Stent underexpansion in angiographic guided percutaneous coronary intervention, despite adjunctive balloon post-dilatation, in drug eluting stent era

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Original Article

Abstract

BACKGROUND: Stent underexpansion is the most powerful predictor of long-term stent patency and clinical outcome. The purpose of this study was to evaluate the incidence and predictors of stent underexpansion despite adjunctive post-dilatation with non-compliant balloon.

METHODS: After elective coronary stent implantation and adjunctive post-dilatation with non-compliant balloon and optimal angiographic result confirmed by the operator, intravascular ultrasound (IVUS) was performed for all the treated lesions. If the treated lesions fulfilled the IVUS criteria, they are considered as the optimal stent group; if not, they are considered as the suboptimal group.

RESULTS: From 50 patients enrolled in this study 39 (78%) had optimal stent deployment and 11 (22%) had suboptimal stent deployment. In the suboptimal group 7 (14%) had underexpansion, 2 (4%) malposition, and 2 (4%) had asymmetry. There were no stent edge dissections detected by IVUS. We did not find any correlation between lesion calcification, ostial lesions, stent length, and stent underexpansion. Stent diameter ≤ 2.75 mm had a strong correlation with stent underexpansion.

CONCLUSION: Despite adjunctive post-dilatation with noncompliant balloon, using a relatively small stent diameter was a strong predictor for underexpansion. IVUS guided percutaneous coronary intervention (PCI) may be considered for drug eluting stent (DES) implantation in relatively small vessels.

Keywords: Stent, Percutaneous Coronary Intervention, Ultrasound, Post-dilatation

Introduction

Angiographic guided percutaneous coronary intervention (PCI) is a common practice for the treatment of coronary artery lesions and procedural success is usually determined by the operator visual estimation. However, such subjective estimation of the procedural result is thought to be of limited reliability. Undoubtedly, intravascular ultrasound (IVUS) analysis is more accurate than angiography in detecting suboptimal stent deployment.[1-4] In comparison with bare metal stents; drug eluting stents (DESs) have led to a dramatic reduction in the rate of stent restenosis and the need for repeated revascularization. Therefore, the importance of optimal stent deployment was less considered.[5-7] This has caused the decreased use of adjunctive post-dilatation with noncompliant balloon. The frequency of achieving optimum stent deployment varied in different studies depending on the IVUS criteria used. Although many IVUS criteria for suboptimal stent deployment have been described, a uniform and accepted definition of optimal expansion is still lacking. The fundamental concepts underlying them include stent underexpansion, incomplete stent apposition, edge dissection, and lesion under coverage. Adjunctive post-dilatation with non-compliant balloon can increase minimal stent area (MSA) and decrease

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suboptimal stent deployment; therefore, it may reduce the frequency of target vessel revascularization (TVR) and stent thrombosis.[8]

This study was designed to evaluate the incidence and predictors of stent underexpansion despite adjunctive post-dilatation with non-compliant balloon. We also hypothesized that relatively small stent diameter might be a predictor of inadequate stent expansion.

Materials and Methods

The present study consisted of 50 patients who underwent stent implantation from April 2012 to March 2013 at Modarres Hospital, Tehran, Iran. All patients were pre-medicated with 325 mg of aspirin and loading dose of 300-600 mg of clopidogrel. Intravenous heparin was administered to maintain an activated clotting time of 250-300 s. The use of glycoprotein IIb/IIIa inhibitors was left to the operator's discretion. Inclusion criteria included coronary significant stenosis scheduled for elective coronary stent implantation. Exclusion criteria included a distal reference vessel diameter < 2.5 mm by visual estimation, acute myocardial infarctions (within 48 h), left main stenting, stent placement within an aneurysmal portion of a vessel, and allergies to aspirin, clopidogrel, or heparin. The study protocol was approved by the Institutional Ethics Committee, and a written informed consent was obtained from all the patients.

All the stents implanted were drug eluting stents and had received FDA approval or CE mark. Stents were deployed at nominal pressure and post-dilatation was done for all the treated lesions with non-compliant balloons, 0.25-0.5 mm larger than the stent delivery balloon at high pressure of 18-20 atmospheres (atm). The need for additional post-dilatation with larger non-compliant balloon depends on angiographic success and operator's decision. Angiographic success is defined as a final stent diameter stenosis of less than 10% of the distal reference vessel with the use of an automated edge detection system (QCA-CMS, Medis Medical Imaging Systems, Nuenen, Netherlands). If the patient fulfilled the angiographic success criteria, IVUS study was performed.

