Culotte versus T-stenting in bifurcation lesions: Immediate clinical and angiographic results and midterm clinical follow-up

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Background Stenting the main vessel with provisional stenting of the side branch (SB) is the method of choice for most bifurcation lesions. There is limited data on which of the two techniques of bifurcation stenting compatible with a provisional approach, culotte or T-stenting, offers the best outcome.

Methods Between February 2004 and October 2005, 80 consecutive patients with bifurcation lesions requiring a second stent on the SB were treated with either culotte (n = 45) or T-stenting (n = 35). Coronary angiograms were analyzed using a quantitative angiography system dedicated to bifurcations. Propensity scores were used to adjust for baseline differences between groups.

Results Acute procedural success was 100% for both groups. Residual diameter stenosis of the SB ostium was 3.44% ± 7.39% in the culotte group versus 12.55% ± 11.47% in the T-stenting group ($P < .0001$). One patient (2.2%) in the culotte group had subacute thrombosis 2 days after the procedure. The culotte group had a lower target lesion revascularization rate compared with the T-stenting group (8.9% vs 27.3% propensity score adjusted; $P = .014$) and a trend toward lower major cardiac adverse events at 9 months (13.3% vs 27.3%; $P = .051$).

Conclusion Both techniques of provisional SB stenting in bifurcation lesions achieve high procedural success with low complication rates. The culotte technique yields a better immediate angiographic result at the SB ostium, and, using drug-eluting stents, a better clinical outcome at 9 months. (Am Heart J 2007;154:336-43.)

When feasible, stenting of the main vessel (MV) with provisional stent implantation of the side branch (SB) is the technique of choice for treating bifurcation lesions. Various studies in the drug-eluting stent (DES) era suggest that there is no advantage on restenosis with the universal use of 2 stents for bifurcation lesions.[1-3] In fact, such a strategy confers a greater risk of developing subacute or late thrombosis, with longer procedure and fluoroscopy times, higher contrast volumes, and higher rates of procedure-related increases in biomarkers of myocardial injury.[3] There is no consensus, however, on the best technique when the provisional approach fails. Two methods can be used to implant the second stent: T-stenting and the culotte technique, but no studies have addressed the relative merits of these techniques to optimize the immediate angiographic result and midterm clinical outcome.

The aim of this study was to compare (*a*) the immediate angiographic result using a new dedicated quantitative angiography program for bifurcation lesions and (*b*) the midterm clinical outcome of the implantation of sirolimus or paclitaxel-eluting stents in bifurcation lesions using culotte and T-stenting.

Methods

Study population

All consecutive patients treated with DES, either sirolimus-eluting (Cypher/Cypher Select; Cordis/Johnson & Johnson, Warren, NJ) or paclitaxel-eluting (Taxus Liberte, Boston Scientific, Natick, MA) for bifurcation lesions were entered into a dedicated database. Patients were excluded if they had an acute myocardial infarction (MI) in the 24 hours preceding the index procedure or if they were treated with any other bifurcation technique. Patients were divided into 2 groups based on the technique used, culotte or T-stenting, and were categorized using the Medina classification.[4] All patients gave written informed consent before the procedure.

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Procedure

The T-stenting technique was introduced by Teirstein[5] and modified to its current form by the Paris-Massy group.[6] It involves stenting of the SB from the ostium, usually after stenting the MV. A second wire is left in position in the SB and jailed by the MV stent. The favorable modification of the angle of origin of the SB and the guidance offered by the jailed wire facilitate entering the SB with MV wire or a third wire. After dilating the stent struts, a second stent is implanted right from the ostium with final kissing balloon dilatation. Occasionally, when the SB is jeopardized by initial predilatation (eg, large dissection), the SB stent can be used first, possibly inserted together with a balloon positioned in the MV and inflated after SB deployment to ensure access to the MV.

In the initial description of the culotte technique by Chevalier et al[7] and Colombo et al,[1] the order is often reversed because it is easier to insert the first stent in the vessel with the sharpest angulation (usually the SB). Modern low-profile stents are firmly crimped and allow the use of the culotte technique in a provisional fashion. Deployment of the first stent traps the wire placed in the other daughter vessel behind the stent struts, and a new wire must be used to recross the struts of the first stent deployed. After removal of the jailed wire, the struts of the first stent are dilated with a balloon enabling passage of a second stent into the unstented daughter vessel. Crossing the struts of the newly deployed stent with a new wire in the direction of the first daughter vessel is required to end the procedure with kissing balloon dilatation.

