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Original article

Application of Intravascular Ultrasound in Stent Implantation for Small Coronary Arteries

Jian-Qi Zhang[a,b], Rui Shi[b], Wei Pang[c], Qiong Guo[b], Ying Xu[b], Juan Zhang[b], Qin Yang[b], Ying Li[b], Jin-Ping Mei[b], Tie-Min Jiang[b], Yu-Ming Li[b]

[a] *Graduate School of Medicine, Tianjin Medical University, Tianjin, China*

[b] *Institute of Cardiovascular Disease and Heart Center, Pingjin Hospital, Logistics University of the Chinese People's Armed Police Forces, 220, Cheng-Lin Road, Tianjin, China*

[c] *Clinical Laboratory, Pingjin Hospital, Logistics University of the Chinese People's Armed Police Forces, 220, Cheng-Lin Road, Tianjin, China*

Abstract: Aims: Recently, the final minimum luminal diameter (MLD) has been regarded as one of the most important determinants of restenosis. Our study was to evaluate if IVUS optimized DES implantation in small coronary artery lesions was superior to angiographic guidance alone in achieving a larger final MLD. Methods and Results: 84 non-diabetic coronary heart disease (CHD) patients with a single de novo lesion in a small vessel (diameter range ≥2.25 and ≤2.75 mm) were randomized as follows: 42 to the angiography group and 42 to the IVUS group. Primary study endpoint was post-procedure in lesion MLD. Secondary end points were combined major adverse cardiac events (MACE) at 1, 6, 9, and 12months. No significant differences were observed in the baseline patient demographic and lesion characteristics, between the angiography group and the IVUS group. The primary study end point post-procedure MLD and acute gain were larger in the IVUS group (2.77±0.19mm versus 2.53±0.21mm, P=0.000, and 1.87±0.28mm versus 1.63±0.27mm, P=0.000, respectively). Final stenosis was smaller in the IVUS group (6.72±2.56% versus 7.94±2.47%, P=0.029). At follow-up, there were no statistically significant differences between the IVUS group and angiography group with respect to MI, TVR, and Cardiac death. Conclusions: A benefit of IVUS optimized DES implantation was observed in a small vessel in the post-procedure minimal lumen diameter. No statistically significant difference was found in MACE up to 12 months (*J clin invasive cardiol 2016;3:2-8*).

Key Words: small vessel, coronary arteries, coronary angiography, intravascular ultrasonography, coronary angioplasty

Introduction

Percutaneous coronary interventions (PCI) targeting small coronary arteries (diameter range 2.25-2.75mm) comprise up to 35% of all catheter-based procedures in daily practice.[1-4] A small reference diameter may indicate a true small coronary artery with large plaque burden, or diffuse disease. Drug-eluting stents (DES) have shown efficacy in small coronary artery lesion subset.[5,6] Nevertheless, patients with small-vessel coronary disease experience increased rates of acute closure, early

Correspondence to: Yu-Ming Li. Institute of Cardiovascular Disease and Heart Center, Pingjin Hospital, Logistics University of the Chinese People's Armed Police Forces, 220, Cheng-Lin Road, Tianjin, China. Tel.: +86 22 60578746; fax: +86 22 24716466. E-mail address: cardiolab@gmail.com. Received January 2016; Revised February 2016; Accepted February 2016; Published March 2016.

complications, and restenosis with target lesion revascularization (TLR). Some studies suggest that stent under expansion remains one of the most important causes of restenosis.[5, 7-9]

Intravascular ultrasound (IVUS) is a procedure that uses high frequency sound waves to acquire 3-dimensional images from the lumen of a blood vessel. One of the advantages of IVUS imaging for clinical work derives from its ability to define both luminal and vessel dimensions.[10, 11] Since arterial remodeling with compensatory vessel enlargement develops to preserve the lumen, the vessel size by IVUS may be significantly greater than the lumen size by angiography.[12-15] IVUS guidance has therefore been advocated as a possible solution to optimize the results of stenting and theoretically improving restenosis rate. Recently, the final minimum luminal diameter (MLD) has been regarded as one of the most important determinants of restenosis, with IVUS having the potential to maximize the final MLD.[16, 17]

Thus, our study aim was to evaluate if IVUS optimized DES implantation in small coronary artery lesions was superior to angiographic guidance alone in achieving a larger final MLD.

