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# The impact of intravascular ultrasound guidance during drug eluting stent implantation on angiographic outcomes

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**Abstract. – OBJECTIVE: Major limitation for the use of stent in the treatment of coronary artery disease is development of stent restenosis. The impact of intravascular ultrasound (IVUS) guidance during drug eluting stent (DES) implantation is presently not yet well established.**

**PATIENTS AND METHODS: For the present study, we included 30 patients who received DES with IVUS-guided stenting (Group A) and 30 patients receiving the DES without IVUS-guided stenting (Group B). The patients were evaluated for their ninth month control angiographies and were followed during two years for the development of relevant clinical events after the DES implantations. The angiographic and clinical results were compared between the groups.**

**RESULTS: After the percutaneous intervention, the minimal luminal diameter and net acute gain were significantly increased in Group A in respect to Group B (3.3 ± 0.34 vs. 2.8 ± 0.33, $p < 0.01$). Moreover, the rate for performing post-dilatation following stent implantation was higher in Group A than in Group B ($p = 0.01$). By contrast, stent restenosis rates were similar between the groups ($p > 0.3$).**

**CONCLUSIONS: The present results indicate that the use of IVUS for the implantation of DES can increase the success rate of the intervention. The IVUS guidance during DES implantation can be complementary percutaneous intervention, in particularly by detecting the situations that need for post-dilatation.**

*Key Words:*
Drug eluting stent, Intravascular ultrasound, Post-dilatation.

## Introduction

Percutaneous coronary intervention (PCI) is one of the most frequently employed revascularization procedures in order to treat coronary artery diseases (CAD). While balloon angioplasties were used originally, several types of stents have been produced and they are widely used today for the purpose of revascularization. Major limitation for the use of stent in the treatment of CDA is the formation of early stent thrombosis (ST) and development of late stent restenosis (SR)[1,2]. Fortunately, introduction of drug eluting stents has markedly reduced the rate of SR; nevertheless, their use has not completely eliminated the development of SR[3].

Most common causes of ST and SR following stent implantation are shown to be inadequate stent expansion and incomplete stent apposition to the effected vessel wall[4]. When the patients who received stent implantation were reevaluated using intravascular ultrasound (IVUS) approach with effective angiographic visualization, inadequate stent expansion and incomplete stent apposition were reported in significant number of these patients[5,6]. Execution of PCI with the help of IVUS can optimize stent implantation and reduce the frequency of developing ST and SR.

In the present study, we aimed to investigate the effect of IVS guidance on angiographic results for drug eluting stent (DES) implantation.

## Patients and Methods

In the present study, we included a total of 60 coronary artery patients. The patients were divided into two groups as Group A and Group B. While the 30 patients that received implantation of DES in the presence of IVUS were designated as Group A, the 30 patients underwent DES implantation with the guidance of direct angiography were designated as Group B. The study was approved by the local Ethics Committee, the patients were informed and written consent of them were also obtained.

Reference vessel diameter we used in this study was ≥ 2.5 mm and the patients showing symptomatic and objective ischemia findings



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with *de-novo* atherosclerotic lesion causing ≥ 70% of occlusion in the vessel where located were included in the present study. On the other hand, the patients suffering from the left main coronary artery stenosis, showing complete occlusion of coronary artery, having bypass graft lesion, acute myocardial infarct or decompensated heart failure were excluded.

### Angiographic Analysis

Angiographic measurements of all the patients were performed quantitatively using the angiographic records obtained after injection of intracoronary nitroglycerine at the projections frozen at the end of the diastole and allowing the best visualization of the lesion. Moreover, we obtained angiographies of the patients prior to and after the interventions in addition to ninth month control angiographies. Through assessing the angiographic records, we calculated proximal and distal reference vessel diameters, minimal luminal diameter of vessels, and percentage of narrowing, minimal luminal diameter of stents, acute gain, late lumen loss, and loss index. The diameter of the stent used was determined according todistal reference vessel diameter. Lesions were classified according to ACC/AHA score system as Type A, B1, B2, and C[7]. Stent restenosis was described as the presence of more than 50% narrowing in vessel lumen at control angiography. The results of angiographic measurements were compared between the groups.

### Stent Implantation with Angiography Guidance

After placing guiding catheter (6F or 7F) into the coronary artery ostium, intracoronary delivery of 100 U/kg heparin was introduced. The stent was then implanted into the lesion site after passing through the lesion with a 0.014-inch guiding wire. Decision for pre-dilatation was left to the operator performing the procedure when required. An angiographic residual narrowing < 10% after the stent implantation was considered to be a successful intervention. At the presence of more residual narrowing, the stent was inflated using noncompliant balloon with post-dilatation procedure under high atmospheric pressure.