Pharmacological treatment and follow-up

Before the procedure, all patients were pretreated with aspirin and clopidogrel. A 300- to 600-mg loading dose of clopidogrel was administered before the index procedure unless patients were on chronic treatment. Six French guiding catheters with large inner lumen (0.71 in; Launcher, Medtronic) were used in 86.2% of cases, with low-profile monorail balloons (Maverick/Quantum Maverick, Boston Scientific, Natick, MA and Sprinter, Medtronic, Minneapolis, MN) used for final kissing inflation.

During the procedure, unfractionated heparin was given to maintain an activated clotting time ≥250 seconds with an initial bolus of 70 IU/kg. Administration of glycoprotein IIb/IIIa inhibitors was at the operator's discretion. Troponin I, creatine kinase (CK) and its MB fraction (CK-MB) were routinely measured between 12 and 24 hours in all patients after the index procedure. Aspirin was continued indefinitely, and clopidogrel 75 mg/d was continued for at least 12 months after the procedure. Clinical follow-up was performed by outpatient visit or telephone contact. Angiographic follow-up was not routine but was recommended in cases of unprotected left main treatment, recurrent angina, or evidence of positive or equivocal stress test.

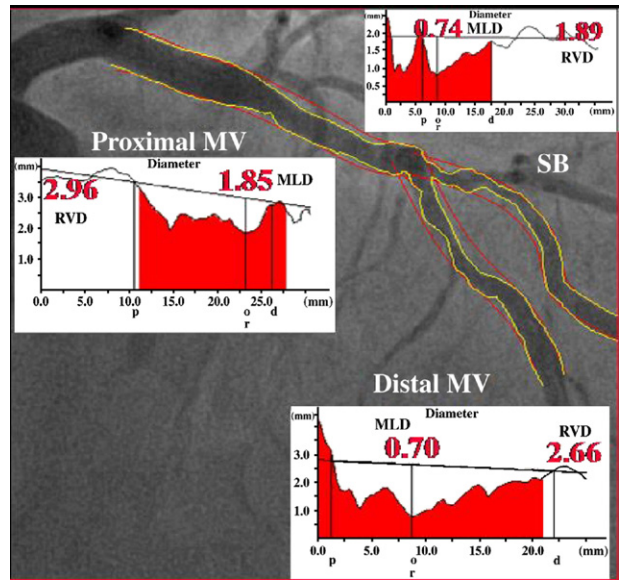
Definitions

Procedural success was defined as angiographic success (<20% residual stenosis at visual estimate) with no death, emergency coronary artery bypass grafting, or Q-wave MI in the 24 hours after the procedure. Major adverse cardiac events (MACE) were defined as cardiac death, MI, target vessel revascularization (TVR), or target lesion revascularization (TLR). All deaths were considered cardiac unless otherwise documented.

A diagnosis of MI was made when there was documentation of new pathologic Q waves or elevation of CK-MB greater than 3 times the upper limit of normal (non–Q-wave MI). Target lesion revascularization was defined as repeat revascularization secondary to a stenosis ≥50% in the stent or within 5 mm proximal or distal to the stent edges in either the MV or SB on follow-up angiography. Target vessel revascularization was defined as repeat revascularization on the target vessel involving the treated or other segments.

Confirmed thrombosis was defined as angiographically or pathologically documented occlusion with thrombosis in myocardial infarction grade 0/1 flow or residual thrombus at the stent site occurring within 24 hours of the procedure (acute), between 24 hours and 1 month after the procedure (subacute), or >1 month after the procedure (late thrombosis). Suspected stent thrombosis was defined as sudden death or MI with electrocardiographic changes in the territory of the treated artery without demonstration at angiography or on postmortem examination.

