Quantitative assessment of coronary artery lesions

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In today's practice, the degree of coronary obstructions is usually estimated; descriptions are expressed as percent stenosis with the understanding that these values are not based on accurate measurements. This evaluation technique, however, leads to substantial intraobserver and interobserver variability.[1,2] Thus, (1) the recommended scoring systems are hampered by the individual grading standards, (2) the comparison of results from different centers is of limited value, and (3) the relation between anatomical (obstruction) and functional (flow) criteria remains inaccurate and indications for bypass surgery for instance are, therefore, often doubtful.

Intravital quantitative evaluation of coronary morphology was first reported by Gensini et al[3] who studied the diameter changes of normal coronary arteries after nitroglycerin. In subsequent years, various reports based on different techniques to assess and objectivate coronary obstructions were published.[4-8] Some of the major difficulties are related to the complex geometry of the coronary arteries, the relatively small vessel size, the phasic motion of all vessels, and the varying concentration of contrast medium during injection.

Our quantitative morphometric method is based on direct measurements of coronary findings from the angiographic screen. Diameters of normal coronary arteries (*Table*) and the degree of obstruction are measured with a vernier caliper (accuracy: 0.05 mm). The 35-mm cinefilms of coronary angiography are projected on the screen of a Tagarno projector. The enlargement factor due to the image amplifier and the projection is approximately 1:3 and is exactly determined for each case by measuring the catheter tip placed into the coronary ostium (for both Sones and Judkins catheters the average tip-diameter is 1.8 ± 0.04 mm, n = 20). In normal coronary arteries only the arteries running nearly parallel to the image plane are measured in the different projections; the left anterior descending artery and the posterior descending branch of the right coronary artery are assessed in right anterior oblique projection of 40° to 50°, the left circumflex and the main trunk of the right coronary artery in left anterior oblique projection of 40°. To minimize errors from pincushion distortion, the measurements are consistently performed near the central x-ray beam. Although we were unable to find any detectable change in lumen diameter during the cardiac cycle in the large extramural arteries, measurements were always performed at end-diastole in order to get neither blurring effect from rapid heart movements nor errors caused by axial or spatial rotations.

Table. Measured diameters of coronary arteries (± 1 SE) and the calculated circular cross-sectional areas

Artery	n	Diameter, mm	Area, mm^2
LCA	27	4.24 ± 0.14	14.12
LAD			
Proximal	57	3.45 ± 0.13	9.35
Middle	33	2.75 ± 0.11	5.94
Distal	48	1.94 ± 0.08	2.95
LCx			
Proximal	54	3.03 ± 0.08	7.21
Middle	33	2.57 ± 0.10	5.19
Distal	33	2.10 ± 0.09	3.46
RCA			
Proximal	56	3.55 ± 0.11	9.89
Middle	33	3.20 ± 0.11	8.04
Distal	33	2.91 ± 0.11	6.65

n = number of measured normal coronary arteries, LCA = mainstem of the left coronary artery, LAD = left anterior descending artery, LCx = mainstem of the left circumflex artery from the origin to the most distal obtuse marginal branch, RCA = main stem of the right coronary artery from the origin to the crux cordis, LAD, LCx and RCA are subdivided into a proximal, middle and distal third.

Taking into account the eccentric lumen of many obstructions, atherosclerotic lesions are measured in as many different projections as possible. Sites of measurements in vessels with obstructions include the prestenotic segment, the narrowest part of the obstruction, the immediate poststenotic segment and the peripheral segment of the vessel. The degree of stenosis is calculated by the formula:

$$\% \text{ area stenosis} = 1 \frac{\text{D sten}^2}{\text{D norm}^2}$$

In this formula, D_{norm} represents the diameter of the undiseased prestenotic vessel and D_{sten} the average stenotic diameter calculated as arithmetic mean of as many measurable diameters as possible. Both diameters are used to calculate the respective cross-sectional area by the formula of a circle ($A = \pi r^2$).

