

A NEW APPROACH TO THE ASSESSMENT OF THE RESULTS OF ENDOVASCULAR CORRECTION OF CORONARY ARTERY BIFURCATION

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The aim of the investigation is to study the results of endovascular treatment of patients with coronary bifurcation disorders performed under the control of selective coronography and intravascular manometry, and to assess on the basis of their analysis the manometric findings of blood flow in bifurcation branches when choosing endovascular correction management.

Materials and Methods. The analysis of peculiarities and the results of endovascular correction of coronary bifurcations was performed in 67 patients with test T-stenting. The bifurcation state of the 1st group patients (n=32) was assessed by contrast angiography and the measurement of fractional flow reserve, the patients of the 2nd group (n=35) — by angiography findings only. Long-term results (follow-up period is 12 months) were studied in 30 patients (93.8%) of the 1st group, and in 33 patients (94.3%) of the 2nd group.

Results. In 11 of 32 cases angiographic assessment of stenosis in the lateral branch mouth was different from that of manometric one. There was determined an average degree of correlation ($R=0.46$; $p=0.008$). In Y-type bifurcation there was no correlation between the assessments of hemodynamic significance of stenosis in the lateral branch ($R=0.21$; $p=0.464$). In a follow-up period, angina recurrence or the increase of its degree was revealed in 3 patients (10.0%) of the 1st group, and in 11 patients (33.3%) of the 2nd one ($p=0.035$). Restenoses in lateral branches were found in 2 patients (6.7%) of the group under study and in 10 patients (30.3%) in the control group ($p=0.024$).

Conclusion. The use of complex approach to the assessment of the results of coronary bifurcation correction improves the results of surgeries due to the decrease of restenoses rate and the necessity of re-revascularization in the follow-up. The advantage of the approach is more accurate assessment of hemodynamic changes in bifurcation branches and, therefore, the possibility to choose an optimal technique of endovascular correction.

Key words: coronary artery bifurcation, coronary stenting, fractional flow reserve.

The complexity of endovascular X-ray correction of affected coronary bifurcations is determined by the variability of bifurcation anatomical features, numerous approaches to their correction, the assessment problem of physiological significance of changes in bifurcation branches, and high rate of restenoses [1–5]. The great majority of percutaneous coronary surgical procedures are performed under the control of coronary angiography to monitor the state of coronary arteries. It's a remarkable method, once marking a milestone in cardiology, enabling to obtain objective information of an initial state of an affected artery, morphological changes in the course of correction, and evaluate the results of the surgery performed [6]. Nevertheless, coronarography has a

number of limitations concerning mainly the assessment of physiological significance of coronary artery stenoses. Recently, relatively simple and available technique to assess coronary blood flow has been introduced into clinical practice. The method is based on intravascular manometry (IVM), the basic index being fractional flow reserve (FFR).

The study of the blood flow in bifurcation branches showed not all stenoses in the mouths of lateral branches resulting from stenting to be functionally significant [7–10]. According to angiography, considerable variability of FFR indexes was found even in stenosis of the mouths of lateral branches by more than 75% of diameter. For this reason, some authors conclude that in some cases there is inconsistency between

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stenosis functional significance in the mouth of lateral branch and its intensity estimated by quantitative coronary angiography [10–12]. It can be expected that angiography of coronary bifurcation supplemented by the information of blood flow in branches will enable to optimize the approach to endovascular intervention and improve its results.

The aim of the investigation is to study the results of endovascular treatment of patients with coronary bifurcation lesions performed under the control of selective coronography and intravascular manometry, and to assess on the basis of their analysis the manometric findings of blood flow in bifurcation branches when choosing endovascular correction management.

Materials and Methods. The analysis of peculiarities and the results of endovascular correction of non-stem coronary bifurcations was performed in 67 patients with test T-stenting by stents with drug coated stents. In the 1st group patients (n=32) the blood flow in bifurcation branches, as well as the morphological and hemodynamic efficiency of correction at different correction stages were studied not only by conventional contrast angiography, but also by IVM (FFR measurement). The control group (the 2nd group) consisted of 35 patients, their state of coronary artery bifurcations and blood flow was assessed based on traditional contrast coronarography. No statistically significant differences in clinical characteristics of the patients were revealed (Table 1).