Figure 1

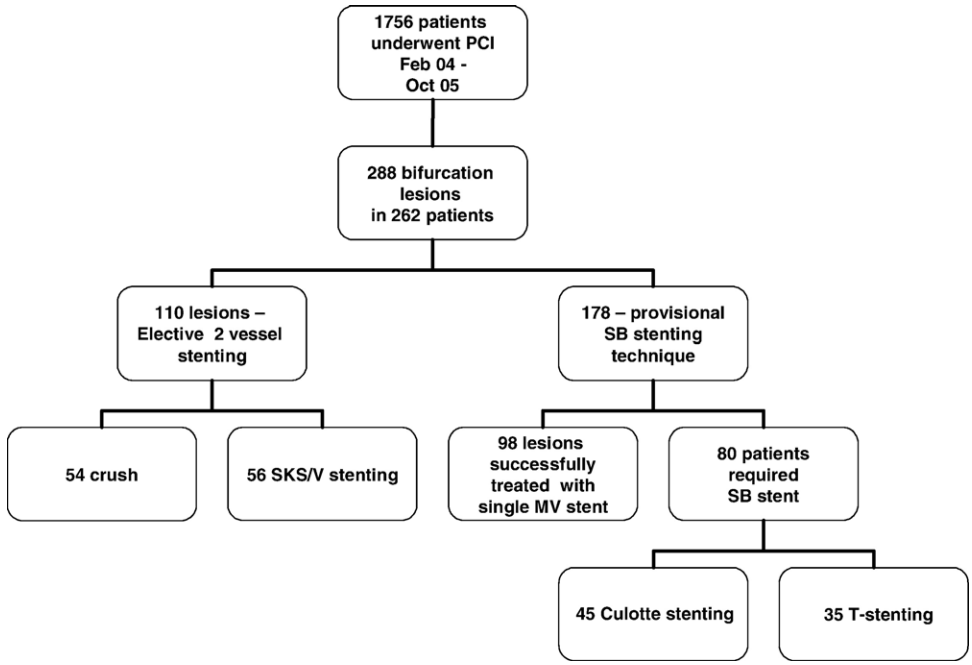


The QVA software requires the user to only define the start point for the vessel and the 2 end points at the distal MV and SB. This is different to the traditional quantitative coronary angiography analysis where the user needs to analyze the MV and the SB independently. Values for the RVD and MLD are shown for this particular bifurcation lesion involving the left anterior descending artery and diagonal branch.

Quantitative Vascular Arteriography analysis

The Quantitative Vascular Arteriography (QVA) bifurcation software (Medis, Leiden, The Netherlands) used in this study has been previously described.[8] In brief, the user defines a start point in the proximal vessel and 2 end points in the distal branches. From the start point, the arterial path lines are

Figure 2



Pathway for the identification of the patients receiving treatment of a bifurcation lesion using either the culotte or T-stenting techniques.

Table I. Baseline clinical characteristics

	Entire cohort (n = 80)	Culotte (n = 45)	T-stenting (n = 35)	*P**
Age, mean ± SD, y	66.4 ± 11.3	68.1 ± 10.0	64.3 ± 12.6	.13
Male, n (%)	63 (78.8)	36 (80.0)	27 (77.1)	.75
Diabetes mellitus, n (%)	21 (28.0)	10 (24.4)	11 (32.4)	.44
Hypercholesterolemia, n (%)	52 (69.3)	31 (75.6)	21 (61.8)	.19
Hypertension, n (%)	51 (68.0)	28 (68.3)	23 (67.7)	.95
Current/former smoker, n (%)	31 (41.3)	16 (39.0)	15 (44.1)	.65
Family history, n (%)	29 (38.7)	15 (36.6)	14 (41.2)	.68
Unstable angina, n (%)	20 (25.0)	12 (26.7)	8 (22.9)	.28
Prior MI, n (%)	37 (49.3)	19 (47.5)	18 (51.4)	.73
Prior PCI, n (%)	21 (27.3)	17 (40.5)	4 (11.4)	.01
Prior CABG, n (%)	4 (5.2)	3 (7.1)	1(2.9)	.39
Diseased vessels (1/2/3)	13/28/39	7/15/23	6/13/15	
LVEF, mean ± SD, %	55.6 ± 10	57.6 ± 9	53.2 ± 11	.07
GPIIb/IIIa inhibitors, n (%)	31 (41.3)	22 (55.0)	9 (25.7)	.01
Aspirin, n (%)	80 (100)	45 (100)	35 (100)	–
Clopidogrel, n (%)	80 (100)	45 (100)	35 (100)	–
Lipid-lowering therapy, n (%)	69 (89.6)	41 (97.6)	28 (80.0)	.01
β-Blockers, n (%)	42 (63.6)	23 (54.8)	19 (79.2)	.05
ACEI, n (%)	52 (70.3)	32 (76.2)	20 (62.5)	.20

ACEI, Angiotensin-converting enzyme inhibitor; *CABG*, coronary artery bypass graft surgery; *GP*, glycoprotein; *LVEF*, left ventricular ejection fraction.
*Culotte versus T-stenting.

defined automatically, and 3 contours are detected using the Minimum Cost Algorithm method[8] (Figure 1). Fragment delimiters are automatically delineated indicating the transition between the straight vessel fragments and the actual bifurcation (or central fragment). The 3 segments are then delineated from the 3 contours and the central fragment.[8]

Angiographic restenosis was defined as ≥50% diameter stenosis on QVA within a previously stented segment (stent and 5 mm proximal and distal) on follow-up angiography. Focal restenosis was defined as a restenotic lesion ≤10 mm in length. Diffuse restenosis was defined as a restenotic lesion >10 mm long.

