Quantitative angiography after directional coronary atherectomy

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Abstract

**Objective**—To assess by quantitative analysis the immediate angiographic results of directional coronary atherectomy. To compare the effects of successful atherectomy with those of successful balloon dilatation in a series of patients with matched lesions.

**Design**—Case series.

**Setting**—Tertiary referral centre.

**Patients**—62 patients in whom directional coronary atherectomy was attempted between 7 September 1989 and 31 December 1990.

**Interventions**—Directional coronary atherectomy.

**Main outcome measures**—Increase in minimal luminal diameter of coronary artery segment.

**Results**—Angiographic success on the basis of intention to treat was observed in 54 patients (87%). In four patients the lesion could not be crossed by the atherectomy device; all four had an uneventful conventional balloon angioplasty. Four of the 58 patients who underwent atherectomy were subsequently referred for coronary bypass surgery because of failure or complications; three of them sustained a transmural infarction. In the successful cases, coronary atherectomy resulted in an increase in the minimal luminal diameter from 1·1 mm to 2·5 mm with a concomitant decrease of the diameter stenosis from 62% to 22%. In the subset of 37 patients in which the changes induced were compared with conventional balloon angioplasty atherectomy increased the minimal luminal diameter more than balloon angioplasty (1·6 ± 0·8 mm; p < 0·0001). Conventional histology showed media or adventitia in 26% of the atherectomy specimens. In hospital complications occurred in six patients who had undergone a successful procedure: two transmural infarctions, two subendocardial infarctions, one transient ischaemia attack, and one death due to delayed rupture of the atherectomised vessel. All patients were clinically evaluated at one and six months. One patient had persisting angina (New York Heart Association class II), one patient sustained a myocardial infarction, one patient underwent a percutaneous transluminal coronary angioplasty for early restenosis, and one patient underwent coronary bypass surgery because of a coronary aneurysm formation. At six months 50% (36/74) of the patients were symptom free.

**Conclusions**—Coronary atherectomy achieved a better immediate angiographic result than balloon angioplasty; however, in view of the complication rate in this preliminary series, which may be related to a learning curve, a randomised study is needed to show whether this procedure is as safe as a conventional balloon angioplasty.

Percutaneous transluminal coronary angioplasty was reported in 1978 by Gruentzig as a non-operative technique for the treatment of single, discrete, and proximal coronary artery stenosis in patients with symptomatic ischaemic heart disease. Over the past decade improved technology and operator experience have led to a greater use of conventional coronary angioplasty with an excellent immediate success rate. As indications for coronary angioplasty expanded and more difficult lesions were attempted, the likelihood of acute complications increased. The most dangerous complication is acute occlusion which is encountered in 2–10% and frequently requires emergency surgical revascularisation. Although acute occlusion is occasionally caused by thrombosis, it is usually caused by an intimal dissection. In particular lesions with a complex shape have a greater tendency to occlude abruptly. The use of new techniques might reduce acute complications after conventional balloon dilatation. Although balloon angioplasty can efficiently dilate a stenosis, recoil is one of the immediate mechanisms that results in the loss of 50% of the balloon angioplasty result. Several newly developed techniques have been designed to debulk coronary tissue thereby reducing the potential effect of elastic recoil.

Atherectomy is one such technique that might lead to fewer acute complications and less recoil because the plaque is removed rather than merely disrupted by the balloon inflation. There are published reports on the safety and short term results of atherectomy.

We have assessed the immediate clinical and angiographic results of coronary atherectomy using quantitative coronary analysis as an objective method.
from optically magnified and video digitised regions of interest (512 × 512 pixels) of a cineframe. The absolute diameter of the stenosis in mm was determined with the guiding catheter as a scaling device. Calibration of the catheter as an absolute value (mm) was achieved by comparing the mean diameter of the guiding catheter in pixels with the measured size in millimetres. Each catheter was measured individually. To correct the detected contour of the arterial and catheter segments for pincushion distortion, a correction vector was computed for each pixel based on a computer-processed cineframe with a centimetre grid placed against the input screen of the image intensifier. Because the functional significance of a stenosis is related to the expected normal cross sectional area of a vessel at the point of obstruction, we used a computer estimation of the original dimension of the artery at the site of the obstruction to define the interpolated reference area. The percentage diameter and area stenosis and the minimal luminal diameter (mm) and cross sectional area (mm²) were then calculated. The length of the lesion (mm) was determined from the diameter function on the basis of a curvature analysis. In addition, this technique allowed the assessment of the eccentricity of the lesion for a given view. The symmetry index ranged from 0 (totally eccentric stenosis) to 1 (symmetric). The degree of coronary bend was assessed by the curvature value at the obstruction site. This variable was computed as the average value of all the individual curvature values along the centreline of the coronary segment, with the curvature defined as the first derivative of the tangent as it moves along the centreline, which for a circle is equal to the reciprocal of the radius.

**ANGIOGRAPHIC MATCHING PROCESS**

We compared the results of the first 37 successful consecutive patients of this series with the results of 37 individually matched angioplasty lesions in 37 other patients. To avoid patient selection bias we selected populations with comparable baseline stenosis characteristics. The coronary artery tree was subdivided into 15 segments according to the American Heart Association guidelines. The lesions were individually matched according to stenosis location and reference diameter. Matching was considered adequate if the mean difference of the reference diameter between the groups was zero.  