The validity of this method in determining true vessel diameter particularly in obstructions was tested in comparing intravital angiograms with postmortem histological measurements of the same coronary lesion. In 12 patients, who had coronary angiograms and who died of various causes (average, 3 months later) the coronary arteries were filled and fixed at autopsy under physiological pressure using a modified Fulton technique. Histological sections were obtained and measured with a scaled optical system. The procedure uses a magnification technique of the true section to allow more accurate planimetry of the coronary cross sections. At 66 measuring points the diameter of coronary arteries from the intravital angiogram was compared with the postmortem histological vessel diameter. The plot demonstrated a linear relationship between these measurements with a correlation coefficient of $r = 0.85$. In addition, in 19 stenoses the area ratio of the prestenotic and constructed stenotic circles with the area ratio measured histologically are compared. The relationship yielded a correlation coefficient of $r = 0.87$.

Some selected results will demonstrate the benefits of intravital quantitative coronary morphometry in coronary artery disease.

1. The effect of isosorbide dinitrate, 5 mg sublingually on the diameter of coronary artery stenoses ($n = 27$), was documented in 20 patients. In 18 stenoses ranging from 28% to 95% there was no significant change in the degree of obstruction after isosorbide dinitrate; the mean prestenotic diameter and mean stenotic diameter both increased slightly from 2.82 ± 0.48 mm to 3.05 ± 0.43 mm and from 1.45 ± 0.49 mm to 1.59 ± 0.51 mm, respectively. However, in the nine other stenoses ranging from 35% to 89%, the mean degree of obstruction decreased significantly (<0.025) from 68% ± 15.6% to 47% ± 15.6% after isosorbide dinitrate. This improvement was due to a significant ($p < 0.05$) increase of the mean stenotic diameter from 1.71 ± 0.47 mm to 2.41 ± 0.55 mm, whereas the prestenotic diameter showed only an insignificant increase from 3.17 ± 0.63 mm to 3.31 ± 0.58 mm after isosorbide dinitrate. In four patients with two obstructions in different coronary branches, isosorbide dinitrate dilated one lesion without significantly affecting the other.

2. The effect of optimal medical therapy for approximately one year on coronary anatomy was evaluated in 25 patients with initially unstable angina pectoris. In each patient, two successive coronary angiograms were performed at approximately a one-year interval (4 to 31 months, average 12 months). Sixty-nine stenoses of the three major coronary branches showed no significant change: the average degree of 27 stenoses of the right coronary artery was 79% in the initial study and 84% in the interval study; 26 stenoses of the left anterior descending artery averaged 78% and 77%, respectively; and the mean degree of 16 stenoses of the left circumflex artery increased slightly from 73% to 83%. In 11 patients, 14 stenoses showed a distinct progression of more than 20% area obstruction. All six stenoses of more than 90% in the first angiogram progressed to complete occlusion within one year. In five other patients, five stenoses regressed by more than 20%. Anatomy of vessel segments distal to obstructions remained unchanged for one year.

3. The effect of a saphenous vein bypass on the diameters of coronary arteries distal to the bypassed obstruction was examined in 51 vessels with a mean degree of obstruction of 88% (Group I) and in 19 vessels with complete obstruction and collateral filling (Group II). In the arterial segments proximal and distal to graft implantation, identical cross sections were measured and compared before and after surgery. In Group I, the proximal segment showed a decrease in diameter (2.71 to 2.18 mm, $p < 0.01$), whereas the distal segment including its imme-

diate vicinity to graft implantation remained unchanged. In contrast, in Group II with complete obstruction but adequate retrograde filling via collaterals, a significant increase in the diameter of the proximal segment occurred after surgery (1.75 to 2.26 mm, $p < 0.005$).

4. The relationship between the degree of obstruction and LV wall motion was studied in 51 cases with proximal left anterior descending obstructions and 41 cases with main stem right coronary artery obstructions. For both arteries no correlation was found ($r = 0.10$ and 0.16), obstructions between 50% and more than 90% being equally common in arteries perfusing normokinetic, hypokinetic, and akinetic segments.

In summary, quantitative assessment of coronary obstructions can be performed today with high accuracy and reliability in the majority of cases; it is desirable in routine arteriography for the assessment of indications for bypass surgery by defining exactly the "critical" lesion; it is mandatory for scientific investigations, which should not be based on estimates any longer.

References

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