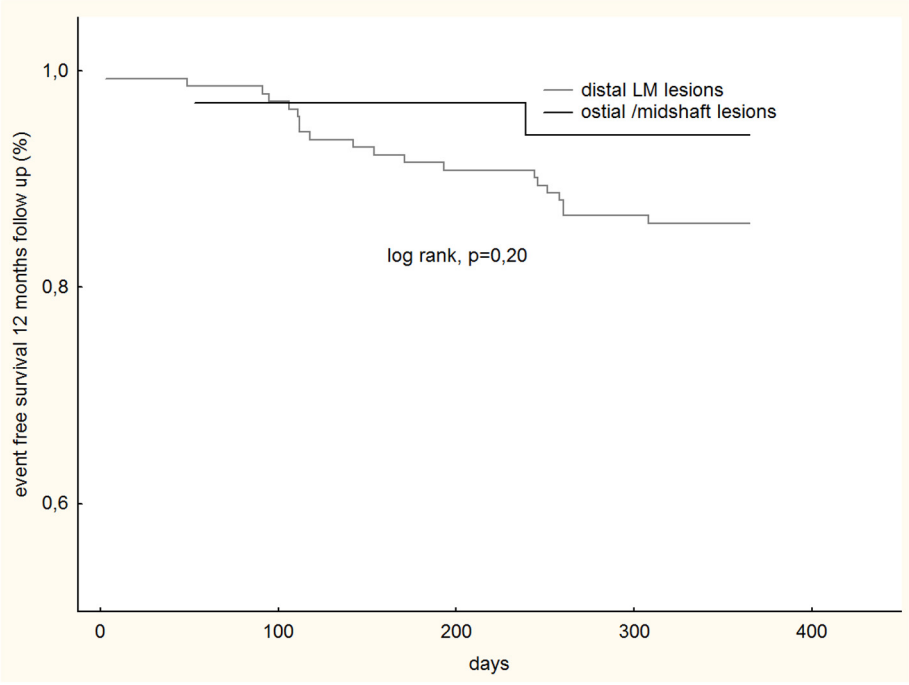


**Fig. 1.** Kaplan-Meier curves of one-year event-free survival among patients with ostial/midshaft and distal left main (LM) disease.

**Table 4**
Clinical follow-up.

| | Total | Distal LMD | Proximal LMD | P-value |
|---|---|---|---|---|
| Stent thrombosis | | | | |
| Acute | 0 (0) | 0 (0) | 0 (0) | – |
| Subacute | 0 (0) | 0 (0) | 0 (0) | – |
| Late | 2 (1.1) | 2 (1.4) | 0 (0) | 0.35 |
| MACE, target vessel related | 22 (12.5) | 20 (14.1) | 2 (5.6) | 0.20 |
| Death, target vessel related | 2 (1.1) | 1 (0.7) | 1 (2.9) | 0.28 |
| MI, target vessel related | 8 (4.5) | 7 (4.9) | 1 (2.9) | 0.59 |
| TLR | 22 (12.5) | 20 (14.1) | 2 (5.6) | 0.20 |

Data are presented as mean ± SD or n (%). The percentages in the subgroups are Kaplan-Meier estimates at the specific time point and do not equal the number of patients divided by the total number in the treatment group.
LMD = left main disease; MACE = major adverse cardiac events; MI = myocardial infarction; STEMI = ST-elevation myocardial infarction, NSTEMI = non-ST-elevation myocardial infarction, TLR = ischemia-driven target lesion revascularization.

segments 1 (0.20 ± 0.70 mm), 4 (0.20 ± 0.66 mm) and 6 (−0.12 ± 0.52 mm), while increased LLL was observed in segments adjacent to the bifurcation, with highest values in segment 7 (0.37 ± 1.1 mm) and segment 11 (0.37 ± 0.7 mm) (Fig. 2). Highest values for binary restenosis were observed in segment 7 (8.2%), segment 8 (6.8%) and segment 11 (6.8%).