Table II. Baseline lesion characteristics

	Entire cohort (n = 80)	Culotte (n = 45)	T-stenting (n = 35)
Total occlusion			
MV, n (%)	4 (5.0)	3 (6.6)	1 (2.9)
SB, n (%)	0	0	0
Restenotic lesions			
MV, n (%)	10 (12.5)	7 (15.5)	3 (8.6)
SB, n (%)	1 (1.3)	1 (2.2)	0
Lesion location			
LAD/LCX, n (%)	5 (6.3)	2 (4.4)	3 (8.6)
LAD/diagonal, n (%)	45 (56.3)	25 (55.5)	20 (57.1)
LCX/OM, n(%)	25 (31.3)	15 (33.3)	10 (28.6)
RCA/PL, RCA/PDA, n (%)	5 (6.3)	3 (6.6)	2 (5.7)

LAD, Left anterior descending artery; *LCX*, left circumflex artery; *OM*, obtuse marginal artery; *PDA*, posterior descending artery; *PL*, posterolateral artery; *RCA*, right coronary artery.

Statistical analysis

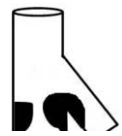
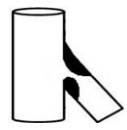
Statistical calculations were performed using StatView 5.0 and R version 2.4.1. Numerical values are presented as mean ± standard deviation. Comparisons between groups were performed using unpaired Student *t* test or χ^2 test as appropriate. Predictors of TLR and MACE within 9 months were identified between baseline demographic and lesion and procedural characteristics using univariate logistic regression analysis. Univariate predictors were included in a multivariate model, and selection of the best model was performed by minimization of the Akaike information criterion. Propensity scores were used to create a covariate that summarizes confounders within baseline demographic and angiographic characteristics and assesses the independent effect of treatment technique on clinical outcome measures (TLR/MACE). In short, a logistic regression model was constructed predicting the probability that a patient with certain characteristics would be treated by culotte or T-stenting.[9-11] Independent variables in the logistic regression model included baseline clinical and angiographic parameters such as age, previous MI, dyslipidemia, β-blocker use, GPIIb/IIIa inhibitors, preprocedural MV and SB reference vessel diameter (RVD) and minimal lumen diameter (MLD). The C-statistic of the model was 0.81, suggesting good accuracy in predicting the type of treatment (culotte vs T-stenting). All patients received an estimated propensity score and were sorted into 4 adjacent bins accordingly. To estimate the impact of treatment technique on outcome measures, a different logistic regression model was used with outcome as a dependent variable and treatment type as well as categories of propensity score as independent variables. Given the small sample size, the confidence intervals (CI) of the odds ratios (ORs) were derived by bootstrapping (R package "boot") to improve the accuracy.[12] A *P* value of .05 was used as the criterion for statistical significance.

Results

Baseline demographic and procedural data

Between February 2004 and October 2005, a total of 1756 patients underwent a percutaneous coronary intervention (PCI) at our institution (Figure 2). Of these,

Table III. Bifurcation lesion type according to the Medina classification[4]

		Entire cohort (n = 80)	Culotte (n = 45)	T–stenting (n = 35)
1,0,0		7 (8.8)	5 (11.1)	2 (5.7)
0,1,0		11 (13.8)	6 (13.3)	5 (14.3)
1,1,0		7 (8.8)	4 (8.9)	3 (8.6)
1,1,1		11 (13.8)	6 (13.3)	5 (14.3)
1,0,1		10 (12.5)	6 (13.3)	4 (11.4)
0,1,1		21 (26.3)	13 (28.9)	8 (22.9)
0,0,1		13 (16.3)	5 (11.1)	8 (22.9)

This simple system divides the bifurcation into 3 segments (proximal MV, SB, distal MV). A 1 or 0 is allocated according to whether there is a lesion at each segment of the bifurcation, so, for example, Medina 1,1,0 indicates plaque in the proximal and distal MV but no disease in the SB.

