

Small coronary vessel angioplasty: outcomes and technical considerations

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Abstract: Small vessel (<3 mm) coronary artery disease is common and has been identified as independent predictor of restenosis after percutaneous coronary intervention. It remains controversial whether bare-metal stent (BMS) implantation in small vessels has an advantage over balloon angioplasty in terms of angiographic and clinical outcomes. Introduction of drug-eluting stent (DES) has resulted in significant reduction in restenosis and the need for repeat revascularization. Several DESs have been introduced resulting in varying reduction in outcomes as compared with BMS. However, their impact on outcomes in small vessels is not clearly known. It is expected that DES could substantially reduce restenosis in smaller vessels. Large, randomized studies are warranted to assess the impact of different DESs on outcomes in patients with small coronary arteries.

Keywords: small coronary arteries, coronary artery disease, stent, drug-eluting stent, restenosis

Introduction

Coronary artery disease (CAD) is the leading cause of mortality and morbidity in the Western world.¹ Percutaneous coronary intervention (PCI) utilizing balloon angioplasty and stenting is a predominant treatment strategy for patients with CAD. Lesions involving the small coronary arteries (with a diameter of <3 mm) are the most relevant in terms of prevalence, and they account for around 40%–50% of all coronary stenosis.² Atherosclerosis of small arteries remains a major challenge to revascularization procedures, as coronary artery bypass grafting is limited by high rates of technical failure,³ and PCI is associated with an increased risk of restenosis and adverse outcome. Small coronary vessel angioplasty remains the independent predictor of repeat revascularization and adverse cardiac events.^{2,4,5} Percutaneous treatment of CAD has evolved from percutaneous balloon angioplasty to bare-metal stent (BMS) and more recently to drug-eluting stent (DES) implantation. As compared with balloon angioplasty, BMS prevents both early elastic recoil and late vascular remodeling in large vessels (>3 mm).^{6–10} However, this benefit is not shown in small coronary vessels (<3 mm).^{11–14} Stent implantation results in arterial injury, initiating a vasculoproliferative cascade with smooth muscle cell proliferation and migration resulting in neointimal hyperplasia. The amount of neointimal hyperplasia is largely independent of vessel size, and thus, late luminal loss, an angiographic measure of neointimal hyperplasia, is similar across a wide range of vessel diameters.^{15,16} Also, small vessels are more prone to restenosis than larger vessels because they are less able to accommodate neointimal tissue without compromising blood flow.¹⁷

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In this review, we describe the impact of balloon angioplasty, BMSs, and DESs on the outcomes after small vessel coronary intervention.

BMS vs balloon angioplasty in small vessels

Several randomized trials have compared stenting and percutaneous transluminal coronary angioplasty (PTCA), in terms of clinical and angiographic outcomes, in coronary arteries with a reference vessel diameter (RVD) of <3 mm. Agostoni et al¹⁸ evaluated these outcomes in a meta-analysis, and they included 13 studies involving 4,383 randomized patients: 2,097 to PTCA and 2,286 to stenting. The studies showing mortality, myocardial infarction (MI) rates, target lesion revascularization (TLR), and combined major adverse cardiac events (MACE) are shown in Table 1.

The mean age of patients in these studies was 62.1 ± 10 years, with 77.2% men and 28.9% with diabetes. BMSs were used in 6 trials (Park et al¹² ISAR-SMART, BESMART, SISA, RAP, CHIVAS), whereas a stent coated with heparin

(SISCA, COAST, Kinsara et al)²¹ or silicon carbide (SVS) or phosphorylcholine (ISAR-SMART, LASMAL, LASMAL 11) was used in the remainder. RVD was 2.33 ± 0.29 mm in the stent group and 2.31 ± 0.29 mm in PTCA group. The mean lesion length was 10.1 ± 5.2 mm, and crossover rate was 22.2% among PTCA group. Postprocedural mean diameter stenosis and minimal luminal diameter were significantly better after stenting as compared with PTCA.