### Stent Implantation with Intravascular Ultrasound Guidance

After the stent implantation, an IVUS catheter (Boston Scientific Corporation, Natick, MA, USA) placed over the 0.014-inch guiding wire was inserted at the distal of the stent. IVUS images were obtained while IVUS catheter was pulled back at the speed of 0.5 mm per second. We evaluated stent expansion and apposition at the implantation site using these IVUS images. Lack of dissection, complete apposition, and the presence of a minimal stent area ≥ 90% reference vessel lumen area were considered to be a successful procedure. In case of inadequate stent expansion or incomplete stent apposition to the effected vessel wall, the stent was inflated using noncompliant balloon with post-dilatation procedure under high atmospheric pressure.

### Statistical Analysis

Continuous variables were expressed as mean ± SD; categorical variables were defined as percentages. While continuous variables showing normal distribution were compared using Student's *t*-test, those not showing normal distribution were compared using Mann-Whitney U-test, where appropriate. Categorical variables were compared via the chi-square test. For all tests, a value of $p < 0.05$ was considered to be statistically significant. The SPSS statistical software package (version 16.0 for windows; SPSS Inc., Chicago, IL, USA) was used to perform all statistical calculations.

## Results

Of the sixty patients included in the present study, 41 were male and 19 were female, their mean age was 62.2 ± 10.8, and their age range was between 49 and 94. Stent implantation to all patients was successfully performed. Overall, basic clinical and angiographic features between Group A and Group B were similar and summarized in Table I.

Inadequate stent expansion after the stent implantation occurred in 73% of the patients in Group A and 30% of the patients in Group B ($p = 0.001$), post-dilatation procedure was performed in order to inflate the implanted stents. Adequate dilation of the stents after the application of the post-dilatation procedure was established in 95% of the patients in Group A and in 96% of the patients in Group B ($p > 0.05$). After the PCI, minimal luminal diameter of the stents (2.9 ± 0.34 vs. 2.66 ± 0.35, $p = 0.009$) and acute gain (2.72 ± 0.49 vs. 2.37 ± 0.51, $p = 0.012$) were larger in Group A than in Group B. On the other hand,

**Table I.** Basic clinical and angiographic features pertaining to the patients.

| | Total (n=60) | Group A (n=30) | Group B (n=30) | *p* value |
|---|---|---|---|---|
| Age (year) | 62.2 ± 10.8 | 63 ± 11.4 | 61.4 ± 10.3 | 0.56 |
| Gender (male) (n, %) | 41 (68.3) | 22 (73.3) | 19 (63.3) | 0.29 |
| Hypertension (n, %) | 48 (80) | 25 (83.3) | 23 (76.7) | 0.37 |
| Smoke (n, %) | 21 (35) | 10 (33.3) | 11 (36.7) | 0.5 |
| Diabetes mellitus (n, %) | 23 (38.3) | 11 (36.7) | 12 (40) | 0.5 |
| Hyperlipidemia (n, %) | 34 (56.7) | 18 (60) | 16 (53.3) | 0.4 |
| Ejection fraction (%) | 44.8 ± 3.4 | 45 ± 3.5 | 44.6±3.3 | 0.65 |
| Clinical diagnosis (n, %) | | | | |
| Stable angina pectoris | 29 (48.3) | 15 (50) | 14 (46.7) | 0.5 |
| Unstable angina pectoris | 31 (51.7) | 15 (50) | 16 (53.3) | |
| Lesion site (n, %) | | | | |
| LAD | 39 (65) | 22 (73.3) | 17 (56.7) | 0.12 |
| Cx | 14 (23.3) | 7 (23.3) | 7 (23.3) | |
| RCA | 7 (11.7) | 1 (3.3) | 6 (20) | |
| ACC/AHA lesion type | | | | |
| B1 | 10 (16.7) | 6 (20) | 4 (13.3) | 0.36 |
| B2 | 15 (25) | 6 (20) | 9 (30) | 0.27 |
| C | 35 (58.3) | 18 (60) | 17 (56.7) | 0.5 |
| Control angiography (month) | 9 ± 1.2 | 9.1 ± 1.2 | 8.9 ± 1.2 | 0.54 |

rate of stent restenosis was comparable between the groups at ninth month control angiographies ($p = 0.3$). Development of SR was determined in two patients in Group A and in five patients in Group B. Stent thrombosis was noted in only one patient in Group B. Results of angiographies pertaining to the patients prior to and after the intervention, and at ninth month follow-up are illustrated in Table II.