According to coronarography findings, 4 types of bifurcation involvements according to A. Medina classification [13] were diagnosed in the patients included

Table 1
Comparative analysis of patients of the 1st and the 2nd groups (M±m), absolute number/%

Parameter	1 st group (n=32)	2 nd group (n=35)	p
Age, yrs	56.3±5.2	54.2±6.3	0.800
Male	19/59.4	23/65.7	0.777
Female	13/40.6	12/34.3	0.777
Functional class of angina pectoris:			
II	9/28.1	11/31.4	0.978
III	20/62.5	19/54.3	0.665
IV	3/9.4	5/14.3	0.809
Left ventricular ejection fraction, %	54.4±11.4	55.3±10.2	0.953
Arterial hypertension	15/46.9	18/51.4	0.898
Smoking	10/31.3	13/37.1	0.803

Table 2
Distribution of patients groups due to bifurcation involvement type, absolute number/%

Lesion type (A. Medina)	1 st group (n=32)	2 nd group (n=35)	p
Type 1.1.1	19/59.4	20/57.1	0.950
Type 1.0.1	3/9.4	7/20	0.381
Type 0.1.1	5/15.6	3/8.6	0.608
Type 1.1.0	5/15.6	5/14.3	0.850

Table 3
Localization of bifurcation involvement in the patients of the 1st and the 2nd groups, absolute number/%

Lesion localization	1 st group (n=32)	2 nd group (n=35)	p
ADA-DB	21/65.6	19/54.3	0.487
CA-OMB	8/25.0	9/25.7	0.831
RCA-PDA-PLB	3/9.4	7/20.0	0.381

Note: ADA-DB — anterior descending artery–diagonal branch; CA-OMB — circumflex artery–obtuse marginal branch; RCA-PDA-PLB — right coronary artery–posterior descending artery–posterior lateral branch

into the study. There were no statistically significant differences in the groups in the frequency of occurrence (Table 2).

The groups did not differ from each other in the frequency of various localizations of bifurcation involvements either (Table 3).

FFR measurement in order to assess the functional significance of coronary artery stenoses, and the efficiency of endovascular correction was performed using Radi Analyzer (RADI, Sweden). For this purpose, a coronary conductor with pressure measuring sensor was inserted through the inner lumen of guiding catheter in an affected coronary artery. The tip of the conductor with a sensor was put distally from the lesion (stent). To develop artificial myocardial hyperemia, papaverine solution (15 mg in the left coronary artery, and 10 mg — in the right one) was injected in the studied artery. FFR was measured before and after correction in the condition of simulated myocardial hyperemia. Hemodynamically significant stenosis was considered to be that with FFR distally from it being below 0.75 [14].

In 1st group patients hemodynamic dependence of coronary artery stenoses was determined on the basis of the complex analysis of angiographic and manometric findings. According to the analysis stenoses were referred to one of the three groups:

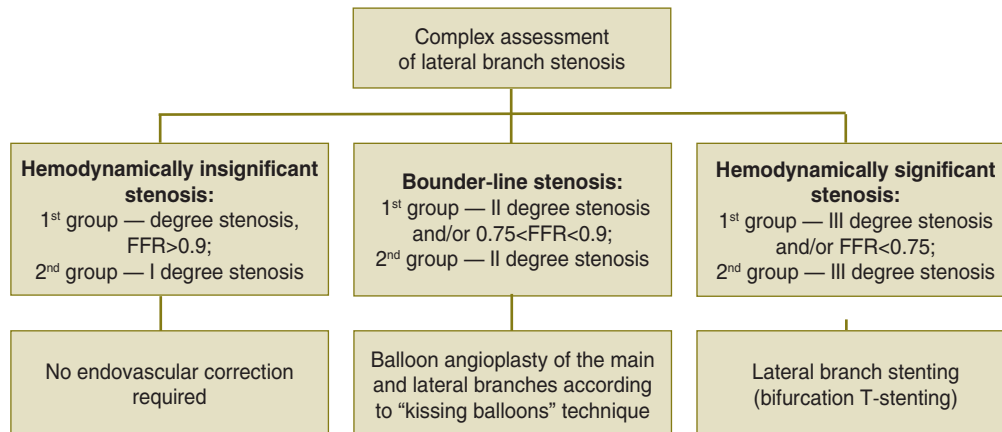
hemodynamically insignificant stenosis — I degree stenosis according to contrast coronarography, FFR — not less 0.9;

border-line stenosis — II degree stenosis according to coronarography and/or FFR more than 0.75, but less 0.9;

hemodynamically significant stenosis — III degree stenosis according to coronarography findings and/or FFR less than 0.75.