The follow-up period ranged from 6–16 months. Death and MI rates did not differ significantly between groups (1.3% and 3.1% in the stent group vs 1.7% and 4.2% after PTCA, respectively). Stenting showed a significant reduction of the risk of TLR when compared with PTCA group (14.9% vs 18.7%, respectively). However, authors have mentioned that there was significant heterogeneity among the trials. Among the studies where optimal PTCA result (diameter stenosis <20%) was achieved, there was no difference in the repeat TLR rates (15% vs 16.7%). On the contrary, among trials in which a suboptimal PTCA result was achieved, stenting resulted in significant reduction of repeat TLR rates

Table 1 Comparison of angiographic characteristics, death, MI, TLR, and MACEs, following BMS and balloon angioplasty

Study	Total No. of patients	RVD (mm)	BMS vs balloon angioplasty			
			Death (%) OR (95% CI)	MI (%) OR (95% CI)	TLR (%) OR (95% CI)	MACE (%) OR (95% CI)
Park et al ¹²	120	<3.0	0.0 vs 0.0 NA	1.6 vs 3.2 0.49 (0.04–5.57)	3.3 vs 5.0 0.66 (0.11–4.07)	5.0 vs 8.3 0.58 (0.13–2.54)
ISAR-SMART ¹¹	404	2.0–2.8	0.9 vs 1.5 0.66 (0.11–3.93)	3.4 vs 3.0 1.15 (0.38–3.48)	20.1 vs 16.5 1.27 (0.77–2.11)	23.0 vs 19.5 1.28 (0.79–2.06)
BESMART ¹³	381	<3.0	0.52 vs 2.1 0.24 (0.03–2.19)	4.6 vs 5.8 0.80 (0.32–1.97)	13.5 vs 23.8 0.50 (0.29–0.85)	17.1 vs 29.6 0.49 (0.30–0.80)
SISA ¹⁹	351	2.3–2.9	0.6 vs 0.5 1.08 (0.07–17.36)	4.1 vs 9.8 0.39 (0.16–0.97)	20.7 vs 24.7 0.80 (0.48–1.31)	20.7 vs 25.2 0.77 (0.47–1.27)
SISCA ¹⁴	145	2.1–3.0	1.3 vs 1.4, 0.96 (0.06–15.63)	2.7 vs 1.4 1.94 (0.17–21.93)	9.4 vs 22.5 0.36 (0.14–0.94)	9.4 vs 23.9 0.33 (0.13–0.86)
COAST ²⁰	588	2.0–2.6	1.0 vs 0.0 4.52 (0.24–84.33)	0.5 vs 1.0 0.49 (0.07–3.53)	10.6 vs 14.3 0.71 (0.43–1.19)	11.7 vs 15.3 0.73 (0.44–1.20)
Kinsara et al ²¹	202	<2.5	1.0 vs 0.0 3.35 (0.13–83.11)	6.2 vs 6.6 0.94 (0.31–2.91)	12.5 vs 23.5 0.64 (0.45–0.92)	19.7 vs 30.1 0.57 (0.30–1.09)
SVS ²²	496	2.0–3.0	2.4 vs 2.4 0.98 (0.31–3.09)	4.8 vs 3.6 1.33 (0.55–3.21)	18.8 vs 14.2 1.40 (0.97–2.25)	23.2 vs 18.6 1.31 (0.85–2.03)
RAP ²³	426	2.2–2.7	0.47 vs 1.4 0.33 (0.3–3.23)	0.9 vs 1.4 0.67 (0.11–4.06)	12.2 vs 22.4 0.48 (0.29–0.91)	13.6 vs 25.2 0.47 (0.29–0.77)
CHIVAS ²⁴	302	<3.0	0 vs 2.5 0.11 (0.01–2.11)	0 vs 0.6 0.34 (0.01–8.53)	10.8 vs 14.9 0.69 (0.35–1.37)	10.8 vs 18.1 0.55 (0.28–1.06)
ISAR-SMART II ²⁵	502	<2.5	3.9 vs 3.6 1.10 (0.44–2.75)	3.9 vs 4.0 0.98 (0.40–2.91)	20.1 vs 20.5 0.98 (0.63–1.51)	26.8 vs 26.9 1.0 (0.67–1.48)
LASMAL ²⁶	246	2.0–2.9	0.8 vs 3.27 0.24 (0.03–2.18)	5.6 vs 9.0 0.60 (0.22–1.61)	15.3 vs 20.4 0.70 (0.36–1.35)	16.9 vs 27.8 0.53 (0.29–0.97)
LASMAL II ²⁷	220	2.0–2.9	1.8 vs 1.8, 0.98 (0.14–7.10)	6.3 vs 7.3 0.85 (0.30–2.43)	15.3 vs 14.6 1.05 (0.50–2.20)	18.0 vs 22.0 0.78 (0.40–1.51)
Total	4,383	<3.0	1.3 vs 1.7 0.81 (0.48–1.36)	3.1 vs 4.2 0.90 (0.58–1.11)	15.5 vs 18.8 0.76 (0.61–0.95)	18.2 vs 22.7 0.71 (0.57–0.90)