Furthermore, the patients were also divided into two groups according to whether they received post-dilation or not and their early and late angiographic results were compared (Table III). In post-dilation performed group, no patient developed ST but four patients developed dissection and only one patient had SR. On the other hand, no dissection was noted in the group of the patients received no post-dilation. While acute gain

**Table II.** Results of angiographies pertaining to the patients prior to and after the intervention, and at ninth month follow-up.

| | Total | Group A (n=30) | Group B (n=30) | *p* value |
|---|---|---|---|---|
| Diameter of reference vessel (mm) | 2.9 ± 0.14 | 2.91 ± 0.14 | 2.88 ± 0.14 | 0.32 |
| Length of lesion (mm) | 20.1 ± 5.3 | 21 ± 5.9 | 19.1 ± 4.7 | 0.18 |
| Percentage of narrowing (%) | | | | |
| Prior to intervention | 85.5 ± 10.3 | 86.6 ± 10.2 | 86.4 ± 10.4 | 0.41 |
| After intervention | 8.1 ± 5.3 | 7.7 ± 5.5 | 8.4 ± 5.1 | 0.63 |
| Follow-up | 28.2 ± 22.1 | 24.8 ± 20.6 | 31.6 ± 23.3 | 0.23 |
| Minimal luminal diameter (mm) | | | | |
| Prior to intervention | 0.25 ± 0.32 | 0.23 ± 0.26 | 0.28 ± 0.37 | 0.56 |
| After intervention | 2.8 ± 0.36 | 2.9 ± 0.34 | 2.66 ± 0.35 | 0.009 |
| Follow-up | 2.15 ± 0.75 | 2.26 ± 0.69 | 2.04 ± 0.86 | 0.28 |
| ISS type: | | | | |
| Paclitaxel | 21 (35) | 9 (30) | 12 (40) | 0.29 |
| Everolimus (n, %) | 39 (65) | 21 (70) | 18 (60) | 0.42 |
| Post-dilatation (n, %) | 31 (51.7) | 22 (73.3) | 9 (30) | 0.001 |
| Balloon: artery rate | 1.07 ± 0.7 | 1.06 ± 0.6 | 1.08 ± 0.7 | 0.52 |
| Acute gain (mm) | 2.55 ± 0.52 | 2.72 ± 0.49 | 2.37 ± 0.51 | 0.012 |
| Late loss (mm) | 0.59 ± 0.76 | 0.49 ± 0.7 | 0.68 ± 0.81 | 0.33 |
| Net gain (mm) | 2.2 ± 0.95 | 2.38 ± 0.88 | 2.02 ± 1 | 0.14 |
| Stent thrombosis (n, %) | 1 (1.7) | 0 (0) | 1 (3.3) | 0.5 |
| Stent restenosis (> 50% narrowing) (n, %) | 7 (11.7) | 2 (6.7) | 5 (16.7) | 0.12 |
| Dissection after post dilatation (n, %) | 4 (6.7) | 3 (10) | 1 (3.3) | 0.3 |

**Table III.** Effect of post-dilatation procedure on the angiographic results.

| | Total (n=60) | Post-dilatation (-) (n=29) | Post-dilatation (+) (n=31) | *p* value |
|---|---|---|---|---|
| Stent restenosis (n, %) | 7 (11.7) | 6 (20.7) | 1 (3.2) | 0.042 |
| Stent thrombosis (n, %) | 1 (1.7) | 1 (3.4) | 0 (0) | 0.48 |
| Acute gain (mm) | 2.55 ± 0.52 | 2.32 ± 0.52 | 2.77 ± 0.43 | 0.001 |
| In-stent minimal luminal diameter (mm) | 2.8 ± 0.36 | 2.62 ± 0.37 | 2.92 ± 0.29 | 0.001 |
| Late lumen loss (mm) | 0.59 ± 0.76 | 0.71 ± 0.85 | 0.47 ± 0.65 | 0.23 |
| Dissection (n, %) | 4 (6.7) | 0 (0) | 4 (12.9) | 0.065 |

and in-stent minimal luminal diameter were higher, the rate of SR was lower in the patients received post-dilation (for all $p < 0.05$).

## Discussion

In the present study, we attempted to study the effect of IVUS guidance on the angiographic results of stent implantation. While we measured comparable rates for in-stent restenosis between the groups, in-stent minimal luminal diameter and acute lumen gain were improved in patients received stent implantation with IVUS guidance. Overall, our findings indicated that the use of IVUS guidance during stent implantation improved the success rate of drug eluting stent (DES).

IVUS enables visualization of vascular tomographic sections; therefore, in contrast to the angiographic visualization that allows two dimensional measurement of vascular lumen, IVUS permits the calculation of vascular area, structure of arterial wall, and detailed lesion morphology in addition to three dimensional measurement of vascular lumen. Moreover, IVUS is more effective in showing the complications of stent implantations such as inadequate stent expansion, incomplete stent apposition, and dissection than angiography. Due to its described features here, IVUS can be used as complementary device to angiography during percutaneous coronary intervention[8,9].