IVUS imaging and analysis

Intravascular ultrasound studies were performed with a commercially available system (Volcano Corporation, Rancho Cordova, CA, USA), incorporating an Eagle Eye catheter. After the administration of 100 to 200 μg of intracoronary nitroglycerine, ultrasound transducer was advanced 5 mm beyond the stent, and an image recording was performed to a point 5 mm proximal to the stent by manual pullback. All IVUS recordings were reviewed and quantitative parameters evaluated. These data consisted of MSA at the lesion, and at proximal and distal stent edges. Optimal stent deployment was defined as either MSA > 5.0 mm² or > 90% of the distal reference lumen area, complete apposition to the vessel wall, no edge dissection, and symmetry of stent.

Statistical Analysis

The statistical analysis was performed using SPSS for Windows (version 15; SPSS Inc., Chicago, IL, USA). The quantitative results were expressed as mean ± SD. Normality of data was evaluated with the Kolmogorov–Smirnov test, and statistical evaluation of data was performed using analysis of variance (ANOVA), followed by the Tukey's post-hoc test. The statistical significance of differences between proportions was determined by chi-square analysis with Yates' correction. Differences were considered significant if $P < 0.05$.

Results

All 50 patients enrolled in this study had adequate data for IVUS core laboratory analysis. Baseline clinical characteristics of patients in this analysis were similar in both groups. Baseline procedural and angiographic characteristics were also similar (Table 1). Of these 50 patients, 39 (78%) met the predefined IVUS criteria for optimum stent deployment, and the remaining 11 patients (22%), who did not meet the IVUS criteria, were classified as the suboptimum stent deployment group. There were no significant differences in baseline clinical, angiographic, and procedural characteristics between patients who met and did not meet the IVUS criteria for suboptimum stent deployment (Table 2).

The suboptimal group included stent underexpansion, stent malposition, asymmetry of stent, and edge dissection (Table 3). Calcification at target lesion, and vessel type were not predictors of stent underexpansion (Table 4). Of the procedural characteristics, stent length was not a predictor of sent underexpansion, but nominal stent diameter ≤ 2.75 mm was a strong predictor of stent underexpansion ($P = 0.002$), (Table 4). There were 22 stents (44% of total number of stents) with a diameter ≤ 2.75 mm implanted in this study, and about one third (7 out of 22) did not meet the IVUS criteria for optimum stent expansion. All implanted stents with a diameter > 2.75 mm had well

Table 1. Base line clinical characteristics

	All	Optimal stent deployment	Suboptimal stent deployment	P
Age (mean ± SD)	60.9 ± 11.8	61.0 ± 12.2	60.8 ± 10.9	0.910[*]
EF (mean ± SD)	47.7 ± 10.8	48.7 ± 10.7	44.1 ± 11.0	0.213[**]
DM	20	15 (75.0%)	5 (25.0%)	0.736[*]
HT	33	26 (79.0%)	7 (21.0%)	1.000[*]
HLP	30	23 (77.0%)	7 (23.0%)	1.000[*]
SM	18	15 (83.4%)	3 (16.6%)	0.734[*]
AMI	14	10 (71.4%)	4 (28.6%)	0.788[*]
Female	18	14 (88.0%)	4 (22.0%)	0.381[*]

[*] Chi-square test; [**] ANOVA
EF: Ejection fraction; DM: Diabetes melitus; HT: Hypertension; HLP: Hyperlipidemia; SM: Smoker; AMI: Acute myocardial infarction

Table 2. Base line angiographic characteristics

Vessel	All	Optimal stent deployment	Suboptimal stent deployment	P
LAD	32	24 (75.0%)	8 (25.0%)	0.501[*]
LCX	11	9 (82.0%)	2 (18.0%)	0.501[*]
RCA	7	6 (85.7%)	1 (14.3%)	0.501[*]
Location				
Ostial	11	10 (90.9%)	1 (9.1%)	0.392[*]
Sent length (mean ± SD)	25.3 ± 8	25.3 ± 8	25.3 ± 8	0.581[**]

[*] Chi-square test; [**] ANOVA
LAD: Left anterior descending artery; LCX: Left cicumflex atery; RCA: Right coronary artery

expanded in IVUS. Stent area at lesion was 4.4 ± 0.3 mm² in the underexpansion group, and 7 ± 2.1 mm² in the optimal stent group. No correlation was found between patients' previous medical history or their risk factors included in this study, and the result of expansion. Additionally, no further significant relations were found among the various variables examined using regression models.

