# Lesion Preparation Prior to Stenting

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*Lesion preparation before stent implantation remains an essential component of the contemporary practice of coronary stent implantation in patients with long lesions, ostial lesions, chronic total occlusions, bifurcations, and calcified or nondilatable lesions. The goal of lesion preparation in these patients is to facilitate stent delivery, reduce plaque shift, and allow optimal stent expansion. Several procedures and second-generation devices have been proposed to achieve this goal, such as directional coronary atherectomy, rotational atherectomy, the cutting balloon, and the FX miniRAIL™ catheter. Even with the advent of drug-eluting stents, theoretically there are several reasons that aggressive lesion preparation would still be beneficial in selected patient subsets.*

[Rev Cardiovasc Med. *2004; 5(suppl 2):S16-S21*]



**Key words:** Coronary stenting • Directional atherectomy • Rotational atherectomy • Cutting balloon • FX miniRAIL catheter

Over the last decade, coronary stenting has evolved into the primary interventional strategy for most patients undergoing catheter-based coronary intervention. However, procedural complexity and long-term recurrence remain major concerns when stents are implanted in "complex lesion subsets," such as long lesions,[1] ostial lesions,[2] chronic total occlusions,[3] bifurcations,[4] and calcified or nondilatable lesions. A common denominator among these various lesion subsets is the large and/or resistant plaque burden

that might lead to stent underexpansion, which increases the likelihood of stent thrombosis and/or restenosis.

Pretreatment of these complex lesions with high-pressure balloon inflation before stent implantation is certainly an option, but it is not always successful. Suboptimal dilatation, acute recoil, plaque shift, dissections, and vessel perforation are all potential shortcomings with this approach. To remedy this problem, several procedures and second-generation devices have been developed to prepare complex plaques before stent implantation; these include directional coronary atherectomy, rotational atherectomy, the cutting balloon, and the FX miniRAIL™ catheter (Guidant Corp., Indianapolis, IN). The purpose of this report is to review the current state of knowledge regarding the utility of these procedures and devices for lesion preparation before stent implantation.

## Directional Coronary Atherectomy Before Stent Implantation

Directional coronary atherectomy (DCA) (Guidant Corp.) has been the most effective procedure for removing fibrotic noncalcified plaque. Stand-alone directional atherectomy has been shown to yield better acute and long-term angiographic results than plain balloon angioplasty when optimally performed; however, recurrence remains high.[5]

Histologic and intravascular ultrasound observations suggest that plaque burden directly impedes stent expansion and is a predictor of restenosis after stent implantation.[6,7] These observations led to the hypothesis that DCA before stent implantation might improve clinical outcomes. Several single-center registries were formed to assess the feasibility, safety, and efficacy of performing DCA before stent implantation.[8–11] These registries demonstrated low restenosis rates (Figure 1) but also showed that optimal results depended on proper selection of high-risk patients and optimal performance of plaque debulking.[8]

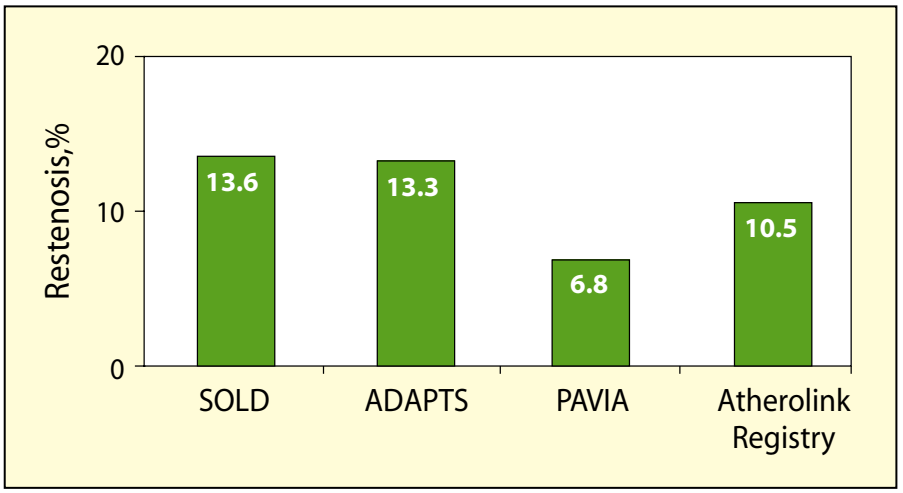



**Figure 1.** *Restenosis rates in single-center registries of directional atherectomy before stent implantation. SOLD, stenting after optimal lesion debulking registry; ADAPTS, acute directional coronary atherectomy prior to stenting in complex coronary lesions registry.*

