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**THE ROLE OF RESISTANCE AS A ONE OF THE MECHANISMS OF DEVELOPMENT OF ISCHEMIC HEART DISEASE IN PATIENTS WITH CORONARY ARTERY TORTUOSITY**

**G. V. Knyshov, Ie. A. Nastenko, Ye. O. Lebedieva, S. V. Salo, N. N. Bryanskiy, S. V. Zubkov, Yu. V. Shardukova.**

Recently in the literature appear messages about the connection of tortuosity of coronary arteries (CA) and ischemic heart disease (IHD). It is about patients have clinic of IHD, left ventricular myocardial perfusion defect and only tortuosity of CA (no angiographic signs of atherosclerotic lesions) [1, 4, 7]. At the same time, the phenomenon of tortuosity of CA is not a rare find (9,2-12,5%) in patients undergoing coronary angiography [5, 7, 10]. However, the mechanisms of ischemic myocardial damage remain unidentified. This is not to determine the strategic issues of prevention and treatment of vascular anomalies. Therefore, the study of the role of geometric characteristics of CA tortuosity in the genesis of ischemic myocardial damage seems relevant.

**The aim** of the study was to evaluate the geometrical characteristics of CA tortuosity and its associated changes their resistance compared to non-tortuous coronary vessels.

**Material and methods.** The research was based on the coronary angiography data of 55 patients which have tortuous CA without atherosclerotic lesions. According to the coronary angiography data we analyzed 208 fragments of CA considering phase of the cardiac cycle. Geometric characteristics were measured at the end of systole and diastole of the ventricles. Analyzed only those fragments of tortuous CA, which were located parallel to the plane of the recording detector (Fig. 1).

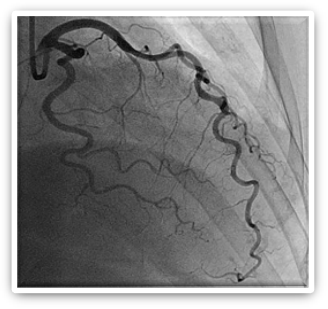
**F4**

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Fig. 1. Assignment of fragments of tortuous coronary artery (CA).

F1-5 – fragments of tortuous CA.

The study of forms of CA tortuosity and their geometric characteristics was based on coronary angiography. Tortuous were arteries with three or more twists (deviation from the straight axis conducted along the artery course ≥ 45 °) of main branches identified in systole and diastole [12].

Using specially designed computer software measured radius of curvature (R), diameter (D) and the length of the individual fragments of tortuous CA, and deflection angles of the longitudinal axis of the vessel from straight line which was carried out between two ends of the artery. Calculated the relative curvature of CA (R/D), angular deformation as a difference of the angles at the end of diastole and systole. According to the formula, Darcy Veysbaha for turbulent blood flow, we calculated coefficients of resistance increase by separate tortuous CA sections as a function of the relative curvature and bending angle of the vessel [3, 9]. We calculated the resistance increase considering the length of the CA. The length of separate tortuous CA section consisted of the length of the vessel curvature and its two straight sections. The length increase of the curved CA fragment was calculated as the ratio of the measured length to the shortest distance between the beginning and the end of the fragment. The length of the tortuous CA fragments measured using our specially created software.

Statistical analysis of the material was performed using the program IBM Statistics 20.0. We used descriptive statistics methods. We calculated the mean, median, quartile, minimum and maximum values. Medians values were not significantly different from the mean, that’s why the table below does not present the mean values.

**Results and discussion.**

The resistance of tortuous CA section is in inverse correlation with the rate of R/D (relative curvature of blood vessel) and in direct with the bending angle δ (Fig. 2).



Fig. 2. The scheme of measuring the deviation angle δ from a straight line, vessels curvature radiuses (R1, R2) of the same diameter (D) larger and smaller curvature: R1/D > R2/D.

The resistance coefficient of tortuous CA section (so-called "removal") *ζremov.* depends on the ratio R/d, the bending angle δ and the shape of the cross section of the vessel [3, 9].

The results of the statistical characteristics of geometrical parameters of separate tortuous CA sections are shown in Table 1.

According to the data relative the curvature (R/D) of tortuous CA sections in systole was about 1.5 times lower than in diastole. According to the literature a significant resistance increase caused by vessel curvature is observed at R/D < 2,5 relative unit [2]. As a known is an existence of differences in myocardial perfusion between different CA (left and right CA) depending on the phase of the cardiac cycle [8, 11]. The results give reason to discuss the impact of vessel curvature on resistance increase, which is determine the rate of coronary blood flow, especially in the case of myocardial perfusion of tortuous right CA during systole [13].

Table 1.