Table IV. Procedural characteristics

	Entire cohort (n = 80)	Culotte (n = 45)	T-stenting (n = 35)	P*
Mean stent length, mean ± SD, mm				
MV	20.84 ± 6.01	19.89 ± 6.19	21.58 ± 5.84	.21
SB	16.60 ± 6.01	17.87 ± 5.81	15.00 ± 5.93	.03
Mean stent diameter, mean ± SD, mm				
MV	2.93 ± 0.35	2.92 ± 0.36	2.96 ± 0.35	.61
SB	2.57 ± 0.29	2.59 ± 0.27	2.55 ± 0.32	.55
Maximum pressure, mean ± SD, atm				
MV	16.46 ± 2.50	16.40 ± 2.40	16.54 ± 2.65	.80
SB	14.91 ± 2.42	14.91 ± 2.84	14.91 ± 1.77	.99
Maximum balloon diameter (mm)				
MV	3.22 ± 0.34	3.20 ± 0.36	3.24 ± 0.31	.57
SB	2.77 ± 0.42	2.73 ± 0.27	2.83 ± 0.55	.31
Final kissing balloon dilatation, n (%)	68 (85)	38 (84.4)	28 (85.7)	.48
Cypher stent, n (%)	39 (48.8)	26 (57.8)	13 (37.1)	.07
Taxus stent, n (%)	41 (51.2)	19 (42.2)	22 (62.9)	.07

*Culotte versus T-stenting.

288 lesions in 262 patients (15%) were bifurcation lesions with a visually estimated percent diameter stenosis (%DS) ≥50% involving the MV at or within 5 mm proximal or distal to the origin of a SB >2 mm in diameter. Elective 2-vessel stenting was performed in 110 lesions (38.2%). A provisional SB stenting technique was used in the remaining cases. A single stent in the MV across the origin of the SB was successful in 98 lesions (37.4%) with final kissing inflation in 85.3% of cases.

In 80 lesions (27.8%), a second stent was required in the SB because of the presence of severe impairment of the SB during the angioplasty procedure (dissection or severe ostial stenosis due to plaque shift). The second stent was implanted using either a culotte technique (45 lesions/patients) or T-stenting (35 lesions/patients) according to the operator's preference. Baseline demographic characteristics and differences between the 2 groups are shown in Table I. Patients were of similar age and had similar risk factors. More patients in the culotte group had undergone previous PCI, were on lipid-lowering therapy, and received a glycoprotein IIb/IIIa receptor antagonist. Fewer patients in the culotte group were on β-blockers. Left ventricular ejection fraction was higher in the culotte group.

Baseline lesion and procedural characteristics are described in Tables II-IV. Procedural and angiographic success was achieved in all patients. The mean stent length implanted for the SB was longer in the culotte group compared with T-stenting (17.87 ± 5.81 vs 15.00 ± 5.93 mm; $P = .03$), but this apparent difference is probably only caused by the different protrusion of the SB stent into the MV with the 2 techniques. Final kissing balloon inflation was performed in 84.4% in the culotte versus 85.7% in the T-stenting group, ($P = .48$) with similar balloon diameter and pressure. Cypher stents were used more often in the culotte group compared with the T-stenting group, although this was not statistically significantly (.07).

Quantitative vascular arteriography analysis

Table V shows the results of the quantitative angiographic analysis. The 2 groups had similar baseline angiographic RVD and stenosis severity in the proximal MV and the SB. The only exception was the RVD of the distal MV in the T-stenting group, which was higher compared to that of the culotte group. Postprocedural quantitative analysis of the distal MV revealed a small but significant difference in residual diameter stenosis (2.13% ± 5.39% for the culotte group and 5.17% ± 6.23% for the T-stenting group; $P = .02$). Furthermore, the SB diameter stenosis in the culotte group was 3.44% ± 7.39% versus 12.55% ± 11.47% in the T-stenting group ($P < .0001$).

The mean preprocedure angle between the distal MV and the SB was 53.6° ± 20.8° for the culotte and 60.4° ± 22.5° for the T-stenting group ($P = .16$). Mean postprocedure angles were 48.9° ± 12.5° and 62.4° ± 23.5° for the culotte and T-stenting groups, respectively ($P = .001$), that is, the angle between the daughter vessels decreased by a mean of 4.7° in the culotte group and increased by 2.0° in the T-stenting group ($P = .01$).

Angiographic follow-up was performed in 17 (37.7%) patients in the culotte group and 18 (51.4%) patients in the T-stenting group at a median period of 6.1 (range, 3.7-9.4) months after the index procedure in the culotte and 6.8 (range, 4.1-9.6) months in the T-stenting group, respectively. The late lumen loss for the SB was 0.28 ± 0.45 mm in the culotte group and 0.72 ± 0.71 mm in the T-stenting group ($P = .046$).