The encouraging results seen in these registries led to the initiation of two large, prospective, randomized clinical trials comparing DCA before stenting with stenting alone: the Atherectomy Before MULTI-LINK Improves Lumen Gain and Clinical Outcomes (AMIGO) trial and the Debulking and Stenting In Restenosis Elimination (DESIRE) trial. The AMIGO trial randomized 753 patients to either DCA followed by stenting or stenting alone. At 8-month follow-up, there was no difference in angiographic or clinical restenosis between the two groups (Figure 2). However, in this trial optimal debulking (defined as post-DCA diameter stenosis <25%) was achieved in only 26.5% of patients despite the fact that the study protocol required this endpoint in all patients who were randomized to the DCA arm. Suboptimal debulking was associated with a significantly higher restenosis rate (32%) compared with optimal debulking (16%; $P = .01$).[12] Furthermore, cumulative major adverse cardiovascular events (death, myocardial infarction, or urgent target vessel revascularization) to 30 days postprocedure were slightly more frequent in the DCA-treated patients.[13]

*Plaque burden directly impedes stent expansion and is a predictor of restenosis after stent implantation.*

The DESIRE trial[14] randomized 500 patients to intravascular ultrasound (IVUS)-guided DCA followed by stenting or stenting alone. Despite the achievement of a lower loss index at quantitative coronary angiography follow-up in the DCA/stent group (0.34 vs. 0.41, $P = .05$), this did not translate into clinical benefit at 6-month follow-up (Figure 2).

In summary, the available evidence indicates that DCA does not improve

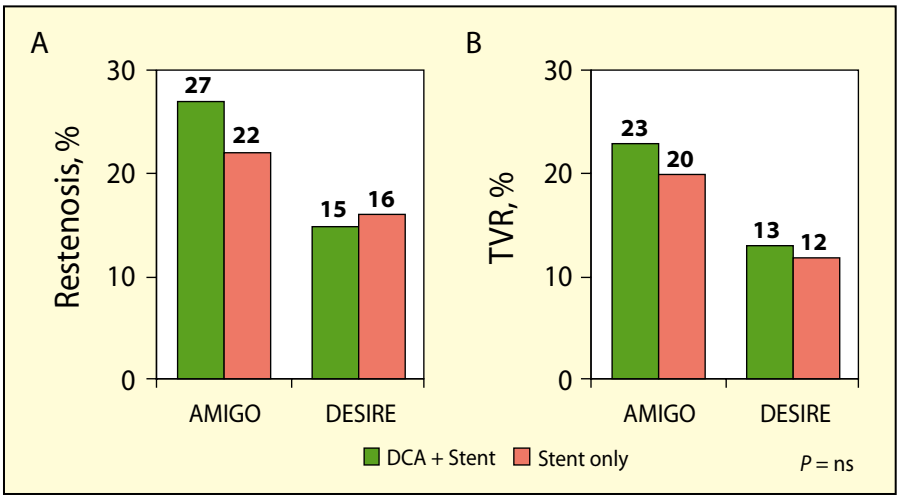



**Figure 2. (A)** *Binary (≥50%) angiographic restenosis rates by quantitative coronary angiography in the AMIGO and DESIRE trials and* **(B)** *target vessel revascularization (TVR) in the AMIGO and DESIRE trials at 6-months follow-up. DCA, directional coronary atherectomy.*

late angiographic outcome when performed before bare metal stent implantation unless optimal debulking is achieved and relatively higher-risk lesions are treated.[15,16]