Materials and methods

Study population

We enrolled 84 non-diabetic coronary heart disease (CHD) patients presenting consecutively to Pingjin hospital, Logistics University of Chinese People's Armed Police Forces between November 2014 and September 2015. The patient inclusion criteria was as follows: (1) 18-80 years old; (2) willing to provide informed consent and agreed to diagnostic coronary angiography; (3) stable angina pectoris(Canadian Cardiovascular Society Classifications 1-4), unstable angina pectoris (Braunwald Classifications B and C 1-2), or documented silent ischemia; (4) a single de novo lesion in a small vessel (diameter range ≥2.25 and ≤2.75 mm, visual estimate) of a major coronary artery requiring treatment; (5) target lesion stenosis ≥50% and ≤100%; (6) target lesion length ≥15 and ≤30 mm; (7) coronary flow ≥TIMI 1.

Patients with the following conditions were excluded: (1) documented left ventricular ejection fraction (LVEF) <30%; (2) severe renal failure; (3) target vessel with multiple or tandem lesions; (4) heavily calcified lesion; (5) unprotected left main coronary artery disease with >50% stenosis; (6) excessively tortuous target lesion or target lesion involving a bifurcation with a diseased side branch>2.25 mm in diameter requiring treatment; (7) previous myocardial infarction in the territory of the target vessel, (8) recent (<1week) ST-elevation or non–ST elevation myocardial infarction involving any territory; (9) prior coronary artery bypass surgery; (10) in-stent restenosis. The research protocol was approved by the ethical committee of Pingjin Hospital, Logistics University of the Chinese People's Armed Police Forces, which was in accordance with the principles of the Declaration of Helsinki. All patients were pretreated with clopidogrel plus aspirin. All the lesions should be treated with the same DES.

Interventional procedures

PCI were carried out according to international guidelines, using a standard technique, through the femoral or brachial route. 10000 IU of heparin was given before the procedure. CHD was confirmed by the presence of coronary stenoses ≥50% lumen obstruction in at least one of the three main coronary arteries. In patients randomized to the angiography guided group, all decisions regarding requirement for post-dilatation, balloon size for post-dilatation and the assessment of optimal stent expansion were based on angiography alone, being left to the discretion of the operator. The appropriate balloon size was chosen based on visual estimates of the reference vessel's diameter. A stent system (available as 2.25, 2.50, or 2.75 mm in diameter and as 18, 23, or 33 mm in length) was selected to provide a stent/vessel ratio of 1.1:1 at nominal pressure. The stent was to be at least 3 mm longer than the balloon or the area of predilatation. However, post-dilatation was strongly recommended.

IVUS examination

The IVUS procedure was performed in a standard fashion using automated motorized pullback (0.5mm/s) with commercially available imaging systems (20 MHz IVUS catheter, Volcano Corporation). To prevent coronary

spasms, optimal dose of i.c. isosorbide dinitrate was given prior to measurement. IVUS analysis was performed by clinicians blinded to the treatment arm. In the IVUS guided group, IVUS was performed before and after DES implantation in order to assess optimal stent expansion.

Quantitative coronary angiography (QCA)
QCA was analyzed by clinicians blinded to the treatment arm with a semi-automated edge contour detection computer analysis system (MedisQAngio XA 7.1) at baseline and following the procedure. QCA was performed of the "stent area" (in stent analysis including only the stented segment) and the in-segment area, which included the stented area as well as both 5 mm areas proximal and distal to the stent (in-segment analysis) and at the point of baseline MLD (in-lesion analysis). The following angiographic quantitative parameters were measured: reference vessel diameter (RVD), MLD, and diameter stenosis (difference between the reference diameter and intimal luminal diameter divided by the reference diameter and multiplied by 100). Three angiograms in identical projections were obtained after intracoronary injection of nitroglycerin immediately before and after the intervention.