On Cox proportional regression analysis late lumen loss for segment 11 (P = 0.03, hazard ratio 1.68, confidence interval 1.1 to 2.7) and diabetes mellitus (P = 0.046, hazard ratio 2.77, confidence interval 1.0 to 7.5) were independent correlates for occurrence of MACE during 12 months follow-up in distal lesions.

## 4. Discussion

The main findings of the present study can be summarized as follows: As anticipated, PCI of distal bifurcation LM disease lesions show

**Table 5**
Angiographic measures pre- and post PCI and at follow-up: ostial lesions.

| | Pre PCI | Post PCI | FUP |
|---|---|---|---|
| Minimal lumen diameter (mm) | | | |
| Total segment | 1.80 ± 0.56 | 3.47 ± 0.53 | 3.3 ± 0.5 |
| In-stent segment | 1.80 ± 0.57 | 3.72 ± 0.48 | 3.5 ± 0.4 |
| Distal segment | 3.35 ± 0.59 | 3.61 ± 0.57 | 3.5 ± 0.5 |
| Reference vessel diameter (mm) | | | |
| Total segment | 3.89 ± 0.54 | 3.81 ± 0.41 | 4.0 ± 0.5 |
| In-stent segment | 3.89 ± 0.54 | 4.16 ± 0.39 | 4.0 ± 0.5 |
| Distal segment | 3.89 ± 0.54 | 4.16 ± 0.39 | 4.0 ± 0.5 |
| Stenosis of luminal diameter (%) | | | |
| Total segment | 54.0 ± 12.9 | 16.58 ± 9.75 | 16.9 ± 8.0 |
| In-stent segment | 53.9 ± 12.9 | 10.7 ± 7.4 | 13.5 ± 7.4 |
| Distal segment | 14.0 ± 9.1 | 13.6 ± 10.8 | 13.2 ± 8.2 |
| | Acute gain (mm) | Late loss (mm) | BR (%) |
| Total segment | 1.67 ± 0.62 | 0.28 ± 0.34 | 0.0 |
| In-stent segment | 1.91 ± 0.61 | 0.42 ± 0.33 | 0.0 |
| Distal segment | 0.26 ± 0.43 | 0.18 ± 0.49 | 0.0 |

Data are presented as mean ± SD or n (%). LMD = left main disease; FUP = follow-up; BR = binary restenosis.