Abbreviations: MI, myocardial infarction; TLR, target lesion revascularization; MACEs, major adverse cardiac events; BMS, bare-metal stent; RVD, reference vessel diameter; OR, odds ratio; CI, confidence interval.

(14.8% vs 20.4%). MACE rates were higher in PTCA group (17.6% vs 22.7%) and were mainly driven by repeat TLR. Angiographic follow-up was performed in 81.9% of the patients, and the angiographic restenosis was seen in 27.8% patients in stent group compared with 35.8% in the PTCA group with significant heterogeneity. Optimal PTCA group has similar angiographic restenosis rates as stent group.

Therefore, stenting appears safe with small vessel CAD and significantly reduces angiographic restenosis and repeat revascularization rates. However, optimal PTCA in this group of patients have achieved comparable results to BMS implantation. The revascularization rates remain high with PTCA or BMS implantation in patients with small vessel CAD.

BMS vs DES in small vessels Paclitaxel-eluting stents vs BMS in small vessels

There are no dedicated trials comparing paclitaxel-eluting stent (PES) and BMS in small coronary arteries. However, large PES trials have described substudy results in small vessels. In TAXUS IV trial,²⁸ there were 176 patients with RVD < 2.5 mm randomized to PES and BMS. Angiographic restenosis rate and 12-month TLR rate in the PES group were significantly lower than that in the BMS group, respectively (10.2% and 5.6% vs 38.5% and 20.6%; $P < 0.001$).

In the TAXUS V trial,²⁹ more patients with complex lesions were investigated. In the patient group treated with the 2.25-mm stent, both PES and BMS have similar acute outcomes. However, at the 9-month follow-up, the angiographic restenosis rates and TLR rates were significantly lower in PES group as compared with BMS group (31% and 10.4% vs 49.4% and 21.5%; $P = 0.01$ and $P = 0.03$, respectively). In this post hoc analysis, 9-month MACE rates were 18.9% vs 26.9%; $P = 0.23$, which did not reach statistical significance.

In the TAXUS VI trial,³⁰ angiographic and clinical outcomes were followed up to 9 months in complex subset of patients. In the subgroup with small vessels (RVD < 2.5 mm), in-stent late lumen loss was considerably smaller in the PES group than in the BMS group (0.23 ± 0.45 mm vs 0.95 ± 0.52 mm; $P < 0.0001$), explaining the significantly lower angiographic restenosis and TLR observed in the PES group (7.3% and 5.0% vs 40.4% and 29.7%, respectively; $P < 0.001$).

Taking these TAXUS subgroup results in consideration, PES seems to confer clinical benefits in patients with small vessels compared with BMS. This is mainly because of marked inhibition of neointimal hyperplasia by PES. These results could have been influenced by the release kinetics of

drug, polymer used, and stent platform. TAXUS[®] Express[®] stent (Boston Scientific Inc, Natick, Massachusetts) was used in TAXUS IV trial, and TAXUS Express2 stent was used in TAXUS V and TAXUS VI trials. TAXUS Express stent consists of balloon-expandable stent with Translute[™] polymer-coating containing paclitaxel (Boston Scientific Inc). TAXUS Express2 stent is composed of a balloon-expandable Express2 stent with a triblock copolymer coating with paclitaxel. The release kinetics of drug was slow in TAXUS IV and V trials, whereas this was moderate in TAXUS VI trial.