Study endpoints
Clinical follow-up was obtained at 30-days, 6, 9, and 12 months (either by office visit or telephone contact). Angiographic follow-up was performed in patients who were symptomatic, had evidence of ischemia or equivocal resultsduring non-invasive testing, or who had experienced an ischemic coronary event at any time following hospital discharge.
The primary endpoint was post-procedural in-lesion MLD as evaluated by QCA. This was the primary efficacy endpoint to test the superiority of the IVUS optimized over the angiography directed stent placement, in the intention to treat population. Secondary endpoints major adverse cardiovascular event (MACE) at 30 days, 6, 9, and 12-month. MACE was defined as the composite of any MI, cardiac death and target vessel revascularization (TVR).

Statistical Analysis
Continuous variables with normal distributions are presented as mean±SD and other wise expressed as medians with interquartile ranges. For comparisons between two groups, an unpaired Student's t test or a Mann–Whitney U test was used. Correlations between variables were calculated using Pearson's (normally distributed continuous variables) or Spearman (ordered categorical variables or skewed continuous variables) coefficient. Categorical data were compared with Fisher's exact test. All statistical analyses were performed using SPSS version 15.0 (SPSS, Chicago, IL). A two-tailed P value≤0.05 was considered statistically significant.

Results

Demographic and lesion characteristics
There were 84 patients were randomized into the study. They were randomized as follows: 42 to the angiography group and 42 to the IVUS group. Table 1 showed the baseline patient demographic and lesion characteristics. As shown in Table 1, no significant differences were found, either in the angiography group or in the IVUS group.

Procedural characteristics of the study population
As shown in Table 2, there is statistical differences in stent diameter (2.64±0.25 mm versus 2.45±0.20 mm, P=0.000), stent length (26.14±4.46 mm versus 23.33±5.77 mm, P=0.014), post-dilatation balloon diameter (2.90±0.22 mm versus 2.64±0.21 mm, P=0.000), and post-dilatation max pressure (15.86±1.84 atm versus 14.14±1.89 atm, P=0.000) between two groups. All these were greater in the IVUS group compared with the angiography group. But, there is no statistical differences in stent pressure (12.95±2.22 atm versus 12.10±2.12 atm, P=0.074).

QCA measurements evaluated of the study population
QCA measurements are shown in Table 3. There was no difference in the IVUS group and the angiography group in lesion length, baseline RVD, baseline MLD, and baseline stenosis. Post-procedure RVD was larger in the IVUS

Table 1. Baseline Clinical Characteristics and Angiographic of the Study Population