**Table 6**
Angiographic measures pre- and post PCI and at follow-up: distal lesions.

| | Pre PCI | Post PCI | FUP |
|---|---|---|---|
| Minimal lumen diameter (mm) | | | |
| Main vessel | | | |
| Segment 9 | 1.70 ± 0.69 | 3.31 ± 0.76 | 2.97 ± 0.95 |
| Segment 1 | 4.10 ± 1.03 | 4.49 ± 0.72 | 4.28 ± 0.71 |
| Segment 2 | 2.44 ± 0.91 | 4.01 ± 0.63 | 3.80 ± 0.65 |
| Segment 7 | 1.77 ± 0.77 | 3.47 ± 0.76 | 3.12 ± 1.02 |
| Segment 11 | 2.99 ± 9.84 | 3.42 ± 0.60 | 3.10 ± 0.86 |
| Segment 3 | 2.06 ± 0.89 | 3.19 ± 0.64 | 2.92 ± 0.87 |
| Segment 4 | 2.66 ± 0.69 | 3.09 ± 0.65 | 2.98 ± 0.72 |
| Side branch | | | |
| Segment 10 | 1.91 ± 1.12 | 2.77 ± 2.24 | 2.32 ± 0.71 |
| Segment 8 | 2.01 ± 0.98 | 2.79 ± 0.69 | 2.52 ± 0.81 |
| Segment 5 | 1.91 ± 1.03 | 2.66 ± 0.65 | 2.42 ± 0.76 |
| Segment 6 | 2.44 ± 0.79 | 2.66 ± 0.64 | 2.81 ± 2.50 |
| Reference vessel diameter (mm) | | | |
| Main vessel | | | |
| Segment 9 | 3.76 ± 0.92 | 4.02 ± 0.84 | 3.92 ± 0.75 |
| Segment 1 | 4.29 ± 0.77 | 4.57 ± 0.69 | 4.43 ± 0.62 |
| Segment 2 | 4.30 ± 0.76 | 4.55 ± 0.69 | 4.43 ± 0.60 |
| Segment 7 | 3.91 ± 2.88 | 4.03 ± 0.84 | 3.81 ± 0.82 |
| Segment 11 | 3.10 ± 0.63 | 4.26 ± 4.94 | 3.48 ± 0.48 |
| Segment 3 | 3.12 ± 0.65 | 3.59 ± 0.63 | 3.43 ± 0.51 |
| Segment 4 | 3.06 ± 0.62 | 3.50 ± 0.64 | 3.37 ± 0.52 |
| Side branch | | | |
| Segment 10 | 2.82 ± 1.08 | 3.00 ± 0.72 | 2.83 ± 0.68 |
| Segment 8 | 2.87 ± 0.88 | 3.08 ± 0.73 | 2.95 ± 0.74 |
| Segment 5 | 2.77 ± 0.73 | 3.01 ± 0.71 | 2.87 ± 0.71 |
| Segment 6 | 2.73 ± 0.7 | 2.94 ± 0.68 | 2.82 ± 0.67 |
| Stenosis of luminal diameter (%) | | | |
| Main vessel | | | |
| Segment 9 | 54.2 ± 16.7 | 19.8 ± 30.4 | 23.8 ± 20.0 |
| Segment 1 | 5.8 ± 14.7 | 2.5 ± 11.3 | 3.3 ± 8.7 |
| Segment 2 | 42.9 ± 19.9 | 11.3 ± 8.6 | 14.0 ± 10.7 |
| Segment 7 | 52.0 ± 18.7 | 13.7 ± 9.1 | 19.0 ± 19.2 |
| Segment 11 | 30.7 ± 23.4 | 5.84 ± 7.1 | 11.0 ± 20.5 |
| Segment 3 | 34.5 ± 22.9 | 10.0 ± 7.9 | 14.6 ± 21.1 |
| Segment 4 | 12.8 ± 14.5 | 11.7 ± 10.2 | 11.6 ± 16.6 |
| Side branch | | | |
| Segment 10 | 35.4 ± 28.0 | 15.4 ± 15.1 | 20.3 ± 21.7 |
| Segment 8 | 30.4 ± 26.6 | 11.4 ± 17.0 | 16.6 ± 22.6 |
| Segment 5 | 34.2 ± 29.1 | 13.1 ± 15.1 | 18.2 ± 21.8 |
| Segment 6 | 12.5 ± 19.9 | 11.5 ± 15.6 | 14.4 ± 22.4 |

| | Acute gain (mm) | Late loss (mm) | BR (%) |
|---|---|---|---|
| Main vessel | | | |
| Segment 9 | 1.61 ± 0.87 | 0.42 ± 0.97 | 8.2 |
| Segment 1 | 0.43 ± 0.98 | 0.20 ± 0.70 | 0.0 |
| Segment 2 | 1.58 ± 0.98 | 0.25 ± 0.65 | 0.0 |
| Segment 7 | 1.70 ± 0.94 | 0.37 ± 1.13 | 8.2 |
| Segment 11 | 0.43 ± 9.89 | 0.37 ± 0.73 | 6.8 |
| Segment 3 | 1.14 ± 0.88 | 0.35 ± 0.88 | 8.2 |
| Segment 4 | 0.43 ± 0.68 | 0.20 ± 0.66 | 2.7 |
| Side branch | | | |
| Segment 10 | 0.87 ± 2.50 | 0.32 ± 0.58 | 8.2 |
| Segment 8 | 0.78 ± 0.97 | 0.30 ± 0.66 | 6.8 |
| Segment 5 | 0.76 ± 0.96 | 0.26 ± 0.58 | 6.8 |
| Segment 6 | 0.22 ± 0.62 | −0.12 ± 2.52 | 4.1 |

Data are presented as mean ± SD or n (%). LMD = left main disease; FUP = follow-up; BR = binary restenosis.

increased rates of repeat revascularization compared to ostial LM disease lesions, angiographically accompanied with increased values for binary restenosis and late lumen loss after 12 month follow-up. Highest values for late lumen loss and binary restenosis were observed in segments nearest to the bifurcation. Finally, presence of diabetes mellitus as a clinical characteristic as well as late lumen loss in a segment adjacent to the bifurcation as a angiographic feature were both independent correlates for occurrence of MACE after PCI in distal LM disease during 12 months follow-up.

