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Minimal Luminal Diameter versus Percent Diameter Narrowing for Assessing Coronary Artery Disease

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UPDATE: *Stenotic coronary arterial segments of 27 patients were measured by the percent diameter narrowing and minimal luminal diameter methods. The measurements were analyzed for correlation with changes in global ejection fraction and segmental wall motion during atrial pacing. Ten patients without coronary artery disease served as a control group. Minimal luminal diameter correlated more closely with impairment of myocardial contractility than did percent diameter narrowing. Therefore, we conclude that the former is a better method for assessing the severity of coronary artery disease.*

Coronary arteriography is indispensable for the clinical assessment of patients with coronary artery disease. Since its development in the early 1960s, coronary arteriography has been relied on for the accurate delineation of coronary anatomy and for allowing inferences to be drawn regarding the hemodynamic effects of coronary arterial stenoses.[1,2] Traditionally, the severity of coronary artery disease has been graded by measuring the percent diameter narrowing between the stenotic segment and a proximal segment with normal appearance.[3,4] Such measurements can be made by visual inspection or computer-assisted quantitative angiographic techniques.[5]

Although percent diameter narrowing is useful for distinguishing patients with normal coronary arteries from those with critical obstruction (greater than 75% stenosis), the potential of this method for estimating physiological effects of coronary obstruction of intermediate severity is controversial. Several investigators have demonstrated a poor correlation between percent diameter narrowing and the physiological effect of a given stenosis based on the coronary reactive hyperemic response.[6,7] Such poor correlation may be at least partially attributed to an inherent limitation of percent diameter narrowing for predicting the physiological effect of a coronary artery obstruction. By definition, percent diameter narrowing is a relative number that depends on the presumed normal segments as well as on the narrowed segments. However, pathological studies have demonstrated that atherosclerosis is a diffuse process that is present to a variable degree along the length of such so-called normal segments.[8] Therefore, designating a given arterial segment as normal is arbitrary, and frequently it is invalid.

Quantitative analysis of coronary arteriograms can be done alternatively by measuring the absolute minimal luminal diameter at the region of maximal arterial narrowing. Another absolute measurement, minimal cross-sectional area, has been found superior to percent diameter narrowing for identifying vessels with normal or abnormal hyperemic responses at the time of bypass surgery. However, it has not yet been demonstrated that minimal luminal diameter correlates better then percent diameter narrowing with functional measurements of the severity of coronary artery disease. To find out whether minimal coronary luminal diameter is superior, we compared these two methods in terms of degree of correlation with measurements of global ejection fraction and segmental wall motion during ischemia induced by atrial pacing stress tests.

Methods

Thirty-seven patients with known or suspected coronary artery disease underwent selective digital coronary arteriography. Baseline digital subtraction left ventriculograms were obtained after review of the coronary angiograms. If there were no contraindications—left main coronary artery disease, unstable angina, recent myocardial infarction (within three months), cardiomyopathy, or valvular heart disease—atrial pacing studies were undertaken. Left ventriculograms were obtained in the 30° right anterior oblique projection to identify wall-motion abnormalities within the distribution of the left anterior descending artery and right coronary artery. Patients who had predominant lesions in the left circumflex artery were excluded, because left ventriculograms in the left anterior oblique projection would have been required. The pacing rate of the right atrium was raised in increments of ten beats per minute every minute until patients experienced chest pain or the heart rate reached 150 beats per minute. Patients in whom atrioventricular Wenckebach block developed before an end point was attained were given atropine and the pacing study was continued. Upon reaching the end point, a second digital left ventriculogram was obtained and the pacing was stopped.

Following the completion of catheterization, the coronary angiograms were examined. The single frame that most clearly demonstrated the stenotic segment was selected. If the stenosis involved the proximal half of the right coronary artery or left anterior descending artery, analysis was done. Quantitative coronary angiography was carried out by two independent observers who used both edge detection and videodensitometry to determine percent diameter narrowing and minimal luminal diameter of a primary stenosis in each of 27 patients with coronary artery disease. Measurements were also obtained from corresponding artery segments of ten patients without coronary artery narrowing. A comparison was made by a linear regression analysis between percent diameter narrowing obtained by the edge detection and videodensitometric techniques. Standard area-length methods were used to calculate volumes and ejection fractions from the digital left ventriculograms. Wall-motion analysis was accomplished by dividing the perimeter of the left ventricle into five segments: anterobasal, anterior, apical, diaphragmatic, and posterobasal. Wall motion in the ventricular segments along radians was calculated, and a percent of area segmental motion was obtained in accordance with the methods of Alderman and colleagues.[9] The measurements of percent diameter narrowing and minimal luminal diameter were correlated to the change in global ejection fraction and segmental wall motion by linear regression analysis.