Table 3. Prevalence of suboptimal stent deployment

Suboptimal stent deployment	N	%
Underexpansion	7	14
Mal apposition	2	4
Asymmetry	2	4
Edge dissection	0	0
Total	11	22

Table 4. Angiographic and procedural predictors of stent underexpansion

Angiographic characteristic	Met IVUS criteria for underexpansion	P[*]
Vessel	5	0.510
LAD, n = 32	2	
LCX, n = 11	0	
RCA, n = 7		
Calcification		0.337
Yes, n = 12	3	
No, n = 38	4	
Procedural characteristic		
Stent diameter		0.002
≤ 2.75 mm, n = 22	7	
> 2.75 mm, n = 28	0	
Stent length		0.660
< 23 mm, n = 16	3	
≥ 23 mm, n = 34	4	
Stent area at lesion (mean ± SD)	4.4 ± 0.3 mm²	

[*] Chi-square test
LAD: Left anterior descending artery; LCX: Left cicumflex atery; RCA: Right coronary artery; IVUS: Intravascular ultrasound

Discussion

This study demonstrated that 22% of lesions, which had undergone angiographic guided DES implantation following adjunctive post-dilatation with noncompliant balloon, did not meet IVUS criteria for optimal stent deployment. We did find that 14% of all implanted stents had either MSA < 5.0 mm² or < 90% of the distal reference lumen area; they were classified as underexpansion subgroup. Nominal stent diameter ≤ 2.75 mm was a strong predictor of stent underexpansion in our study. It showed that despite adjunctive post-dilatation with noncompliant balloon, PCI on relatively small vessel or choosing an undersized stent could result in stent underexpansion.

It has been shown that post-dilatation with noncompliant balloons improved stent expansion and decreased the frequency of suboptimum stent deployment.[9,10] In the Bare Metal Stent (BMS) era, several studies demonstrated the beneficial effect of a larger MSA with adjunctive post-dilation balloon on post procedural angiographic results and stent restenosis during long-term follow up.[11-13] The importance of adjunctive balloon for post-dilatation has been shown in the post-dilatation clinical comparative study (POSTIT) trial; with optimal stent expansion defined as MSD ≥ 90% of the average reference lumen diameter, only 36% of patients undergoing coronary stenting met the IVUS criteria without adjunctive balloon post-dilatation.[9] In the angiography versus intravascular ultrasound-directed (AVID) study, optimum stent deployment (defined as MSA ≥ 90% of the average reference lumen area by blinded IVUS) was achieved in 57% of patients.[8] In comparison to our study, such a high incidence of underexpansion, despite adjunctive post-dilatation in AVID trial, was due to strict IVUS criteria used for optimizing BMSs.

In the DES era, in a substudy of the Sirius trial, the adequate DES patency was defined as a follow up IVUS MSA > 4.0 mm². When the adequate post-interventional MSA of sirolimus-eluting stents (SESs) was defined as > 5.0 mm², the positive predictive value of patency was 90%.[14] de Ribamar et al. found that without adjunctive balloon post-dilatation, 24% of SES and 28% of paclitaxel-eluting stent (PES) did not achieve a final MSA of 5 mm².[15] In comparison to our study, the higher rate of underexpansion observed by de Ribamar et al. indicated the importance of adjunctive balloon post-dilatation in DES implantation.

There are several potential reasons to the occurrence of suboptimal stent expansion despite post-dilatation with a larger noncompliant balloon. First, the inflated balloon pressure could be inadequate for optimal stent deployment. In the POSTIT trial, stent deployment at less than 12 atm was associated with a high frequency of suboptimal stent deployment. However, this did not appear to be the case in our study, since all stents were deployed at nominal pressure and post-dilated with larger noncompliant balloon at a high pressure of 18-20 atm. Second, selecting an undersized stent delivery balloon for the target lesion may usually cause stent underexpansion.[8] Since we did not perform IVUS before stent implantation, the operator could not assess whether the vessel was really a small vessel or just appeared as such at angiography.

This practice might result in stent underexpansion. Although the benefit of IVUS guidance is most important in complex lesion subsets, such as left main and bifurcation lesions, IVUS guided PCI even in relatively small vessels resulted in larger MSA. In health outcome and mortality evaluation (HOME) DES study all the IVUS guided PCI group had optimal stent expansion.[16]

Calcified vessels could affect final stent lumen area, preventing complete stent expansion even when higher pressures or larger balloons were applied.[17,18] However, vessel calcification was not a predictor of stent underexpansion in our study; this result was in accordance with the study of de Ribamar et al.[15]

The present study showed that about one third of implanted DESs with nominal diameter ≤ 2.75 mm met the IVUS criteria for underexpansion. In nominal diameter > 2.75 mm all implanted DESs with adjunctive post-dilatation had expanded well.

Study limitations
This was a single-center study with a relatively small sample size. Interobserver and intraobserver differences in interpretation may affect the results.

Conclusion

The present study showed that despite adjunctive post-dilatation with noncompliant balloon, stent diameter ≤ 2.75 mm was a strong predictor of DES underexpansion. IVUS guided PCI in relatively small vessels may prevent stent underexpansion. Angiographic guided PCI with adjunctive post-dilatation had acceptable IVUS results in DES implantation in stent diameter > 2.75 mm.

Conflict of Interests

Authors have no conflict of interests.

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