International Journal of Cardiology 185 (2015) 29–33

Contents lists available at ScienceDirect

International Journal of Cardiology

journal homepage: www.elsevier.com/locate/ijcard

# Assessment of stent edge dissections by fractional flow reserve

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ARTICLE INFO

*Article history:*
Received 22 September 2014
Received in revised form 23 February 2015
Accepted 3 March 2015
Available online 4 March 2015

*Keywords:*
Stent edge dissection
Fractional flow reserve
Drug eluting stent

ABSTRACT

*Backgrounds:* Edge dissections after intervention have been studied with imaging techniques, however, functional assessment has not been studied yet. We investigated the relationship between fractional flow reserve (FFR) and the angiographic type of stent edge dissections and tried to assess the use of FFR-guided management for edge dissection.

*Methods:* 51 edge dissections assessed by FFR were included in this prospective observational study. FFR was measured for each type of edge dissection and compared with quantitative coronary angiographic findings. Clinical outcomes were evaluated based on FFR measurements.

*Results:* Edge dissections were classified as type A (47.1%; 24/51), type B (41.2%; 21/51), type C (2.0%; 1/51) and type D (9.8%; 5/51). Mean FFR in type A dissection was 0.87 ± 0.09, in type B 0.86 ± 0.07, in type C 0.72 and in type D 0.57 ± 0.08. All type C and D dissections (6/51) had FFR ≤0.8 and were treated with additional stents. Among the 45 type A and B dissections, 8 had a FFR ≤0.8 (17.8%), and 50% received additional stenting. All dissections with FFR >0.8 were left untreated except one long dissection case. There was no death, myocardial infarction or target lesion revascularization during hospitalization or the follow-up period (median 152 days; IQR 42–352 days).

*Conclusions:* FFR correlates well with an angiographic type of edge dissection. Angiographic findings are sufficient for deciding the treatment of severe dissections such as types C and D, while FFR-guided management may be safe and effective for mild edge dissections such as types A and B.



## 1. Introduction

Stent edge dissections occur as a complication of stent implantation between the rigid stent struts and the adjacent arterial wall [1]. The traditional method to diagnose dissections at the stent edge is coronary angiography and the incidence of edge dissections detected by angiography after stent implantation is between 0 and 6% of all percutaneous coronary interventions (PCI) [1–3]. Using intracoronary imaging modalities, such as intravascular ultrasound (IVUS) and optical coherence tomography (OCT), the diagnosis of edge dissections increases up to 24% [1–6]. Minimal dissections with normal antegrade flow detected only with IVUS or OCT may not be associated with the development of adverse long-term outcome such as late in-stent restenosis [2,4], however, stent edge dissections detected angiographically have been associated with increased short-term incidence of major adverse cardiac events (MACE) and stent thrombosis [3].

Fractional flow reserve (FFR) is the ratio of maximal blood flow across a stenotic lesion compared to the normal maximal flow and has been suggested as an accurate index to identify functionally non-significant and non-ischemic lesions where PCI may be deferred [7]. In patients with multivessel coronary artery disease undergoing PCI with drug eluting stents (DES), routine FFR measurement results in a significant reduction in major adverse cardiac events (MACE) [8]. Low FFR measurements after stent implantation are reported to be associated with higher risk of restenosis in sirolimus-eluting or paclitaxel-eluting stents [9–11]. Although edge dissections after PCI have been vastly studied and detected during various imaging techniques, functional assessment of the edge dissections has not been looked at. Therefore, the objectives of this study were to compare FFR and the angiographic type of stent edge dissections and to assess the clinical outcomes of FFR-guided management of edge dissections.

*Abbreviations:* CAG, Coronary angiography; DES, Drug eluting stents; DS, Diameter stenosis; FFR, Fractional flow reserve; IQR, Interquartile range; IVUS, Intravascular ultrasound; LL, Lesion length; MACE, Major adverse cardiac events; MLD, Minimal lumen diameter; OCT, Optical coherence tomography; PCI, Percutaneous coronary intervention; QCA, Quantitative coronary angiography; RD, Reference diameter; TIMI, Thrombolysis in myocardial infarction; TVR, Target lesion revascularization.

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http://dx.doi.org/10.1016/j.ijcard.2015.03.043
0167-5273/

## 2. Methods

### 2.1. Patient population

Patients enrolled and registered in the clinical implications of a 3-vessel FFR (NCT01621438) trial were reviewed. Among 989 cases from three medical institutions in South Korea who underwent successful PCI between June 2012 and March 2014, 50 patients (51 lesions and 51 dissections) were selected for the current post-hoc analysis of the 3-vessel FFR trial. The inclusion criteria were lesions with an edge dissection seen after stent implantation without antegrade flow impairment and the availability of the corresponding FFR measurement. Exclusion criteria were those with primary PCI, left main disease, chronic total occlusion and life expectancy of <1 year. This study was approved by the institutional review board at each hospital.