Sirolimus-eluting stent vs BMS in small vessels

Sirolimus-eluting stent (SES) has been tested in pivotal SIRIUS trial,³¹ and the substudy involving small vessels (≤ 2.75 mm) showed significantly lower TLR rates with SES as compared with BMS (6.6% vs 22.3%; $P < 0.0001$). Similarly, angiographic substudy³² has shown significantly lower restenosis in SES group (17.6% vs 42.7%; $P < 0.001$).

The SES-SMART trial,³³ which enrolled patients with small vessels (mean RVD = 2.2 mm), indicated that the incidence of TLR and MACE in the SES arm was significantly lower compared with BMS arm (7.0% and 9.3% vs 21.1% and 31.3%; $P = 0.002$ and $P < 0.001$, respectively). Angiographic restenosis in the SES arm was also significantly lower compared with the BMS arm (9.8% vs 53.1%, $P < 0.001$).

Lee et al³⁴ evaluated the predictive factors for restenosis following implantation of SES in small coronary arteries (<2.8 mm) in an observational study. They identified lesion length and restenotic lesions as independent predictors of angiographic restenosis in small vessels.

Zotarolimus-eluting stent vs BMS in small vessels

ENDEAVOR program has assessed the efficacy of zotarolimus-eluting stent (ZES) in patients with CAD. ENDEAVOR II³⁵ trial has randomly assessed outcomes after ZES and BMS in patients with native CAD. In a subgroup analysis of patients who had angiographic follow-up at 8 months, results were reported for 371 patients with RVD < 3 mm. There were significantly less angiographic restenosis rates with the use of ZES in both <2.5-mm and 2.5–3 mm group as compared with BMS (18.2% vs 38.6%; odds ratio [OR] = 0.47; 95% confidence interval [CI]: 0.28–0.79 in <2.5-mm group and 4.6% vs 35.1%; OR = 0.13; 95% CI: 0.05–0.32 in 2.5–3.0 mm group, respectively). They have also reported significantly less TLR rate with the use of ZES as compared with BMS (7.2% vs 16.5% in <2.5-mm group and 3.0% vs 11.5% in 2.5–3.0 mm group).

PES vs SES in small vessels

There is limited information available comparing SES and PES in small vessels. Some trials comparing the outcomes in small vessels are shown in Table 2. ISAR-SMART 3³⁶ was the first head-to-head trial comparing SES and PES. This trial showed significantly less angiographic restenosis and TLR rates with the use of SES as compared with PES (11.4% and 6.6% vs 19.0% and 14.7%, respectively).

More recently, subgroup analysis of SIRTAX trial,³⁷ which included patients with RVD < 2.75 mm was reported. In patients with small vessel stents, SES reduced MACE by 55% (10.4% vs 21.4%; $P = 0.004$), mainly driven by a 69% reduction of TLR rate (6.0% vs 17.7%; $P = 0.001$). However, there were no significant differences with respect to death and MI.

There are two nonrandomized trials that have been performed comparing SES and PES in small coronary vessels. Park et al³⁸ have performed retrospective study involving 197 patients with RVD of nearly 2.45 mm and reported lower angiographic restenosis and TLR rates with the use of SESs (6.7% and 3.3% vs 27.7% and 14.4%; $P < 0.01$). Another RESEARCH and T-SEARCH^{39,40} registry adopted a nonrandomized design and evaluated outcomes in patients treated with SES and PES in small coronary vessels (RVD = 2.25 mm). The incidence of 12-month TLR and MACE was numerically more frequent with the use of PES, but they did not reach statistical significance (11.1% and 18.9% vs 6.5% and 9.3%; $P = 0.31$) and $P = 0.06$, respectively.