Due to significant advances in device technology, increased operators´ expertise, and availability of improved antithrombotic therapy,

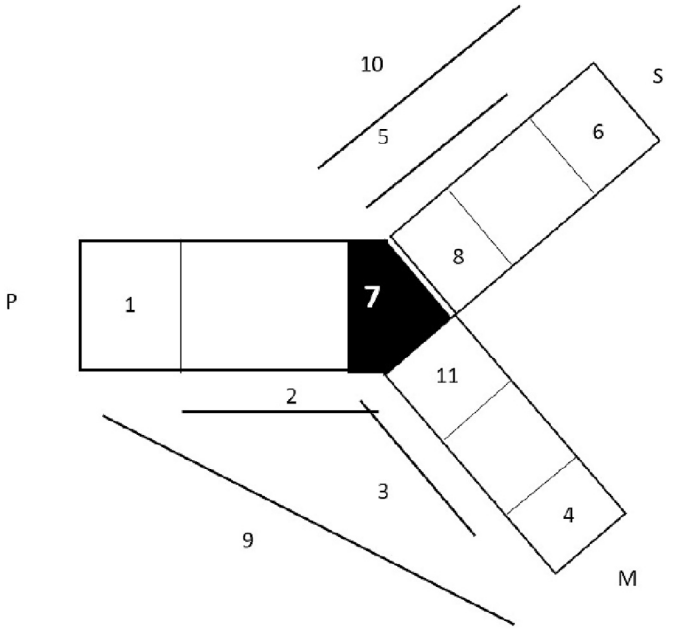


**Fig. 2.** Diagram of left main bifurcation with detailed segments. P = proximal side; M = main vessel; S = side branch.

PCI in LM coronary artery disease has emerged as a valid alternative technique to operative coronary artery bypass grafting [2,8–10]. Current European and American guidelines recommend both CABG and PCI for treatment of LM disease with overall less complex anatomy [3,11]. This is strengthened by encouraging recent data, showing equivalent results in terms of 'hard' endpoints such as incidence of myocardial infarction, stroke, or cardiac and all-cause mortality at long-term follow-up. Early safety advantages of PCI are subsequently offset by higher rates of repeat revascularizations [1,2,12,13]. In a meta-analysis of 6 randomized trials, including 4.717 patients with LM disease, one year results revealed rates for all cause death of 5.4%, myocardial infarction of 3.4% and repeat revascularization (TVR) of 8.7% in the PCI group compared to 6.6%, 4.3% and 4.5% in the CABG group [14]. In this meta-analysis, the entire population was in the 60th decade with a rather lower SYNTAX score in most of the included trials (for example in the EXEL and NOBLE trial SYNTAX score was 20 and 22, respectively). In contrast to the mentioned analysis, we enrolled patients with a higher clinical risk profile. Patients in our study were older (mean age 72.3 years) and had a higher SYNTAX score with a mean of 28. In addition, mean EuroSCORE was 6.4 in the total cohort, 39.8% of patients had moderate to severe impairment of the left ventricular ejection fraction and 45.5% of patients were treated because of acute coronary syndrome. Especially due to these differences in baseline characteristics a comparison of the results with those of other trials is difficult. Nevertheless, the results from our study are comparable to those of previous trials and registries, considering an older population with poorer health status, which represent real-world conditions. The largest study that addressed the issue of ostial versus distal LM disease was the analysis from the DELTA registry (Drug-Eluting Stent for Left Main Coronary Artery Disease), including 1.612 patients with LM disease [4]. In this multicenter registry 482 patients with ostial LM lesions were compared to 1.130 patients with distal LM lesions for a median follow-up of 1.250 days. This trial demonstrated that PCI for ostial/midshaft lesions was associated with better clinical outcomes at long term follow-up than for distal lesions in LM disease, largely because of a lower need for repeat revascularization. Noteworthy, no significant differences were observed in terms of all-cause death and the composite endpoint of all-cause death and MI. The trial confirmed the results of previous studies, reporting better outcomes of PCI for lesions not involving the distal LM [15,16]. Our results completely correspond to these findings. Although baseline