Clinical outcomes

Clinical follow-up data were available for 80 (100%) patients at 30 days and for 78 (98%) at 9 months (45 in

Table V. Quantitative vascular angiographic analysis

	Entire cohort (n = 80)	Culotte (n = 45)	T-stenting (n = 35)	P*
MV proximal (baseline)				
RVD (mm)	3.04 ± 0.63	2.98 ± 0.71	3.12 ± 0.52	.29
MLD (mm)	1.73 ± 0.83	1.59 ± 0.78	1.90 ± 0.88	.10
%DS	43.68 ± 23.63	46.19 ± 23.11	40.45 ± 24.24	.28
Lesion length (mm)	6.37 ± 4.71	6.73 ± 5.06	5.92 ± 4.24	.45
SB (baseline)				
RVD (mm)	2.35 ± 0.44	2.29 ± 0.49	2.42 ± 0.38	.21
MLD (mm)	1.08 ± 0.61	1.03 ± 0.59	1.14 ± 0.63	.42
%DS	54.61 ± 21.33	55.54 ± 21.61	53.42 ± 21.22	.66
Lesion length (mm)	8.05 ± 4.67	7.45 ± 4.42	8.83 ± 4.93	.19
MV distal (baseline)				
RVD (mm)	2.57 ± 0.50	2.44 ± 0.49	2.74 ± 0.48	.0066
MLD (mm)	1.22 ± 0.65	1.19 ± 0.63	1.25 ± 0.69	.69
% DS	53.34 ± 21.35	52.35 ± 20.46	54.61 ± 22.69	.64
Lesion length (mm)	8.70 ± 6.11	7.70 ± 4.62	9.98 ± 7.49	.09
MV proximal (postprocedural)				
RVD (mm)	3.25 ± 0.63	3.15 ± 0.57	3.37 ± 0.68	.20
MLD (mm)	3.18 ± 0.58	3.11 ± 0.56	3.27 ± 0.61	.11
%DS	0.88 ± 5.11	1.18 ± 5.15	0.49 ± 5.11	.55
Lesion length (mm)	0.51 ± 1.03	0.57 ± 1.22	0.44 ± 0.74	.56
SB (postprocedural)				
RVD (mm)	2.53 ± 0.65	2.56 ± 0.76	2.49 ± 0.47	.63
MLD (mm)	2.30 ± 0.52	2.39 ± 0.49	2.18 ± 0.54	.08
% DS	7.43 ± 10.38	3.44 ± 7.39	12.55 ± 11.47	<.0001
Lesion length (mm)	1.40 ± 1.71	0.80 ± 1.32	2.17 ± 1.85	.0002
MV distal (postprocedural)				
RVD (mm)	2.73 ± 0.46	2.67 ± 0.49	2.80 ± 0.42	.18
MLD (mm)	2.62 ± 0.47	2.59 ± 0.48	2.67 ± 0.47	.43
%DS	3.44 ± 5.92	2.13 ± 5.39	5.17 ± 6.23	.02
Lesion length (mm)	6.37 ± 4.71	6.73 ± 5.06	5.92 ± 4.24	.45
Bifurcation angles				
Preprocedure	56.6 ± 21.7°	53.6 ± 20.8°	60.4 ± 22.5°	.16
Postprocedure	54.9 ± 19.3°	48.9 ± 12.5°	62.5 ± 23.5°	.001
MV proximal (follow-up)	n = 35	n = 17	n = 18	
RVD (mm)	3.35 ± 0.46	3.41 ± 0.45	3.29 ± 0.47	.42
MLD (mm)	3.05 ± 0.54	3.13 ± 0.45	2.98 ± 0.62	.42
%DS	8.86 ± 10.17	7.86 ± 8.46	9.81 ± 11.72	.58
Lesion length (mm)	2.88 ± 3.80	2.83 ± 3.75	2.94 ± 3.93	.93
Late lumen loss (mm)	0.29 ± 0.50	0.23 ± 0.52	0.34 ± 0.49	.70
SB (follow-up)				
RVD (mm)	2.73 ± 0.43	2.76 ± 0.49	2.71 ± 0.39	.74
MLD (mm)	1.93 ± 0.78	2.26 ± 0.62	1.62 ± 0.80	.012
%DS	29.53 ± 25.24	17.90 ± 15.41	40.52 ± 28.07	.006
Lesion length (mm)	4.06 ± 3.46	4.30 ± 4.40	3.83 ± 2.36	.70
Late lumen loss (mm)	0.51 ± 0.63	0.28 ± 0.45	0.72 ± 0.71	.046
MV distal (follow-up)				
RVD (mm)	2.88 ± 0.48	2.91 ± 0.51	2.86 ± 0.47	.75
MLD (mm)	2.27 ± 0.79	2.34 ± 0.72	2.20 ± 0.87	.62
%DS	21.65 ± 22.53	18.84 ± 20.28	24.32 ± 24.74	.48
Lesion length (mm)	4.08 ± 3.71	3.70 ± 3.66	4.45 ± 3.82	.56
Late lumen loss (mm)	0.46 ± 0.64	0.42 ± 0.61	0.49 ± 0.68	.93