		Angiography (n=42)	IVUS (n=42)	*P*
Age (years)	61.65±8.77	60.10±9.36	63.21±7.96	0.104
Gender (Male%)	46(54.8%)	25(59.5%)	21(50.0%)	0.511
Hypertension, n (%)	52(61.9%)	25(59.5%)	27(64.3%)	0.653
Hypercholesterolemia, n (%)	45(53.6%)	25(59.5%)	20(47.6%)	0.274
Family history of cardiovascular disease, n (%)	29(34.5%)	13(31.0%)	16(38.1%)	0.647
History of smoking, n (%)	44(52.4%)	22(52.4%)	22(52.4%)	1.000
BMI (Kg/m^2)	27.27±3.88	27.14±3.86	27.40±3.94	0.763
SBP (mmHg)	143.55±15.57	140.56±16.49	146.55±14.15	0.078
DBP (mmHg)	77.11±10.18	78.84±8.79	75.39±11.25	0.121
LVEF (%)	57.80±4.58	57.48±4.79	58.12±4.39	0.523
UN (mmol/L)	5.48±1.62	5.51±1.62	5.45±1.64	0.847
Cr (μmol/L)	63.42±13.80	64.38±13.70	62.45±13.99	0.525
UA (μmol/L)	290.82±75.25	291.14±73.61	290.50±77.75	0.969
FPG (mmol/L)	5.06±0.50	5.04±0.52	5.08±0.49	0.763
TC (mmol/L)	5.07(4.36,5.57)	4.98(4.66,5.28)	5.17(4.22,5.80)	0.714
TG (mmol/L)	2.07±0.58	2.05±0.53	2.10±0.62	0.683
HDL-c (mmol/L)	1.28±0.21	1.26±0.22	1.30±0.20	0.343
LDL-c (mmol/L)	3.28±0.82	3.13±0.78	3.43±0.84	0.095
Hcy (μmol/L)	12.03±4.05	11.27±4.49	3.46±0.84	0.087
Medications, n (%)				
Nitrates	68(81.0%)	35(83.3%)	33(78.6%)	0.782
β-Blockers	44(52.4%)	24(57.1%)	20(47.6%)	0.512
ACEI/ARB	41(48.8%)	21(50.0%)	20(47.6%)	0.827
Calcium antagonists	26(31.0%)	13(31.0%)	13(31.0%)	1.000
Statins	82(97.6%)	41(97.6%)	41(97.6%)	1.000
PPI	18(21.4%)	11(26.2%)	7(16.7%)	0.426
Target vessel, n (%)				
Right coronary artery	18(21.4%)	8(44.4%)	10(55.6%)	0.595
Left anterior descending artery	29(34.5%)	15(51.7%)	14(48.3%)	0.818
Left circumflex artery	37(44.0%)	19(51.4%)	18(48.6%)	0.826

BMI, body mass index, SBP, systolic blood pressure, DBP, diastolic blood pressure, LVEF, left ventricular ejection fraction, UN, urea nitrogen, Cr, creatinine, UA, uric acid, FPG, fasting plasma glucose, TC, total cholesterol, TG, triglyceride, HDL-c, high-density lipoprotein cholesterol, LDL-c, low-density lipoprotein cholesterol, Hcy, homocysteic acid, ACEI, angiotensin-converting enzyme inhibitor, ARB, angiotensin receptor antagonist, PPI, proton pump inhibitor.

group (2.74±0.20 mm versus 2.48±0.21 mm, P=0.000). Especially, post-procedure MLD and acute gain were larger in the IVUS group (2.77±0.19 mm versus 2.53±0.21 mm, P=0.000, and 1.87±0.28 mm versus 1.63±0.27 mm, P=0.000, respectively). Final stenosis was smaller in the IVUS group (6.72±2.56% versus 7.94±2.47%, P=0.029).

Clinical outcomes at 30 days and up to 12-month

Of the 84 patients who received a stent, follow-up angiography was performed in 76 (90.4%). At follow-up, there were no statistically significant differences between the IVUS group and angiography group with respect to MI, TVR, and Cardiac death, as shown in Table 4.

Discussion

Some studies have showed stent implantation in small arteries is a well-known independent risk factor for restenosis and major adverse cardiac events after the intervention.[13,18,19] In addition to small post-procedural lumen diameter, high plaque burden and pronounced diffuse disease may be important factors.[20,21] In coronary arteries that appear angiographically small but are actually large,[22] the risks of undersizing or