Results

Twenty-seven patients with coronary artery disease and ten patients with chest pain syndrome but normal coronary angiograms underwent atrial pacing studies. A total of 27 primary stenoses were analyzed, 18 in the left anterior descending coronary artery, eight in the right coronary artery, and one in a large diagonal artery. Atrial pacing induced chest pain in 15 patients (56%) who had stenoses, and positive electrocardiographic criteria for ischemia was induced in only eight (35%). The mean percent diameter narrowing of the 27 primary stenoses was 60 ± 16% as measured by the edge-detection technique and 60 ± 18% as measured by videodensitometry, a difference that is not significant. The mean minimal luminal diameter of the 27 stenoses was found to be 1.4 ± 0.6 mm by the edge-detection method and 1.4 ± 0.7 mm by videodensitometry, also a difference that is not significant. A close correlation was found over the range of 0.4 mm to 2.8 mm between measurements of individual stenoses by edge detection and videodensitometry. Differences between the mean minimal luminal diameter for left anterior descending coronary artery obstructions (1.2 ± 0.4 mm) and right coronary artery obstructions (1.6 ± 0.6 mm) were not significant.

For ten patients who did not have coronary artery disease, the mean global ejection fraction at rest was 66 ± 7%, and at peak pacing it increased to 72 ± 5% ($p < 0.001$). The mean global ejection fraction at rest was 64 ± 15% for the 27 patients with coronary artery disease, and it fell to 54 ± 20% at peak pacing ($p < 0.001$). Segmental wall-motion response was significantly different for patients who did and did not have coronary artery disease. At rest, the mean segmental radial area shortening for the wall section affected by the stenotic artery was 60 ± 20%, whereas during pacing it decreased to 48 ± 28% ($p < 0.01$). There was a significant difference between this segmental wall-motion response to pacing and the increase in the segmental area shortening, from 61 ± 11% at rest to 79 ± 9% during peak pacing that occurred in the patients who did not have coronary artery disease ($p < 0.001$).

Compared with percent diameter narrowing, the minimal luminal diameter was more closely correlated with changes in global ejection fraction ($r = -0.41$ versus $r = 0.61$) and, as demonstrated in FIGURES 1 and 2 (pages 103 and 104), with changes in seg-