In control patients hemodynamic significance of coronary arteries lesions were estimated based on contrast coronarography findings only. In this regard, I degree stenosis was considered hemodynamically insignificant, II degree stenosis was border-line, and III degree stenosis — hemodynamically significant.

The first angiographic and manometric estimation of bifurcation state was given before the correction, consecutive coronarography and FFR measurement — after the main branch stenting. Hemodynamic significance of lateral branch stenosis was assessed based on angiography



Options for lateral branch endovascular correction in groups depending on stenosis hemodynamic significance

findings combined with FFR measurements (the 1st group) and angiography findings only (the 2nd group). Depending on the results of the assessment, one of the variants of correction continuation was chosen. To choose the variant at this stage of correction the algorithm was followed: 1) if the lateral branch had hemodynamically insignificant stenosis (I degree stenosis according to angiography findings, $FFR \geq 0.9$), no lateral branch correction was made; 2) in case of border-line stenosis of the lateral branch (II degree stenosis according to angiography findings, $0.75 < FFR < 0.9$), post-dilation of the main and the lateral branches according to "kissing balloons" technique was performed; 3) if hemodynamically significant stenosis (III degree stenosis according to angiography findings, $FFR \leq 0.75$) was found in the lateral branch after the main branch stenting, there was performed the stenting of the lateral branch with stent implantation from the lateral branch mouth, i.e. in this case the correction was completed by bifurcation T-stenting (see Fig.).

The criteria of achieving a good short-term result of the intervention: the 1st group — residual stenosis intensity <20%, blood flow TIMI 3, no dissections on stent margins, $FFR > 0.9$; the 2nd group — residual stenosis intensity <20%, blood flow TIMI 3, no dissections on stent margins.

Clinical criteria of intervention good results in hospital period were: no complications relating to MACCE group (ANA, USA), the increase of exercise tolerance by 2 functional classes and more, or complete disappearance of angina pectoris and/or ischemic objective signs.

Long-term results were studied in 63 patients: in 30 patients (93.8%) of the 1st group, and in 33 patients (94.3%) of the 2nd group. The control point of long-term period was the 12th month of the study. The results were determined based on collective estimate of unfavourable events, integration criterion of clinical efficiency taking into account the absence of angina pectoris and the frequency of repeated revascularization of target stenosis. The results were assessed in planned and follow-up examinations and according to questionnaire and telephone inquiry.

Results and Discussion. The comparison of angiographic and manometric evaluations of the main branch state before the correction proved that there was a

high degree of correlation ($R=0.85$; $p < 0.001$) between the contrast angiography findings and the results of intravascular manometry.

In regard to the main branch, all the patients had a good angiographic result after completing the first stage of correction (the main branch stenting), in the meantime, according to angiography findings, the aggravation of the stenosis of the lateral branch mouth was noted in 41 from 67 bifurcations (61.2%). The comparison of selective coronarography and IVM findings showed angiographic estimation of hemodynamic significance of lateral branch mouth stenosis in 11 from 32 cases to differ from manometric evaluation. There was revealed medium correlation ($R=0.46$; $p=0.008$) between the angiography and IVM findings. Thus, angiography appeared to be less accurate in assessing the coronary flow disturbance in the lateral branch than in more straight main branch. On this assumption, the reliability of angiographic estimation of changes in the lateral branch will be different in various geometric bifurcation types.

To prove the supposition, the patients of the 1st group were subdivided in accordance with branch union classification by T. Lefevre et al. [15]. The first subgroup consisted of 14 patients with T-type bifurcation, and the second — 18 patients with Y-type bifurcation. The comparison of angiography and IVM results in the first subgroup showed medium statistically significant relation between this data ($R=0.49$; $p=0.037$). The comparing of angiography and IVM results in the second subgroup (Y-type bifurcation) stated the results of angiographic assessment of blood flow disturbance in the lateral branch not to coincide with those of IVM in the majority of cases. In this subgroup there was no correlation between angiographic and manometric assessments of stenosis hemodynamic significance in the lateral branch ($R=0.21$; $p=0.464$).