### 2.2. Percutaneous coronary intervention

All patients were pretreated with aspirin 200 mg and a loading dose of clopidogrel 300 mg and 100 U/kg of unfractionated heparin was injected intravenously to maintain an activated clotting time ≥250 s during the procedure. Coronary angiography (CAG) and PCI were performed as per standard practice via radial or femoral artery approach. The selection of stent size and length to cover the predilated diseased segment was at the operator's discretion. Stent diameter and stent length were assessed when overlapping stents were used in the lesion by calculating the mean diameter and total length of two stents. Successful PCI was defined by an angiographic residual stenosis of less than 30% with thrombolysis in myocardial infarction (TIMI) 3 antegrade flow. The decision for additional stent implantation for edge dissection was operator dependent and based on the angiographic severity of each edge dissection and the corresponding FFR value.

### 2.3. Identification of edge dissection

An experienced interventional cardiologist and an investigator reviewed the angiograms to first detect the presence of stent edge dissections and then all stent edge dissections were analyzed to identify their severity and dissection types. These two independent reviewers (SH. A and JH. C) were blinded to the clinical presentations. When there was discordance between the two observers on type of stent edge dissection seen, a consensus reading was obtained from a third investigator (ES. S). Lesion sites extending 5 mm proximally and distally to the stent were examined and the severity of stent edge dissections was classified as types A to F using the 1985–1986 NHLBI PTCA Registry criteria [12,13].

### 2.4. Quantitative coronary angiography (QCA)

Two-dimensional QCA was performed after the procedure at the site of edge dissection using dedicated software packages (CASS 5.9; Pie Medical Imaging, Maastricht, Netherlands). Reference diameter (RD), minimal lumen diameter (MLD), diameter stenosis (DS), and lesion length (LL) were measured. All measurements were performed by an experienced QCA analyst (JH. C) blinded to the FFR results in a core laboratory.

### 2.5. Intracoronary pressure measurement

After administration of nitroglycerin, a pressure-monitoring guidewire (PressureWire Certus, St. Jude Medical Systems, Uppsala, Sweden) was advanced with a 6F or 7F guiding catheter. According to the standard protocol of the 3-vessel FFR trial, FFR was measured at the distal segments of the stented vessel past the edge dissection. This was followed by pull back pressure tracing for offline core lab analysis. Maximal hyperemia was induced by administering intravenous adenosine (140 μg/kg/min) in 47 patients and intracoronary nicorandil (2 mg) [14] in 3 patients. The FFR was calculated by dividing the mean distal coronary pressure by the mean aortic pressure during hyperemia.

### 2.6. Clinical outcomes

Clinical adverse outcomes such as death, myocardial infarction (MI), target lesion revascularization (TLR), target vessel revascularization (TVR) and stent thrombosis were monitored during hospitalization and the follow-up periods with hospital visits or telephone calls at 3 month-intervals.

### 2.7. Statistical analysis

All statistical analyses were performed using SPSS 21.0 (SPSS Inc., Chicago, IL, USA). Continuous variables are presented as mean ± SD and categorical variables are expressed as counts and percentages. Student's *t*-test or Mann–Whitney's *U* test were performed to compare the means of continuous variables, and chi-square or Fisher's exact test for categorical variables. Nonparametric analysis was also performed using the Kruskal–Wallis test. A two-sided p value of <0.05 was used to indicate statistical significance.

## 3. Results

### 3.1. Patient demographics and lesion characteristics

The baseline characteristics of the 50 patients (51 edge dissections) and their angiographic findings are shown in Table 1. The mean age of patients was 61.3 ± 9.5 years and 74% (37 of 50) were men. Coronary lesions were mostly types B2 (19 of 51) and C (19 of 51). A total of 50 lesions were treated with drug eluting stents (DES) and 1 lesion was treated with a bare metal stent. The mean stent diameter was 3.1 ± 0.4 mm and mean stent length 31.4 ± 12.8. 31 stent edge dissections (60.8%) were located in the left anterior descending artery, 8 (15.7%)

**Table 1**
Characteristics of study population and angiography.

| | | |
|---|---|---|
| *Demographics* | | |
| Age, years | | 61.3 ± 9.5 |
| Male | | 37 (74.0) |
| Hypertension | | 31 (62.0) |
| Diabetes | | 19 (38.0) |
| Hypercholesterolemia | | 24 (48.0) |
| Current smoking | | 10 (20.0) |
| Family history of coronary disease | | 8 (16.0) |
| Prior myocardial infarction | | 2 (4.0) |
| Prior percutaneous coronary intervention | | 9 (18.0) |
| *Clinical presentation* | | |
| Stable angina | | 26 (52.0) |
| Unstable angina | | 18 (36.0) |
| Acute myocardial infarction | | 6 (12.0) |
| *Lesion characteristics* | | |
| Lesion type | B2 or C | 38 (74.6) |
| Stent | Diameter, mm | 3.1 ± 0.4 |
| | Length, mm | 31.4 ± 12.8 |
| | Pressure, atm | 11.4 ± 3.2 |
| *Edge dissections* | | |
| Vessel | LAD | 31 (60.8) |
| | LCX | 8 (15.7) |
| | RCA | 12 (23.5) |
| Location | Proximal stent | 13 (25.5) |
| | Distal stent | 38 (74.5) |

Values are presented as mean ± SD or n (%).
LAD = left anterior descending aorta; LCX = left circumflex artery; RCA = right coronary artery.