continued on page 103

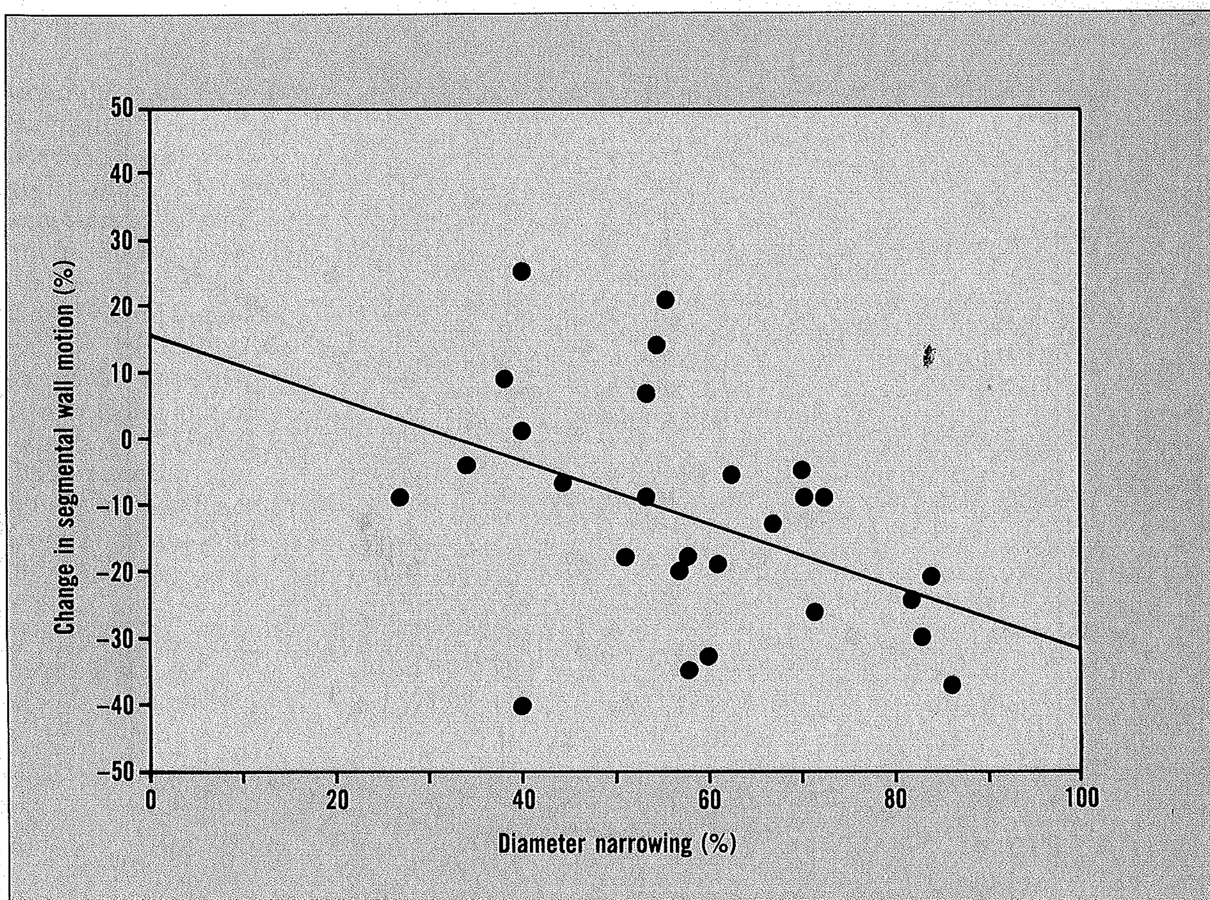


FIGURE 1 Effect of atrial pacing on 27 patients with coronary artery disease. There was a moderate correlation between measurements of percent diameter narrowing at 27 stenotic sites and changes in segmental wall motion from rest to peak pacing ($r = -0.44$). The standard error of the estimate was 15.7.

mental radial wall motion from rest to peak pacing ($r = -0.44$ versus $r = 0.78$). A minimal luminal diameter of 1.5 mm or less tended to distinguish patients who had an abnormal ejection fraction response to atrial pacing (greater than a 4% decrease) from patients who had a normal response ($p < 0.001$). Likewise, a minimal luminal diameter of 1.5 mm or less tended to identify patients who had an abnormal change in segmental wall motion during atrial pacing. This was found for primary stenoses in both the left anterior descending coronary artery and, as illustrated in FIGURE 3 (page 105), the right coronary artery.

Discussion

The primary method used to assess the severity of coronary artery stenosis, angiographic measurement of the percent of diameter narrowing relative to an assumed normal segment of the artery, may be mislead-