Table 2. Procedural Characteristics of the Study Population

	Angiography (n=42)	IVUS (n=42)	*P*
Stent diameter, mm	2.45±0.20	2.64±0.25	0.000
Stent length, mm	23.33±5.77	26.14±4.46	0.014
Stent pressure, atm	12.10±2.12	12.95±2.22	0.074
Postdilatation balloon diameter, mm	2.64±0.21	2.90±0.22	0.000
Post dilatation max pressure, atm	14.14±1.89	15.86±1.84	0.000

underexpansion of a stent exist, and both may increase stent-related complications. In the present study, the main findings are (1) stent diameter, stent length, post-dilatation balloon diameter, and post-dilatation maximum pressure are larger in the IVUS group than in the angiography group; (2) a larger final MLD was obtained with IVUS-guided DES post-dilatation (primary end point); (3) IVUS guided post-dilatation was a relatively safe procedure (no difference in 30-day MACE); (4) no difference was observed in cumulative MACE between IVUS and angiography guided procedures at 12-months. All these results showed angiographically small vessels are actually large , and need larger stent diameter, stent length, post-dilatation balloon diameter, and post-dilatation maximum pressure in the IVUS group than in the angiography group.

Although stenting in small coronary arteries remains somewhat controversial, it is currently performed routinely. Many trials have demonstrated that IVUS could be used to guide stent implantation properly and accurately, while CAG often underestimates the size of balloon and stent.[23-26] Kiemeueij et al[27] believed that most stent deployment often needed further dilation with bigger low-compliance balloon. Regar et al[26,28] thought that IVUS-based stent selection still cannot achieve complete dilation, and a larger balloon is needed. Satisfactory stent deployment is strongly correlated with clinical prognosis. Although there is great interest on the part treating small vessels, there has been even greater interest for the patients themselves who have those small vessels being treated.

It has been shown that is possible to optimize stent deployment by IVUS guidance, mainly due to bigger balloons or higher inflation pressures. After IVUS guided over-dilation, stent dimensions were shown to increase. In the present study, 1-year TLR decreased with increasing stent expansion in small coronary vessels. Thus, and importantly, stent over-expansion did not increase clinical restenosis. This finding correlates with studies in larger vessels in which stent overexpansion resulted in larger final lumen dimensions that were maintained at follow-up. Stent implantation guided by intravascular ultrasound can acquire

Table 3. Quantitative Coronary Angiography Measurements evaluated of the Study Population

	Angiography (n=42)	IVUS (n=42)	*P*
Lesion length, mm	15.07±5.53	16.99±4.22	0.077
Reference vesse diameter (RVD)			
Baseline RVD, mm	2.39±0.27	2.40±0.23	0.833
Post-procedure RVD, mm	2.48±0.21	2.74±0.20	0.000
Minimal lumen diameter (MLD)			
Baseline MLD, mm	0.90±0.31	0.91±0.30	0.931
Post-procedure MLD, mm	2.53±0.21	2.77±0.19	0.000
Acute gain, mm	1.63±0.27	1.87±0.28	0.000
Diameter stenosis, %			
Baseline stenosis (%)	77.75±8.50	77.82±9.06	0.973
Final stenosis (%)	7.94±2.47	6.72±2.56	0.029

RVD, reference vesse diameter, MLD, minimal lumen diameter

Table 4. Major adverse cardiac events at 30 days and 12 months

	Angiography (n=42)	IVUS (n=42)	*P*
30 days MACE (%)			
MI	1(2.4%)	0(0.0%)	1.000
TVR	1(2.4%)	0(0.0%)	1.000
Cardiac death	0(0.0%)	0(0.0%)	
12-month MACE (%)			
MI	2(4.8%)	1(2.4%)	1.000
TVR	7(16.7%)	2(4.8%)	0.078
Cardiac death	0(0.0%)	0(0.0%)	

MACE, major adverse cardiovascular event, MI, miocardial infarction, TVR, target vessel revascularization

larger final lumen area and identify more procedurally related complications.