Statistical characteristics of geometry and resistance of separate tortuous CA sections considering phase of the cardiac cycle: median [Q25%; Q75% - interquartile range] (min; max).

|  |  |  |
| --- | --- | --- |
| Index | Systole | Diastole |
| The relative curvature of CA (R/D), relative unit. | 4,7 [3,7; 6,7] (1,3; 19) | 7,3 [5,4; 9,7] (2,1; 23,3) |
| Deflection angle of CA (δ), degree. | 75,6 [58,7; 93,8]  (26,1; 134) | 52,5 [37,6; 67,1]  (7,7; 113) |
| Angular (systolic-diastolic) deformation of CA (Δδ), degree. | 22,7 [13,5; 33,4] (0; 72,2) | |
| The resistance coefficient of CA (ζremov.) | 0,08 [0,06; 0,11]  (0,03; 0,23) | 0,05 [0,04; 0,07]  (0,01; 0,14) |
| Extra resistance increase, %. | 8% [6%; 11%] (3%; 23%) | 5% [4%; 7%] (1%; 14%) |

The similar ratios were for angles deformation of CA relatively straight line. Typical CA angles bend should be considered as 58.7о - 93.8о in systole and 37.6о - 67.1о in diastole. Typical systolic-diastolic gradients values of CA angle bend (Δδ) were in the range from 13.5о to 33.4о (Table. 1). In our view, such changes of angle bend gradient of CA can lead to a loss of vascular wall mechanical strength and be responsible for the development of clinical manifestations of IHD.

Medians of resistance coefficient (*ζremov.*) as a value of relative resistance increase were 0.08 in systole and 0.05 in diastole. Typical ranges of resistance increase were from 0.06 to 0.11 in systole and from 0.04 to 0.07 in diastole.

The results showed in 25% fragments of tortuous CA extra resistance increase caused by the angle bend and vessel curvature and can be very significant: 11 to 23% in systole and 7 to 14% in diastole (Table. 1). Due to the fact that the tortuous CA may have 3 or more bends, in accordance with the principle of imposing of losses, the total resistance will equal to the sum of resistance tortuous CA fragments [9]. In this way the resistance increase due to the number of bends can be able to significantly change coronary hemodynamics. According to our preliminary coronary angiography research the actual length of tortuous CA could be on 40% larger in comparison with the length of the shortest line between the beginning and the end of the analyzed CA fragment [2]. According to Poiseuille formula vascular resistance is directly proportional to its length [3]. Extra resistance increase can also be caused by extra vessels lengthening because of the bends (Table. 2).

Table. 2

Statistical characteristics of length and resistance increase of separate tortuous CA sections considering phase of the cardiac cycle: median [Q25%; Q75% - interquartile range] (min; max).

|  |  |  |
| --- | --- | --- |
| Index | Systole | Diastole |
| Extra length caused by tortuous CA section, relative unit. | 1,21 [1,16; 1,27] (1,08;1,45) | 1,30 [1,24; 1,38] (1,11; 1,59) |
| Extra resistance increase due to additional length, %. | 21% [16%; 27%] (8%; 45%) | 30% [24%; 38%] (11%; 59%) |

The obtained resistance changes considering phase of the cardiac cycle caused by extra length of CA allow to assume the possibility of hemodynamic mechanism of coronary circulation disorders. Typical values of relative extra length of CA in systole were in the range from 1.16 to 1.27 relative units. However, the typical range of relative extra length of CA in diastole was in range from 1.24 to 1.38 relative units (Table. 2). One of the mechanisms of coronary failure in patients with CA tortuosity can also be a local transmural pressure increase in the area of the vessels bend that can cause to spasm development in that area. It should be noted that such a mechanism explains the presence of acute myocardial infarction in patients without atherosclerotic lesions of CA [5, 6].

It should be mentioned that all given calculations and considerations above were concerning of the bend and were obtained in rest condition without taking account of compensatory mechanisms, therefore is appropriate to consider the resistance changes at different physiological conditions (rest and exercise). At rest the blood flow velocity in tortuous CA can be saved by reducing peripheral vascular resistance (vascular tone). During exercise the blood flow velocity in tortuous CA can be significantly decreased by increasing peripheral resistance. During exercise in patients with CA tortuosity can be absent the ability to adapt peripheral vascular resistance in order to compensate additional resistances caused by bends, which can lead to ineffective regulation of coronary blood flow and myocardium blood supplying. This is consistent with clinical manifestations of IHD caused by tortuosity of CA [1, 4].

Based on the obtained above results we consider that the number of bends and vessel length have to be used for displaying the severity of CA tortuosity but in patients with angina and absence of atherosclerotic lesions of the vascular wall its clinical significance to be solved through the diagnostic methods of IHD.

**Conclusions**

1. In some cases, in the absence of atherosclerotic plaques, myocardial perfusion disorders (development of IHD) can be caused by tortuosity of CA.
2. The resistance changes of separate tortuous CA sections due to their curvature and angle of the bend can be responsible for the development of IHD in patients without atherosclerotic lesions of CA.
3. The resistance increase caused by extra vessel length due to the bends can be an additional factor in the development of myocardial perfusion disorders.
4. High cyclic deformations of tortuous CA sections may lead to stability loss of the vessel walls, trauma and spasm which is confirmed by our clinical observations.

***Abstract***

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The research was based on the coronary angiography data of 55 patients with clinical manifestations of angina pectoris, which have tortuous coronary arteries without atherosclerotic lesions. According to the coronary angiography were analyzed 208 fragments of tortuous coronary arteries. It was shown that the increment of resistance of separate segments of tortuous coronary arteries, which were associated with their curvature, bend angle and an increased in length, may be responsible for the development of ischemic heart disease in patients without of atherosclerotic lesions.

***Key words:*** ***resistance of the coronary arteries, tortuous coronary arteries, ischemic heart disease.***