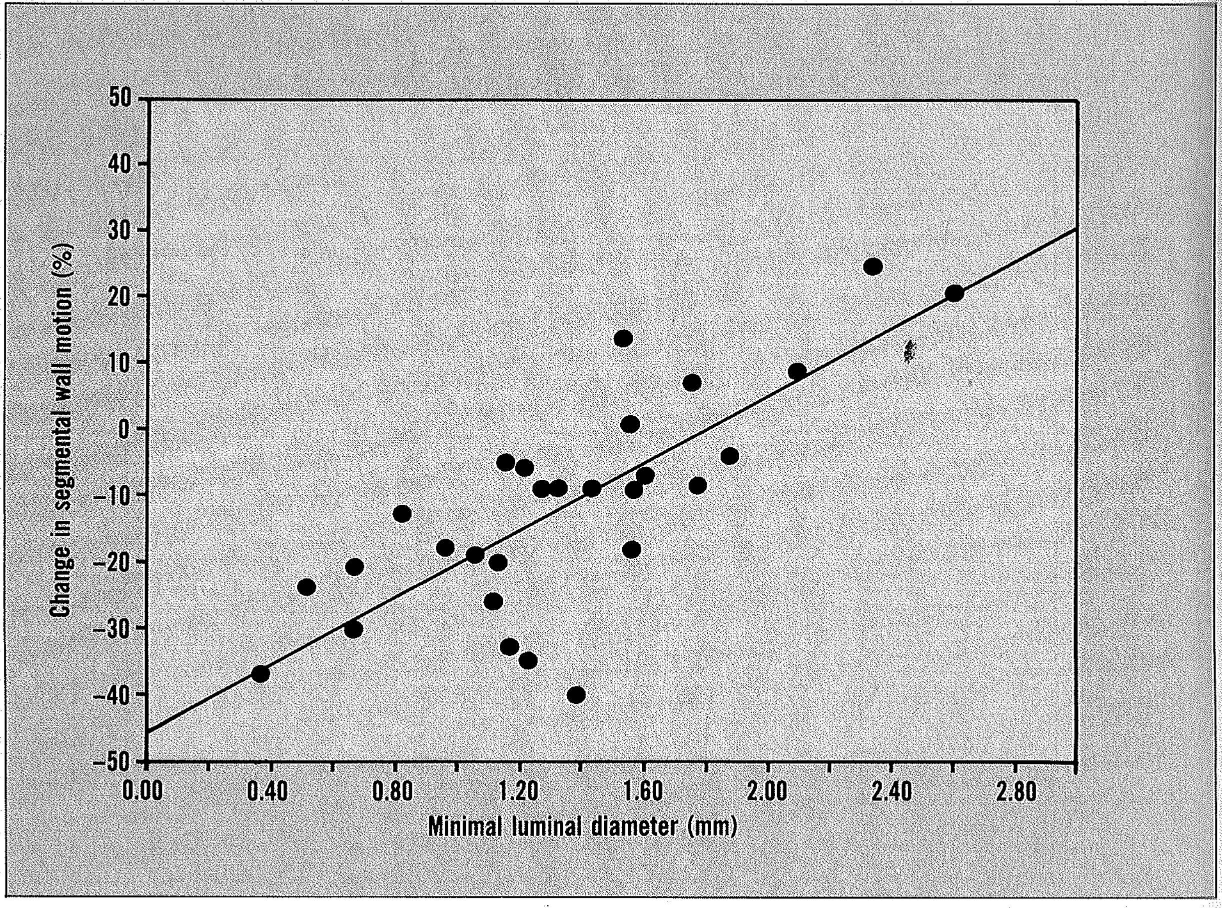
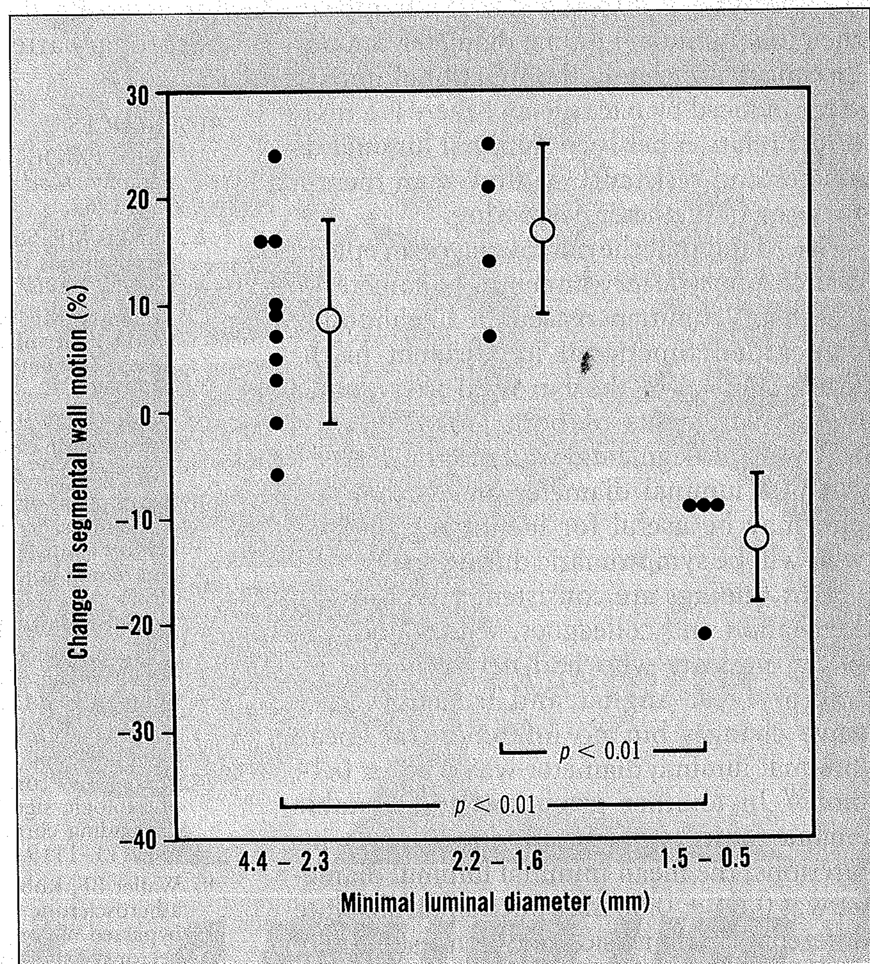