ZES vs PES in small vessels

ENDEAVOR IV⁴¹ compared outcomes following implantation of ZES and PES in patients with CAD. In a subgroup analysis involving small vessels (<2.5 mm), there was significantly less target vessel failure at 12 months with the use of ZES as compared with PES (8.3% vs 13.4%; OR = 0.62; 95%

CI: 0.37–1.03). However, there was no difference observed between PES and ZES in 2.5–3 mm group (8.8% vs 7.5%; OR = 1.18; 95% CI: 0.69–2.04).

Everolimus-eluting stent vs PES in small vessels

SPRIT IV⁴² trial has compared the efficacy of everolimus-eluting stent (EES) and PES in patients with CAD. In a whole cohort, 1,352 patients were treated for small vessel disease (≤ 2.75 mm). In this subgroup analysis, there was significantly less occurrence of target vessel failure with the use of EES as compared with PES (3.9% vs 6.8%; OR = 0.57; 95% CI: 0.35–0.91).

Biolimus-eluting stent vs SES in small vessels

LEADERS trial⁴³ compared biolimus-eluting stent (BES) with biodegradable polymer and SES with durable polymer in patients with CAD. In a substudy, investigators have assessed the impact of vessel size on outcomes with these two different stent strategies. All-comer patients (1,707 patients) were included in the study, and comparison was done between vessel size <2.75 mm (50.0% of the total cohort) and >2.75 mm. There was no significant difference between TLR rate (9.6% vs 7.4%; $P = 0.26$) and MACE (12.1% vs 11.8%; $P = 0.89$) in both BES and SES arms. However, the TLR rate (9.6% vs 2.6%) and MACE (12.7% vs 7.1%) were significantly higher in small vessels as compared with large vessels in the BES arm.

Summary of impact of DES in small vessels

As evident from the aforementioned studies, the outcomes in small coronary arteries have improved following the introduction of DESs. TLR rate has improved from

Table 2 Comparison of angiographic characteristics, death, MI, TLR, and MACEs, following SES and PES

Study	Total No. of patients	RVD (mm)	SES vs PES			
			Death (%)	MI (%)	TLR (%)	MACE (%)
ISAR-SMART 3 ³⁶	360	<2.75	1.7 vs 2.2 $P = 0.99$	3.9 vs 3.3 $P = 0.78$	6.6 vs 14.7 $P = 0.008$	
Park et al ³⁸	197	<2.75	0 vs 0 $P = 1$	12.4 vs 13.2 $P = 0.54$	3.3 vs 14.4 $P < 0.01$	15.7 vs 27.6 $P < 0.01$
RESEARCH and T-SEARCH ^{39,40}	199	<2.25	0.9 vs 4.3 $P = 0.18$	2.8 vs 7.8 $P = 0.19$	6.5 vs 11.1 $P = 0.31$	9.3 vs 18.9 $P = 0.06$
SIRTAX ³⁷	370	<2.75	6.0 vs 5.4 OR = 1.10; 95% CI, 0.47–2.60	3.8 vs 3.7 OR = 1.01; 95% CI, 0.35–2.88	6.0 vs 17.7 OR = 0.31; 95% CI, 0.16–0.62	10.4 vs 20.4 OR = 0.45; 95% CI, 0.26–0.78

Abbreviations: MI, myocardial infarction; TLR, target lesion revascularization; MACEs, major adverse cardiac events; RVD, reference vessel diameter; SES, sirolimus-eluting stent; PES, paclitaxel-eluting stent; OR, odds ratio; CI, confidence interval.