Even though the presence of advanced stent technology and widespread use of DES, development of SR still continues to be the most important obstacle in the use of stents. While the percentage of SR formation is about 30% when bare-metal stents are used, the use DES is shown to reduce it to 10%[3]. Previous studies report contradictory results regarding whether the use of IVUS guidance decreases risk of developing SR. While some studies[10-12] indicate that the use of IVUS guidance during stent implantation reduces rate of SR development, other studies claim no such effect. The AVID study[13] carried out on this issue indicate that use of IVUS-guided stent implantation in patients with ≥ 2.5 mm of distal reference vessel diameter decreases SR rate and need for target vessel revascularization.

Development of SR is shown to be dependent on a number of factors such as patient, lesion, procedure, and others. Stent under-expansion and/or use of small-diameter stents are the major factors for the occurrence of procedural SR[9,14]. An earlier study[5] reported that more than half of the stents that were noted to be well expanded at angiographic inspection after implantations were inadequately expanded when they were reexamined with IVUS. IVUS also enables better detail examination of lesion, measurement of lesion length, and computation of vessel diameter in addition to determination of stent expansion[15,16]. Similarly, Oemrawsingh et al[17] showed that the use of IVUS guidance during stent implantation for longer lesions (> 20 mm) diminished the frequency of SR. IVUS guidance can help us with choosing the stent with more suitable diameter and length, which in turn might improve early and late results. In the present study, we determined SR in 11.7% of entire of the control angiographies. SR frequency was lower for the stents implanted with IVUS guidance than the stents implanted with angiography guidance; however, the difference was not statistically important. We are aware of the fact that the use of DES has significantly reduced the frequency of SR. The number of the patients we studied here might be inadequate to show beneficial effect of IVUS guidance on development of SR that is already reduced markedly with the use of DES. Nevertheless, increase in acute lumen gain and in-stent minimal luminal diameter suggests that use of IVUS guidance for DES implantation fur-

ther reduces the SR frequency. Moreover, another similar study[12] reported that while net lumen gain was markedly increased in the group of the patients received stent implantation with IVUS-guided stenting with respect to the patients underwent stent implantation with coronary angiography approach; they did not find a significant difference in frequency of angiographic stenosis and revascularization between the groups. Our present results are comparable with SIPS study.

Moreover, IVUS can guide post-dilatation procedure of inadequate stent expansion using non-compliant balloon. Mintz et al[18] indicated that 41% of the treatment decisions established using angiographic images were changed after assessing the data obtained with IVUS. In the present investigation, while we noted inadequate stent expansion in 22 cases (73.3%) in IVUS group, we noticed inadequate stent expansion in 9 cases (30%) in angiography group. These patients were treated with post-dilatation procedure using non-compliant balloon under high pressure and increased in-stent minimal luminal diameter was obtained in patients treated with post-dilatation procedure. Dissection was developed at the edge of the stent in four patients treated with post-dilatation intervention. While two of these patients were treated with another stent to close up dissected area, the other two patients with small dissection that was hindering the flow were allowed to recover spontaneously. None of these patients developed ST or SR during their follow-up visits. Achievement of enlarged in-stent minimal luminal diameter might improve angiographic and clinical results. In a similar multicenter study, Fitzgerald et al[19] indicated that achievement of larger vessel lumen reduces risk of restenosis and revascularization of targeted vessel. Colombo et al[5] suggest that if stent implantation is not performed with IVUS guidance, stent implantation should be secured with routine post-dilatation procedure. Underexpansion and malposition of stent are higher after implantation; however, complication rate of post-dilatation procedure with non-compliant balloon is low. Therefore, we support suggestions of Colombo et al[5] and Fitzgerald et al[19] that if stent implantation would not be performed with IVUS-guided stent, routine post-dilation procedure should be carried out after the angiographic stent implantation. In addition, occurrence of inadequate stent dilatation after stent implantation is an important cause for the development of ST. Performing post-dilatation procedure when required can reduce the frequency of ST. Likewise, in the present study the observation that no patients who underwent post-dilatation procedure developed ST further supports earlier observations. Use of IVUS guidance can indicate more effectively the need for post-dilatation procedure and serves as a complimentary technique for better stent implantation.

## Conclusions

Widespread use of DES has notably reduced the development of neo-intimal hyperplasia. Nonetheless, mechanical problems such as inadequate stent expansion**,** incomplete stent apposition, and partial overcastting of lesion by the stent are still foremost reasons behind the formation of ST and SR. Current findings suggest that the use of IVUS guidance during DES implantation can help reducing rate of ST and SR through decreasing such mechanical problems.

### Conflict of Interest

The Authors declare that there are no conflicts of interest.

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