## Rotational Atherectomy Before Stent Implantation

Coronary stent implantation in severely calcified lesions remains a significant challenge owing to difficulties in stent delivery and expansion. In these patients, lesion preparation with high-pressure balloon inflation might occasionally succeed but is often insufficient to overcome vessel-wall resistance. Rotational atherectomy has proven to be the preferred strategy to ablate calcified plaque, but despite the high procedural success rate, late stenosis recurrence remains high when it is used as a stand-alone treatment.[17]

Several observational studies demonstrated that when the culprit lesion is severely calcified or nondilatable, the performance of rotational atherectomy might facilitate stent delivery and expansion.[18,19] Furthermore, observational data indicate that aggressive debulking before stent implantation might yield superior long-term results compared with less aggressive debulking but at the cost of a higher incidence of periprocedural myocardial infarction.[20]

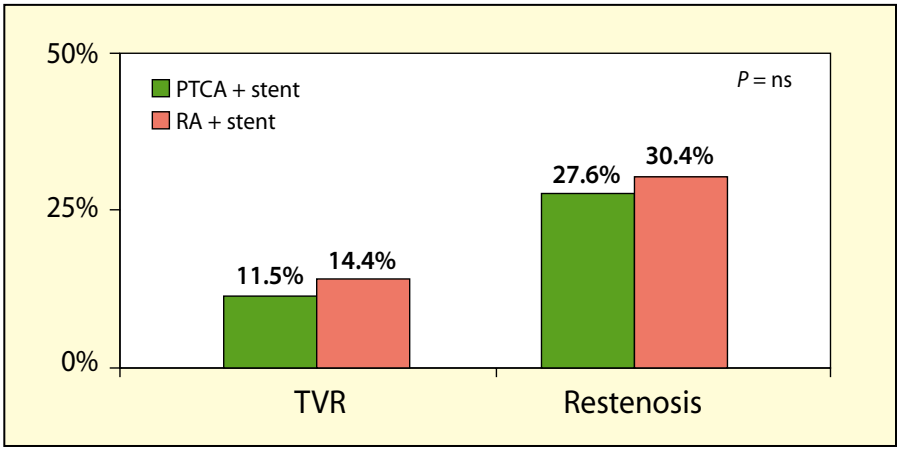
The Stent Implantation Post Rotational Atherectomy (SPORT) trial was the largest prospective, randomized clinical trial that compared rotational atherectomy before stent implantation with stenting alone. However, patients with severely calcified lesions or chronic total occlusions, who would most likely benefit from this approach, were excluded from this trial. In this study, 735 patients were randomized to rotablation versus balloon angioplasty before stent implantation. At 6-month follow-up, there were no differences in angiographic or clinical endpoints (Figure 3). Recently, a prospective, randomized trial comparing rotational or directional atherectomy with balloon angioplasty before stent implantation in patients with chronic total occlusion was reported.[16] In this trial, a strategy of debulking before stenting yielded significantly better late angiographic outcomes at follow-up.

In summary, rotational atherectomy seems to be superior to balloon angioplasty before stent implantation in patients with severely calcified lesions or chronic total occlusions. On the other hand, this approach does not offer advantages to other subsets of patients.

## Cutting Balloon Angioplasty Before Stent Implantation

The Cutting Balloon Ultra™ (Boston Scientific Interventional Technologies, Natick, MA), is an angioplasty balloon with three to four longitudinally bonded microtomes that is designed to score the atherosclerotic plaque. It has been hypothesized that the discrete longitudinal incisions

**Figure 3.** *Target vessel revascularization (TVR) and binary (≥50%) restenosis in the SPORT trial at 6-months follow-up. PTCA, percutaneous transluminal coronary angioplasty; RA, rotational atherectomy.*