20%–30% in the BMS era to around 10% with the usage of various DESs. This still remains higher as compared with other subgroups of CAD. Among the various DESs available, the TLR rate is relatively low (3%–7%) with the use of EES and SES as compared with PES and ZES (8%–13%). These results are biologically plausible because a reduction in luminal diameter by a constant amount of neointimal hyperplasia results in proportionally higher-grade diameter stenosis in small vessels compared with large vessels. Moreover, EES and SES have been invariably shown to afford lower late luminal loss in the trials (0.14 ± 0.41 mm for EES in SPIRIT III⁴⁴ trial and 0.16 ± 0.30 mm for SES in pivotal trials) as compared with higher late luminal loss with the use of ZES and PES (0.67 ± 0.49 mm for ZES and 0.42 ± 0.50 mm for PES in ENDEAVOR IV and 0.61 ± 0.46 mm in ENDEAVOR III),⁴⁵ and a late luminal loss is an established marker to discriminate between different stent types.⁴⁶

Influence of stent strut thickness on outcomes in small vessels

The mechanical differences of the BMS and the DESs may affect the outcomes in small coronary arteries. Briguori et al⁴⁷ have shown that strut thickness was an independent predictor of angiographic restenosis in small coronary arteries (RVD = 2.75–2.99 mm); thinner-strutted stents were associated with lower incidence of restenosis than thicker-strutted stents.

Brambilla et al⁴⁸ have assessed that in a prospective, multicentre registry, the impact of thin-strut chrome–cobalt stent (Mini VISION-strut size 0.081 mm) angiographic and clinical outcomes in small coronary vessels. The average RVD was 2.41 ± 0.41 mm, and the 6 months MACE was 11.6%, death 2.9%, MI 2.9%, and TLR 5.8%. These outcomes are comparable with DES outcomes.

TAXUS ATLAS Small Vessel (SV) program⁴⁹ is a multicentre study comparing the performance of the thin-strut (0.095 mm) TAXUS Liberte[®] 2.25-mm stent (Boston Scientific Inc) in small vessels. This study compared the outcomes following implantation of TAXUS Liberte and TAXUS Express (0.132-mm strut size) stents in small vessels. TAXUS Liberte significantly reduced the rate of 9-month angiographic restenosis (18.5% vs 32.7%; $P = 0.02$) and 12-month TLR (6.1% vs 16.9%; $P = 0.0003$) as compared with TAXUS Express stents. This TAXUS liberte (Atom[™]; Boston Scientific Inc) stent was specially designed for small vessels (<2.25 mm) and was approved by the US Food and Drug Administration for the treatment. This stent has 27-inch thinner struts, and the unique, uniform repeating

cell geometry supports even drug distribution and delivery. This stent also has lowest stent crossing and tip profile making it a more trackable stent delivery system.

Safety issue following small vessel DES implantation

Since DESs were approved, these devices have been implanted in a large number of patients with CAD and with off-label indications including small vessels. Their use seems to be safe. However, issue of stent thrombosis has been one of the concerns. Although BMS implantation in small vessels had been previously cited as a risk factor for stent thrombosis,^{50–52} improved techniques of optimal stent deployment and dual antiplatelet therapy appear to have largely resolved this problem so that the risk of stent thrombosis of BMS in small vessel stenting now seems to be similar to that in large vessel stenting.^{53,54}

DES implantation in small vessels may increase the risk of stent thrombosis. The incidence of stent thrombosis in small vessel DES implantation has not been shown to differ between PES and BMS or SES. In a subanalysis conducted in the TAXUS V²⁹ clinical trial, both acute and late stent thrombosis rates were similar between PES and BMS (0.9% vs 1.1% and 1.0% vs 1.1%; $P = 1.00$ and $P = 1.00$, respectively). In ISAR-SMART 3³⁶ trial and a study by Park et al³⁸ no acute stent thrombosis was reported in both SES and PES arms, whereas there was no information about late stent thrombosis in either trial. In a subanalysis of the RESEARCH and T-SEARCH^{39,40} registries, 2.2% of patients had acute stent thrombosis in the PES arm; no thrombosis was observed in the SES arm ($P = 0.21$). No late stent thrombosis occurred in either arm. In SIRTAX³⁷ trial there was similar stent thrombosis seen in SES and PES arms in small vessels (2.2% vs 2.7%; $P = 0.75$, respectively). This was similar to the stent thrombosis rates seen in large vessels (1.9% vs 3.3%; $P = 0.35$) with the use of SES and PES, respectively. Lee et al³⁴ have reported the late stent thrombosis of 0.4% up to 20 months following implantation of SES in small vessels.