**HISTOLOGY**

Tissue samples were carefully removed from the collecting chamber of the atherectomy device. Part of the material was used for microscopical and morphological examination while the other part was processed for cell culture studies.  

Specimens were fixed in 10% buffered formalin and embedded in paraffin. Tissue sections were cut and stained with haematoxylin-azofloxin. Light microscopical examination of each specimen was performed.

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*Figure 2.* (A) Detected contours superimposed on the original video image for a representative right coronary artery stenosis, filmed in right anterior oblique projection before directional atherectomy. Diameter function is shown at the bottom. White area is a measure of the "atherosclerotic plaque." The minimal luminal diameter (vertical line) is 0.71 mm, corresponding to a diameter stenosis of 79% and an area stenosis of 96%. (B) A single frame angiogram of the right coronary artery filmed in right anterior oblique projection after directional atherectomy. Minimal luminal diameter increased to 2.27 mm, corresponding to a diameter stenosis of 21% and an area stenosis of 38%. (C) Contour analysis of the atherectomy device and inflated support balloon with diameter function shown beneath. Mean diameter of the device together with the inflated balloon is 3.06 mm and the minimal luminal diameter increased from 0.71 mm to 2.27 mm.
were separately assessed by quantitative angiography. Such a study is precluded by
ethical considerations.

Does the removal of atheromatous tissue explain the improvement in the luminal
diameter? Rensing et al and others suggested that part of the luminal improvement is due to
"facilitated angioplasty".25 26 Our study helps to clarify this issue. The intracoronary quanti-
tative assessment of the device size showed a mean diameter of 2.1 mm increasing to 3.4 mm
after balloon inflation, while the minimal luminal obstruction diameter and reference
diameter were 1.1 mm and 3.0 mm, respect-
ively. The introduction of the atherectomy
device itself has a "dottering" effect that is
subsequently combined with an angioplasty
effect when the support balloon is inflated.

Atherectomy was predominantly performed in
long eccentric stenoses located in a proximal
coronary artery containing a large athero-
matous mass. Our primary angiographic suc-
cess rate (87%), based on intention to treat
analysis, is similar to the results reported so
far.15 16 The treatment of such a lesion is
currently a major challenge in interventional
cardiology because it is known that the risk of
acute complication is high in these lesions. We
need a randomised study to establish whether
these lesions are more safely and successfully
treated by atherectomy than by conventional
balloon dilatation.

POTENTIAL RISKS
This new and vigorous technique produces a
larger luminal diameter than any other intra-
coronary interventional technique.25 27 Because
the depth of the resection and precise spatial
orientation of the device are not controlled, it is
possible to remove both medial and adventitial
tissue. In one study adventitia was identified in
30% of the resected specimens.28 The 26% incidence of media in our specimens supports
these findings.

In one of our patients coronary perforation
occurred three days after a bail-out atherec-
tomy. Conventional angioplasty had led to an
obstructive dissection which was removed by
atherectomy; three days later the patient died of
cardiac tamponade. In one patient formation of
a coronary aneurysm occurred after the use of
a relatively oversized 7 F atherectomy device.
Embolisation of atheromatous material from
the plaque to the periphery of the treated vessel
occurred in two patients resulting in a non-Q
wave infarction. Side branch occlusion was
noted once. With the use of an 11 French sheath,
major groin complications may occur; howev-
er, none of our patients developed a
haematoma requiring blood transfusion or vas-
cular surgical repair. These cases underline the
risks associated with the aggressiveness of
atherectomy. In future the device will un-
doubtedly be modified to produce smaller,
more flexible, and less traumatic systems.

ATHERECTOMY AS A BIOPSY TECHNIQUE
Recently Johnson et al reported their histo-
logical observations on excised peripheral
arterial tissue from atherectomy procedures.29
They found that 75% of restenosis showed
intimal fibrous proliferation compared with 9%
in primary atherectomy lesions which consis-
ted predominantly of typical atherosclerotic
plaque.30 Our results are consistent with theirs:
89% of restenoses showed intimal hyperplasia
compared with 24% of primary stenoses.

In our study atherectomy was performed
within a stent on five occasions. The tissue
excised resembled that of other restenosis
specimens. Microscopy showed intimal hyper-
plasia and capillary ingrowth. Immunohisto-
chemical staining showed that most of these
cells were smooth muscle cells. We and others
are currently investigating the behaviour of
smooth muscle cells in culture from atherec-
tomy material.30 31 Thus atherectomy can be
used to obtain material to throw light on the
development of restenosis or to monitor pharma-
ological treatments.

Directional coronary atherectomy is an effec-
tive non-operative treatment of coronary artery
lesions. It is particularly effective in removing
atheromatous tissue specimens from eccentric
lesions which are not particularly amenable to
conventional balloon angioplasty. Quantitative
analysis of the immediate results after coronary
atherectomy shows a greater gain in minimal
luminal diameter than with balloon angi-
oplasty. Using quantitative analysis we found
evidence that a facilitated angioplasty effect
partly accounts for the luminal improvement.
Because the depth and site of the resection is
not controlled, atherectomy can lead to serious
complications. Atherectomy is a method of
obtaining human (re)stenosis tissue which can be
used to study the causes of restenosis.
Despite the encouraging short term results,
however, we need further studies of the
ultimate indications and long term follow up.

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