characteristics were equally distributed in both groups, hard endpoints death and myocardial infarction were similar in both groups. One death in the ostial LM group occurred as a result of a target lesion non-ST-elevating myocardial infarction after 239 days. One patient died in the distal LM group because of a target lesion ST-elevating myocardial infarction after 244 days follow-up. The most striking difference between ostial/midshaft and distal bifurcation LM disease remains the need for repeat revascularization due greater late lumen loss and higher binary restenosis.

A trend toward higher rates of binary restenosis after PCI of distal LM lesions was already suggested in former analyses [4]. The development of atherosclerosis in the LM coronary artery has been linked to flow hemodynamics, with atherosclerotic plaques described at areas of low endothelial shear stress in the lateral wall of the bifurcation, opposite of the carina [19]. Furthermore, the utilized stent implantation technique might play an eminent role. Results of the DKCRUSH-II -trial show that an upfront two-stent strategy is associated with a significant improvement in clinical outcomes compared to a single-stent approach in complex coronary bifurcation lesions [20]. According to current data, DK Crush represents the preferred treatment strategy for bifurcation lesions [21]. To what extent a consistent application of this strategy would have influenced our angiographic results remains unanswered. In our study, distal LM lesion segments nearest to the bifurcation showed the highest values for late lumen loss with highest values in segment 7 ($0.37 \pm 1.13$) and 11 ($0.37 \pm 0.73$) and rather focused on the main vessel ($0.42 \pm 0.97$ mm).

It is also interesting that actual TLR rate is higher than the binary restenosis. This raises the question whether it is really recommendable to require symptom-free patients for angiographic follow-up. D'Ascenzo and colleagues revealed in a propensity score matched analysis with 440 patients that a planned angiographic follow-up after PCI of LM disease results in more TLR, but may reduce mortality [22]. Up to date, the optimal choice for follow up these patients is still largely debated. While angiographic restenosis has been linked to mortality [23], angiographic control was associated with higher rates of revascularization without affecting mortality [24]. Consequently, routine angiographic follow-up for LM disease is actually not recommended by guidelines [25].

## 5. Limitations

The limited number of subjects and the retrospective manner of the study is a limitation of the trial. *IVUS/OCT was not performed routinely* and was not analyzed. T-stenting was the leading technique in case of two-stent strategy (80.0%), and therefore no angiographic results for the use of DK Crush for bifurcation stenting can be presented. However, according to current data, this technique should be privileged for complex coronary bifurcation disease. Further studies issuing this topic are required.

## 6. Conclusion

PCI of ostial LM is accomplished with low late lumen loss and binary restenosis rates.

In distal LM lesions quantitative coronary analysis reveals highest values for late lumen loss and binary restenosis in segments nearest to the bifurcation. Presence of diabetes mellitus as well as late lumen loss in segments close to the bifurcation are independent correlates for occurrence of MACE during 12 months follow-up.

## Disclosure statement

The authors report no financial relationships or conflicts of interest. The study was carried out within the scope “research and education” of the University hospital Ulm.

## CRediT authorship contribution statement

**Tilman Stephan:**Data curation, Writing - original draft.**Mirjam Keßler:**Visualization, Validation.**Nadine Goldberger:**Data curation, Software, Investigation.**Wolfgang Rottbauer:**Supervision.**Sinisa Markovic:**Conceptualization, Methodology, Software, Writing - review & editing.

## Declaration of competing interest

None.

## Acknowledgements

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