However, late stent thrombosis is multifactorial, and the limited data available so far have shown similar rates with the use of DES.

Factors predictive of adverse outcome after DES in small vessels

Revascularization of small coronary arteries has been problematic because of high risk of restenosis. Before the introduction of DES, the restenosis rate in these lesions was very high, ranging from 30%–50%, and there was

only marginal benefit from stent implantation. However, DESs have markedly reduced the risk of restenosis, and their benefits are evident in small vessels. Small vessel disease still remains because of DES failure as compared with other groups. Lee et al³⁴ have evaluated the predictive factors of adverse outcome following implantation of SES in a consecutive series of 1,092 patients with reference vessel size <2.8 mm. They have reported significant correlation between restenosis rate and lesion length, and restenosis rate was highest (29.4%) in patients with very long lesions (>60 mm). Multivariate analysis showed that lesion length (OR = 1.04; 95% CI: 1.02–1.05; $P < 0.001$) and in-stent restenotic lesions (OR = 3.38; 95% CI: 1.80–6.35; $P < 0.001$) were significant predictors of restenosis, but diabetes was not shown to be significant predictor of restenosis (OR = 0.79, 95% CI: 0.47–1.33, $P = 0.378$).

Small vessel disease has become more common, and the proportion of patients requiring coronary intervention is likely to further increase. However, these patients have higher clinical and angiographic restenosis rates following small vessel angioplasty as shown in the aforementioned data. The risk of complications and restenosis in many of these patients are increased by other factors, particularly diffuse disease and diabetes mellitus. Although BMS have an advantage in acute gain compared with balloon angioplasty, the former results in more late loss due to neointimal overgrowth. This tissue encroachment presents a greater problem in small than in large vessels because it leaves less room for the lumen in the former. Therefore, using BMS, the long-term results of small vessel stenting were disappointing, and provisional stenting was considered a better option. The use of DESs in small coronary arteries, however, has reduced the rate of restenosis in comparison to BMSs. Various types of DESs are widely used in clinical practice. In head-to-head studies, the SES and EES have shown lower rate of late lumen loss as compared with PES and ZES, suggesting that the former group may be more effective in preventing restenosis in high-risk patients.

Future directions in small vessel coronary angioplasty

A number of stent-related properties, including stent configuration, strut thickness, and stent coating, can affect the long-term clinical outcome. Many trials have shown that the mesh-wire and coil-related stent designs suffer from a significantly higher risk of restenosis compared with the tubular or multicellular stent design. Studies have shown that stent with less strut–strut intersections (Multilink stent) is

associated with the most favorable angiographic and clinical outcomes.⁵⁵ The design, material composition, surface features of the stent, and stent deployment technique affect strongly the acute performance of the stent, risk of stent thrombosis, degree of vascular response, and subsequent risk of in-stent restenosis.

The availability of new, highly biocompatible, and more radiovisible alloys with the same if not superior tensile strength than stainless steel will enable the production of low metal density stents that may further improve the anatomical and clinical outcomes of current stainless steel stents. Drug elution from these stent platforms could further improve the outcomes in small vessels. In future, different stent designs and variable strut thickness with different drug elutions need to be tested in small coronary vessels.

Conclusion

We have reviewed balloon angioplasty and the placement of BMS and different DESs in small vessels with respect to clinical outcomes. We could conclude that (1) small vessel coronary angioplasty is common; (2) DES considerably reduces the incidence of angiographic restenosis and TLR as compared with BMS; and (3) a trend is observed with regard to better angiographic and clinical outcomes of EES and SES over PES and ZES but with similar safety profile. Stent design and strut thickness along with DES influence the outcomes in small coronary vessels similar to other coronary lesions.

Large size, randomized, controlled, double-blinded multicenter trials with long-term follow-up are needed to evaluate different DESs and designs in small vessel CAD.

Disclosure

The author reports no conflicts of interest in this work.

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