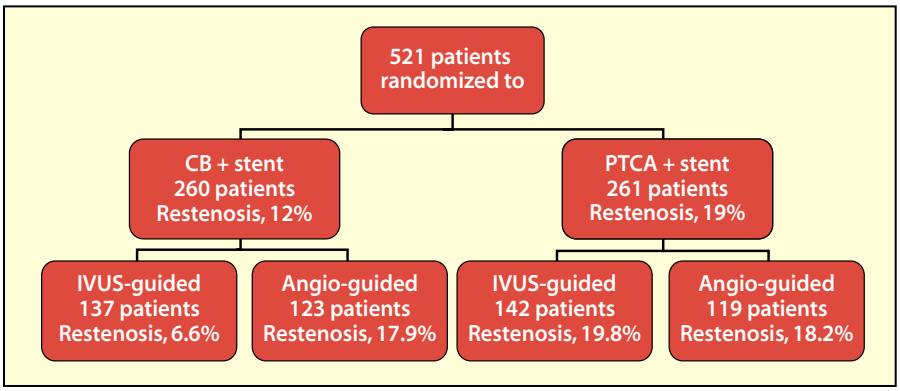



**Figure 4.** *A diagram illustrating the design and outcome of the REDUCE III trial. CB, cutting balloon; IVUS, intravascular ultrasound; PTCA, percutaneous transluminal coronary angioplasty.*

created during balloon inflation might reduce elastic recoil and minimize intimal injury, thereby reducing subsequent neointimal proliferation. However, a prospective, randomized clinical trial comparing the cutting balloon with plain balloon angioplasty showed no differences in clinical or angiographic outcomes.[21]

Nonetheless, the mechanism of action of this device makes it an attractive tool for lesion preparation before stenting. IVUS observations have demonstrated that the cutting balloon, with lower balloon inflation pressure, achieves larger lumen gain with increased plaque reduction compared with plain balloon angioplasty. It should be noted, however, that restenosis rates for balloon angioplasty and the cutting balloon remained similar.[22]

Recently, the Restenosis Reduction by Cutting Balloon Evaluation III (REDUCE III) trial[23] randomized 521 patients to cutting balloon before stenting (260 patients) or balloon angioplasty before stenting (261 patients). Additionally, each group was randomized to IVUS versus angiographic guidance. At 6-month follow-up, the cutting balloon treatment group had a significantly lower rate of angiographic restenosis, primarily in the IVUS-guided group (Figure 4). Multivariate analysis demonstrated that the use of plain balloon angioplasty, presence of diabetes mellitus, left anterior descending artery lesion location, and small vessel size were independent predictors of restenosis.

*It has been hypothesized that the discrete longitudinal incisions created during cutting balloon inflation might reduce elastic recoil and minimize intimal injury.*

## The FX miniRAIL™ Catheter

The FX miniRAIL™ catheter consists of an integral wire positioned external to a semicompliant dilating balloon and a short, 12-mm guidewire lumen that is located distal to the balloon. With this design, the balloon inflates against both the standard coronary guidewire and the integral external wire to prevent slippage and to introduce high focal longitudinal stresses at low inflation pressures. The safety and efficacy of this approach has been reported in several studies,[24] the largest of which is the FX miniRAIL™ U.S. Investigational Device Exemption Registry. In this registry, 263 patients with 321 lesions were enrolled. The prevalence of diabetes mellitus and unstable angina was 32% and 33%, respectively. Culprit lesions were classified as moderately to severely calcified in 9% of patients. The mean balloon inflation pressure required for stenosis resolution was 6.1 atm. Major adverse coronary events at 14 days were acceptable (Table 1).

The utility of the FX miniRAIL™ catheter before stent implantation is currently being evaluated in the PreFX Registry. A case-matched comparison between lesion predilation with the FX miniRAIL™ catheter and balloon angioplasty before stent implantation is shown in Table 2. In

**Table 1**
**14–Day Clinical Outcomes with the FX miniRAIL™ Catheter in the U.S. Investigational Device Exemption Registry**

| MACE | % Patients (N = 263) |
|---|---|
| Total MACE | 2.9 |
| Death | 0 |
| Q wave MI | 0.8 |
| Non-Q wave MI | 1.7 |
| Target lesion revascularization | 1.3 |

MACE, major adverse coronary events; MI, myocardial infarction.

this preliminary comparison, the use of the FX miniRAIL™ catheter before stent implantation provided somewhat better stent expansion (86% vs 82%), which did not reach statistical significance.