Values are presented as numbers (%) or mean ± SD.
*Culotte versus T-stenting.

the culotte and 33 in the T-stenting group) (Table VI). The overall rate of in-hospital MACE was 8%, with 2 (5%) of the patients in the culotte and 4 (12%) of the patients in the T-stenting group having a diagnosis of non–Q-wave MI. At 30 days, there was 1 noncardiac death in the culotte group secondary to pneumonia in an 85-year-old female patient. One patient (2%) in the culotte group had subacute stent thrombosis in the SB (obtuse marginal) with subsequent non–Q-wave MI 2 days postprocedure. The patient was taking aspirin and clopidogrel and was treated with repeat PCI after confirmation of distal dissection.

Thirteen (16%) patients underwent TLR within 9 months of the index procedure (4 patients in the

Table VI. Clinical outcomes

	Entire cohort (n = 80)	Culotte (n = 45)	T-stent (n = 35)
In-hospital MACE, n (%)			
Cardiac death	0	0	0
Noncardiac death	0	0	0
Q-wave MI	0	0	0
Non–Q-wave MI	6 (7.5)	2 (4.4)	4 (11.4)
TLR	0	0	0
TVR	0	0	0
1-mo MACE, n (%)			
Cardiac death	1 (1.3)	1 (2.2)	0
Noncardiac death	0	0	0
Q-wave MI	0	0	0
Non–Q-wave MI	1 (1.3)	1 (2.2)	0
TLR	1 (1.3)	1 (2.2)	0
TVR	1 (1.3)	1 (2.2)	0
9-mo MACE, n (%)	15 (19.2)	6 (13.3)	9 (27.3)
Cardiac death	0	0	0
Noncardiac death	1 (1.3)	1 (2.2)	0
Q-wave MI	0	0	0
Non–Q-wave MI	4 (5.1)	2 (4.4)	2 (6.1)
TVR	14 (17.9)	5 (11.1)	9 (27.3)
9-mo TLR, n (%)	13 (16.7)	4 (8.9)	9 (27.3)
MV	3 (3.8)	2 (4.4)	1 (3.0)
SB	4 (5.1)	1 (2.2)	3 (9.1)
Both	6 (7.7)	1 (2.2)	5 (15.2)
9-mo stent thrombosis, n (%)			
Intraprocedural	0	0	0
Subacute	1 (1.3)	1 (2.2)	0
Late	0	0	0

culotte group [8.9%] vs 9 in the T-stenting group [27.3%]; $P = .06$). On logistic regression analysis, the only predictor of TLR within 9 months was treatment type (OR of T-stenting vs the culotte technique 3.84; 95% CI, 1.12-15.45; $P = .04$). Six patients (13.3%) had MACE at 9 months in the culotte group versus 9 (27.3%) in the T-stenting group ($P = .15$). Diabetes mellitus was the only significant predictor of MACE at 9 months (OR, 3.36; 95% CI, 1.05-11.06; $P = .04$).

After adjustment for baseline differences between the culotte and T-stenting groups using propensity scores, treatment type was a significant predictor of TLR at 9 months (OR for T-stenting 6.66; 95% bootstrap CI, 1.66-44.33; $P = .014$) and was associated with a borderline significant difference in MACE at 9 months (OR for T-stenting 3.87; 95% bootstrap CI, 1.03-21.56; $P = .051$).

Discussion

This study is, to our knowledge, the first report in the DES era comparing the 2 double stenting techniques for bifurcation lesions suitable for a provisional approach: culotte and T-stenting. The culotte technique for bifurcation lesions was previously limited by high thrombosis and restenosis rates when bare metal stents were used[13] and has hence fallen out of favor among interventional cardiologists. Moreover, culotte was perceived as a 2-stent technique, unsuitable for a provisional approach. Our study shows that high procedural success and good midterm clinical outcomes can be expected when performing culotte stenting using DES. Culotte stenting of bifurcation lesions ensures complete lesion coverage of all segments,[14] which may explain the significantly lower mean residual stenosis at the SB ostium compared to T-stenting.