On the other hand, application of IVUS in small vesells has some limitations: (1) The diameter of ultrasonic catheter is 2.9F, sometimes ultrasonic catheter cannot pass the remote of small vessels. (2) Sometimes ultrasonic catheter could injury vascular endothelial or cause spasm when pass through small vessel cavity. (3) Sometimes IVUS provides the accuracy of quantitative parameters are affected by factors such as vascular calcification and distortion. (4) Costa et al suggested: patients with moderate stenoses in small vessels, IVUS and QCA parameters are unreliable in defining the hemodynamic status. They use fractional flow reserve (FFR) in determining hemodynamically significant of small vessels. They suggested that most moderate stenoses in small vessels with FFR (>0.75) values do not require revascularization.[29]

Limitations

Similar to previous studies combining different diagnostic invasive modalities (angiography, and IVUS) to guide PCI, the small number of patients of the present study may represent a main limitation of our investigation. In addition, the follow-up period was limited to 12 months, warranting additional observation to clarity the effect of these IVUS results on longer term clinical outcomes.

In summary, the present study shows that in a small vessel IVUS can optimized DES implantation with the post-procedure minimal lumen diameter, and the procedure with IVU is safety.

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REFERENCES

1) Moreno R, Fernandez C, Macaya C. Coronary stenting in small vessels. Eur Heart J, 2005, 26(15): 1562; author reply 1562-1563.
2) Morice MC. Stenting for small coronary vessels. J Invasive Cardiol, 2003, 15(7): 377-379.
3) Rodriguez-Granillo GA, Valgimigli M, Garcia-Garcia HM, et al. One-year clinical outcome after coronary stenting of very small vessels using 2.25 mm sirolimus- and paclitaxel-eluting stents: a comparison between the RESEARCH and T-SEARCH registries. J Invasive Cardiol, 2005, 17(8): 409-412.
4) Tanimoto S, Daemen J, Tsuchida K, et al. Two-year clinical outcome after coronary stenting of small vessels using 2.25-mm sirolimus- and paclitaxel-eluting stents: insight into the RESEARCH and T-SEARCH registries. Catheter Cardiovasc Interv, 2007, 69(1): 94-103.
5) Bartorelli AL, Serruys PW, Miquel-Hebert K, et al. An everolimus-eluting stent versus a paclitaxel-eluting stent in small vessel coronary artery disease: a pooled analysis from the SPIRIT II and SPIRIT III trials. Catheter Cardiovasc Interv, 2010, 76(1): 60-66.
6) Umeda H, Iwase M, Gochi T, et al. Safety and efficacy of 2.5-mm sirolimus-eluting stent implantation at lower deployment pressures in very small vessels (<2.5 mm). Coron Artery Dis, 2009, 20(2): 163-168.
7) Biondi-Zoccai G, Moretti C, Abbate A, et al. Percutaneous coronary intervention for small vessel coronary artery disease. Cardiovasc Revasc Med, 2010, 11(3): 189-198.
8) Koh AS, Chia S, Choi LM, et al. Long-term outcomes after coronary bare-metal-stent and drug-eluting-stent implantations: a 'real-world' comparison among patients with diabetes with diffuse small vessel coronary artery disease. Coron Artery Dis, 2011, 22(1): 96-99.
9) Puymirat E, Mangiacapra F, Peace A, et al. Safety and effectiveness of drug-eluting stents versus bare-metal stents in elderly patients with small coronary vessel disease. Arch Cardiovasc Dis, 2013, 106(11): 554-561.
10) Goto K, Zhao Z, Matsumura M, et al. Mechanisms and Patterns of Intravascular Ultrasound In-Stent Restenosis Among Bare Metal Stents and First- and Second-Generation Drug-Eluting Stents. Am J Cardiol, 2015, 116(9): 1351-1357.
11) Kataoka Y, Puri R, Nicholls SJ. Inflammation, plaque progression and vulnerability: evidence from intravascular ultrasound imaging. Cardiovasc Diagn Ther, 2015, 5(4): 280-289.
12) Ma T, Zhou B, Hsiai TK, et al. A Review of Intravascular Ultrasound-Based Multimodal Intravascular Imaging: The Synergistic Approach to Characterizing Vulnerable Plaques. Ultrason Imaging, 2015.