FIGURE 2 Effect of atrial pacing on 27 patients with coronary artery disease. There was a relatively close correlation between measurements of minimal luminal diameter of 27 coronary artery stenoses and changes in segmental wall motion (r = 0.78). The standard error of the estimate was 11.0.

ing for several reasons. The most important is that pathological studies have shown that atherosclerosis is a diffuse process and even in instances in which an angiogram demonstrates only a single obstruction, less than 25% of the length of the arteries will be disease free and therefore truly normal.[8] Another reason is that since stenoses frequently occur at bifurcations, identifying a normal proximal portion of the same arterial segment may be difficult.

In our study, the functional significance of coronary artery stenosis was determined from measurements of the left ventricular response to atrial pacing. Although both percent diameter narrowing and minimal luminal diameter correlated with the change in global ejection fraction (r = −0.41 and r = 0.61, respectively), we recognized that, because the myocardial wall supplied by nonstenotic arterial segments probably compensates for the diminished motion of the af-

FIGURE 3
Changes in segmental wall motion between rest and peak atrial pacing for ten subjects with minimal luminal diameters of 4.4 to 2.3 mm (normal coronary arteries), four patients with minimal luminal diameters of 2.2 to 1.6 mm, and four patients with minimal luminal diameters of 1.5 to 0.5 mm. Statistically significant differences between groups are indicated.



fected myocardium, the degree of correlation may have been reduced. Therefore, we measured localized segmental wall motion to isolate the effect of ischemia attributable to a specific stenosis. Percent diameter narrowing, however, correlated only moderately with segmental wall motion ($r = -0.44$), a degree of correlation similar to that obtained by measuring global ejection fraction. A likely explanation for this is that percent diameter narrowing is a relative number that does not accurately represent the effective resistance to coronary flow. For example, since the Poiseuille equation for laminar flow states that resistance to flow is inversely proportional to the fourth power of the radius, a 50% reduction of a 2-mm vessel will produce much greater resistance to flow than a 50% reduction in a 4-mm vessel. When minimal luminal diameter was correlated with the effect of atrial pacing on segmental radial wall motion, a clear difference between our two methods of measurement emerged, since minimal luminal diameter correlated with segmental wall motion much more closely than did percent diameter narrowing (r =

0.78 versus $r = -0.44$; $p < 0.05$). It appears then that minimal luminal diameter can predict more accurately the functional impairment induced by pacing, since there is a more direct relation between minimal luminal diameter and resistance to flow than there is for percent diameter narrowing.

We found that the narrowing of an epicardial coronary artery lumen to a diameter of less than 1.5 mm increased the likelihood of myocardial functional impairment in the region supplied by the narrowed artery, based on measurements of both global ejection fraction and segmental wall motion. Thus, a minimal luminal diameter of less than 1.5 mm may be useful for identifying patients who will be symptomatic during stress.

Our findings are consistent with those of McMahon and colleagues, who found that in ten patients who had new onset of refractory rest angina and ischemic ST-T wave changes but no infarction the mean minimal luminal diameter was 0.88 ± 0.14 mm.[10] In another group of five unstable angina patients who had non-Q-wave infarctions, the mean minimal luminal diameter was 0.64 ± 0.08 mm. Such small absolute differences in dimension between lesions may result in large differences in their hemodynamic impact. These studies suggest that characteristic clinical syndromes of effort angina, unstable angina, and non-Q-wave infarction correlate with mean minimal luminal diameters of approximately 1.5 mm, 0.9 mm, and 0.65 mm, respectively.

In addition to predicting the clinical correlation of a given stenosis, minimal luminal diameter may be a more accurate method for comparing studies or interpreting the results of coronary angioplasty. We conclude that determination of minimal coronary luminal diameter is a better method than calculation of percent diameter narrowing for assessing the physiological significance of coronary artery disease. ❦

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