Table 2
An Intravascular Ultrasound Matched Comparison Between the FX miniRAIL™ Catheter and Standard Balloon Angioplasty Before Stent Implantation

| | FX miniRAIL™ (n = 51) | Control (n = 62) | *P* |
|---|---|---|---|
| **Baseline** | | | |
| Arc calcium in lesion (degrees) | 40.98 ± 93.68 | 41.29 ± 84.55 | ns |
| Proximal reference vessel area ($mm^2$) | 13.88 ± 5.01 | 14.94 ± 5.52 | ns |
| Distal reference vessel area ($mm^2$) | 12.83 ± 6.13 | 11.48 ± 4.66 | ns |
| Lesion site vessel area ($mm^2$) | 13.23 ± 5.07 | 12.59 ± 5.11 | ns |
| Lesion MLA ($mm^2$) | 3.16 ± 1.57 | 2.83 ± 0.72 | ns |
| Lesion obstruction (%) | 75 ± 1 | 75 ± 9 | ns |
| **Postprocedure** | | | |
| In-stent MLA ($mm^2$) | 6.99 ± 2.01 | 6.69 ± 2.12 | ns |
| Stent expansion (%) | 86 ± 18 | 82 ± 15 | ns |

MLA, minimum lumen area.

## The Role of Lesion Preparation in the Drug-Eluting Stent Era

Drug-eluting stents are expected to improve patient outcomes compared with bare metal stents.[25,26] However, optimal stent geometry and final lumen diameter remain important predictors of restenosis.[27] Theoretically, there are several reasons that aggressive lesion preparation would still be beneficial in selected patient subsets. First, a predefined injury zone allows optimal application of therapy where injury occurred ("radiation model"). The debate regarding the relationship between edge recurrence with drug-eluting stents and uncovered balloon injury zone is ongoing. A recent subanalysis of the Sirolimus-Eluting Stent in De Novo Native Coronary Lesions (SIRIUS) trial[28] showed no relationship between stent-to-lesion ratio and edge restenosis. This study suggested that edge restenosis is related to small vessel size, history of diabetes, and recent cigarette smoking. On the other hand, Munoz and colleagues[29] reported that a longer drug-eluting stent in relation to lesion length results in less plaque growth at the edges. Second, optimal strut circumferential expansion (and drug distribution) after stent deployment might reduce restenosis. Recently, Fujii and colleagues[27] demonstrated that stent underexpansion remains a factor associated with higher recurrence after implantation of drug-eluting stents. Third, polymers might be susceptible to trauma in long calcified "tunnels." Finally, better preparation might facilitate passage of longer, less-flexible devices.

## Summary

Lesion preparation before stent implantation has been and remains

### Main Points

- Procedural complexity and long-term recurrence remain major concerns when coronary stents are implanted in patients with long lesions, ostial lesions, chronic total occlusions, bifurcations, and calcified or nondilatable lesions.
- Several procedures and second-generation devices have been developed to prepare complex plaques before stent implantation; these include directional coronary atherectomy, rotational atherectomy, the cutting balloon, and the FX miniRAIL™ catheter.
- Directional coronary atherectomy does not improve late angiographic outcome when performed before bare metal stent implantation unless optimal debulking is achieved and relatively higher-risk lesions are treated.
- Rotational atherectomy seems to be superior to balloon angioplasty before stent implantation in patients with severely calcified lesions or chronic total occlusions, but it does not offer advantages to other subsets of patients.
- The FX miniRAIL™ catheter is designed such that the balloon inflates against both a standard coronary guidewire and an integral external wire to prevent slippage and to introduce high focal longitudinal stresses at low inflation pressures; the device's utility before stent implantation is currently being evaluated in the PreFX Registry.

an active area of debate. It has been a challenge to reconcile the favorable results of registry experiences with relatively negative results of multicenter, randomized trials. Although multicenter, randomized trials remain the cornerstone methodology for evaluating new therapies, they might not be the optimal venue for studying complex techniques that depend on operator expertise and selection of appropriate lesions. Any future randomized trials that attempt to test the utility of aggressive lesion preparation before stent implantation should restrict enrollment to patients with high-risk lesions at centers that have demonstrated expertise in the specific technology being tested. ■

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