The analysis of the results obtained enabled to conclude that in T-type bifurcation angiographic estimation of coronary flow disturbance is more reliable than in Y-type. It is likely to be related to the difficulties and shortcoming of an objective estimation of angiographic image of bifurcation branch lumen. So, in local short narrowing of lateral branch mouth that frequently develops after main branch stenting,

Table 4

Dynamics of myocardial ischemia level in postoperative period, absolute number/%

Parameters	1 st group	2 nd group	p
The increase by 2 FC and more	31/96.9%	33/94.3	0.937
The increase by 1 FC	1/3.1%	2/5.7	0.937
Previous symptoms of angina pectoris	0	0	—

the stenosis is well demonstrated in a certain view. The X-ray beam direction in this view is to be true-perpendicular to bifurcation surface. If a technician during the intervention uses a view that is different from an optimal one even by 10–15°, there will be no true information gained concerning the stenosis degree in the lateral branch mouth. Therefore, hemodynamic significance of this narrowing will be underestimated. The described effect is more expressed in Y-type bifurcation. An acute angle between the bifurcation branches contributes to the “overlapping” of one branch on another that is longer than in T-type bifurcation. So, in Y-type bifurcation non-optimal (but close to optimal) view chosen by a technician is unlikely to estimate the true intensity of lateral branch stenosis. In practice the necessity of limitation on contrast substance amount and X-ray dose makes it impossible to choose such a view empirically. In this case IVM for the assessment of hemodynamic significance in lateral branch mouth seems to be very useful, mainly in Y-type bifurcation.

In hospital period both groups had no fatal cases, acute myocardial infarctions, acute and subacute thromboses of stents, re-operations, cerebrovascular complications (Table 4). Over 12 months after the operation there were no fatal cases, and strokes, no heart bypass performed. There was angina pectoris recurrence or its grade increase in 3 patients (10.0%) of the 1st group and in 11 patients (33.3%) in the 2nd group ($p=0.035$), and recurrent percutaneous coronary intervention — in 3 and 11 patients, respectively.

Two patients (6.1%) of the 2nd group underwent nonQ-myocardial infarction in arteries previously operated, though no statistically significant differences between the groups were found. Among the patients of the 1st group there were no unfavourable events relating to MACCE.

Coronarography performed in long-term period showed the predominance of patients with restenoses in lateral branches of bifurcation lesions in both groups: in 2 patients of the main group (6.7%), and in 10 control patients (30.3%). The difference between the patients of the two groups was statistically significant ($p=0.024$). 1 patient (3.3%) of the 1st group and in 1 patient (3.0%) of the 2nd group had restenoses involving both the main and the lateral branches of bifurcations.

Conclusion. The assessment of the main branch bifurcation stenosis using the results of selective coronarography and intravascular manometry revealed high degree correlation between these techniques ($R=0.85$; $p<0.001$). The findings of selective coronarography and intravascular manometry of bifurcation lateral branch condition turned out to have marked differences

($R=0.46$; $p=0.008$). And the differences were maximal in Y-type bifurcation ($R=0.21$; $p=0.464$). Considering that the correlation between angiography and intravascular manometry findings concerning the lateral branch was medium (in T-type) and was absent (in Y-type), the decision on the necessity and type of correction is to be made based on complex assessment (angiographic and manometric) of the lateral branch condition.

In the group of patients who underwent endovascular correction of bifurcation lesions under angiography and intravascular manometry control, restenosis rate in correction zone was statistically significantly lower. The most of restenoses in both groups were located in the lateral branch mouth, but restenosis rate in the patients of the main group was statistically significantly lower than that of in the control patients. Restenoses rate in the main branch in both groups had no statistically significant differences.

The use of complex approach to the assessment of the results of coronary bifurcation correction improves the results of surgeries due to the decrease of restenoses rate and the necessity of re-revascularization in the follow-up. The advantage of the approach is more accurate assessment of hemodynamic changes in bifurcation branches and, therefore, the possibility to choose an optimal technique of endovascular correction.

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