Midterm safety and efficacy of the culotte stenting technique

The 9-month TLR rate in our DES culotte group was significantly lower compared to that of the T-stenting group. We observed no episodes of intraprocedural stent thrombosis with a rather liberal use of glycoprotein IIb/IIIa receptor antagonists, at least for European standards.

Comparison with previous studies

The overall TLR rate (16%) in our study is higher than that reported in the group receiving 2 stents with T-stenting (n = 63) of the SIRIUS Bifurcations Study (TLR rate 9.5%).[1] Similarly, Tanabe et al[15] reported a TLR rate of 8.6% in 58 patients treated with various bifurcation techniques using sirolimus-eluting stents. In these studies, however, complex bifurcation stenting was used liberally for most lesions and was not reserved, as in this study, only to lesions not responding to single stent implantation. A common feature of these bifurcation studies is localization of restenosis at the SB ostium. Incomplete lesion coverage (particularly with T-stenting where the ostium may be missed) or stent underexpansion, common at the SB ostium, is thought to contribute to this phenomenon.[13,16,17] Our study seems to confirm this hypothesis. In fact, we observed a significantly higher residual diameter stenosis at the SB ostium in the T-stenting group despite a similar dilatation pressure and balloon-to-artery ratio in the culotte and T-stenting groups.

Data for culotte stenting in the DES era are limited. In a series of 23 patients treated with the culotte technique using DES, Hoye et al[17] reported a TLR rate at 8 months of 5%, with a late lumen loss for the MV and SB of 0.48 ± 0.56 and 0.53 ± 0.33 mm, respectively, with binary restenosis rates of 18.8% and 12.5%. Most of the repeat procedures in our study were due to proximal MV restenosis. This may in part be due to the initial use of normal length semicompliant balloons protruding outside the stented segment resulting in edge restenosis.

The recently published NORDIC Bifurcation study[3] randomized 413 patients with bifurcation lesions to stenting only of the MV (n = 207) or both the MV and SB (n = 206) with 50% treated by crush stenting, 21% by culotte, and 29% by a variety of techniques

(predominantly T-stenting). Unfortunately, there is no breakdown of the results for each of the techniques used in the complex treatment arm. In this arm, the TLR rate at 6 months remained extremely low (1%) using sirolimus-eluting stent, although restenosis did occur both at the proximal MV and SB, which was usually left untreated. Potential differences include the shorter duration of clinical follow-up (6 vs 9 months) and universal use of Cypher stents in NORDIC (48.7% in our study). The higher rate of TLR in our study may also be explained by the higher rate of assessing patients using functional tests post procedure and treatment of silent ischemia.

The bifurcation angle

Lefevre et al[18] categorized bifurcation lesions according to the angle between the MV and SB as either Y-shaped (SB and MV angle less than 70°) or T-shaped (SB and MV angle >70°). This separation has procedural implications, with Y-shaped lesions generally allowing easier SB access but with greater potential for plaque shift in heavily atheromatous vessels.[18] Dzavik et al[19] recently found that bifurcation angle >50° was an independent predictor of MACE in patients undergoing crush stenting. The authors postulated that lesions with high bifurcation angles are susceptible to increased turbulent flow that is further exacerbated by suboptimal dilatation of the crushed SB stent.[19] The presence of a relatively rigid stent straightening the transition of the MV into the SB in the culotte group may also explain the postprocedural reduction of the angle between the 2 daughter vessels. We could not find, however, any relationship between absolute postprocedural angle and pre/postprocedural angle changes and TLR or MACE.

Limitations

The present study has several limitations due to its retrospective nature. The most important is the lack of randomization with regard to stenting strategy and the use of final kissing inflation, both left to the operator's discretion. Moreover, the relatively small number of patients and the low incidence of events used as clinical end points (TLR, MACE) may have affected part of our analysis, resulting in wide CIs for the ORs. Propensity scores were used in an attempt to account for the differences between the culotte and T-stenting groups and the small number of events, but larger, randomized studies are needed to confirm our findings.

Conclusions

When used for SB stenting in a provisional stent strategy, culotte and T-stenting of bifurcation lesions using DES achieve high procedural success with low complication rates. The culotte technique appears to provide a better immediate angiographic result at the level of the SB compared to the T-stenting and is associated with a lower TLR rate at 9 months follow-up.

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