13) Yazici HU, Agamaliyev M, Aydar Y, et al. The impact of intravascular ultrasound guidance during drug eluting stent implantation on angiographic outcomes. Eur Rev Med Pharmacol Sci, 2015, 19(16): 3012-3017.
14) Gussenhoven EJ, Essed CE, Lancee CT, et al. Arterial wall characteristics determined by intravascular ultrasound imaging: an in vitro study. J Am Coll Cardiol, 1989, 14(4): 947-952.
15) Werner GS, Sold G, Buchwald A, et al. Intravascular ultrasound imaging of human coronary arteries after percutaneous transluminal angioplasty: morphologic and quantitative assessment. Am Heart J, 1991, 122(1 Pt 1): 212-220.
16) Chieffo A, Latib A, Caussin C, et al. A prospective, randomized trial of intravascular-ultrasound guided compared to angiography guided stent implantation in complex coronary lesions: the AVIO trial. Am Heart J, 2013, 165(1): 65-72.
17) Schiele F, Meneveau N, Gilard M, et al. Intravascular ultrasound-guided balloon angioplasty compared with stent: immediate and 6-month results of the multicenter, randomized Balloon Equivalent to Stent Study (BEST). Circulation, 2003, 107(4): 545-551.
18) Akiyama T, Moussa I, Reimers B, et al. Angiographic and clinical outcome following coronary stenting of small vessels: a comparison with coronary stenting of large vessels. J Am Coll Cardiol, 1998, 32(6): 1610-1618.
19) Chen SL, Xu B, Chen JB, et al. Diagnostic accuracy of quantitative angiographic and intravascular ultrasound parameters predicting the functional significance of single de novo lesions. Int J Cardiol, 2013, 168(2): 1364-1369.
20) Mintz GS, Popma JJ, Pichard AD, et al. Intravascular ultrasound predictors of restenosis after percutaneous transcatheter coronary revascularization. J Am Coll Cardiol, 1996, 27(7): 1678-1687.
21) Kasaoka S, Tobis JM, Akiyama T, et al. Angiographic and intravascular ultrasound predictors of in-stent restenosis. J Am Coll Cardiol, 1998, 32(6): 1630-1635.
22) Okabe T, Asakura Y, Ishikawa S, et al. Determining appropriate small vessels for stenting by intravascular ultrasound. J Invasive Cardiol, 2000, 12(12): 625-630.
23) Rogacka R, Latib A, Colombo A. IVUS-Guided Stent Implantation to Improve Outcome: A Promise Waiting to be Fulfilled. Curr Cardiol Rev, 2009, 5(2): 78-86.
24) Gerber RT, Latib A, Ielasi A, et al. Defining a new standard for IVUS optimized drug eluting stent implantation: the PRAVIO study. Catheter Cardiovasc Interv, 2009, 74(2): 348-356.
25) Kataoka T, Shimada K, Fukuda D, et al. The impact of IVUS guided bare metal stent implantation for non-small vessel. Osaka City Med J, 2004, 50(2): 79-86.
26) Regar E, Klauss V, Werner F, et al. Quantitative changes in reference segments during IVUS-guided stent implantation: impact on the criteria for optimal stent expansion. Catheter Cardiovasc Interv, 1999, 47(4): 434-440.
27) Kataoka T, Grube E, Honda Y, et al. 7-hexanoyltaxol-eluting stent for prevention of neointimal growth: an intravascular ultrasound analysis from the Study to COmpare REstenosis rate between QueST and QuaDS-QP2 (SCORE). Circulation, 2002, 106(14): 1788-1793.
28) Regar E, Werner F, Klauss V, et al. IVUS analysis of the acute and long-term stent result using motorized pullback: intraobserver and interobserver variability. Catheter Cardiovasc Interv, 1999, 48(3): 245-250.
29) Costa MA, Sabate M, Staico R, et al. Anatomical and physiologic assessments in patients with small coronary artery disease: Final results of the Physiologic and Anatomical Evaluation Prior to and After Stent Implantation in Small Coronary Vessels (PHANTOM) trial. Am Heart J, 2007, 153(2): 296.e1-296.e7.