Computed tomographic assessment of left ventricular aneurysms

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SUMMARY Twenty patients with left ventricular aneurysms were studied by left ventricular angiography and computed tomography. Measurements of left ventricular short axis, percentage of non-aneurysmal myocardium, and size of aneurysm were determined by both techniques. Qualitative assessments of left ventricular size together with the anatomical relation of the aneurysm to the ventricle were also made. The aneurysm was assessed for resectability by both techniques using these criteria. In all cases there was a distinct and diagnostic change in the contour of the ventricle on computed tomography. Computed tomography indicated eight aneurysms to be unresectable, and this agreed with the angiographic assessment. Of the remaining 12 aneurysms, seven were considered to be resectable on angiography. Computed tomography appears to be a reliable non-invasive technique for identifying left ventricular aneurysms and a useful screening method for identifying unresectable aneurysms.

Left ventricular aneurysms are found at necropsy in 3.5-20% of patients who have had a myocardial infarct,^{1,2} and one clinical study found an incidence as high as 35%.³ There is no precise definition of a left ventricular aneurysm in the literature, and the pathological definition does not always relate to the findings in life.⁴ Gorlin *et al* defined an aneurysm as a localised area of total lack of wall motion or paradoxical wall motion.⁴ Every transmural infarction necessarily gives rise to local akinesia, but an akinetic area in the ventricular wall is not necessarily an aneurysm. A more satisfactory definition must take into account the shape of the ventricle. For the purposes of this study a left ventricular aneurysm is defined either as a localised area of paradoxical wall motion or as an area of total lack of wall motion with projection of this area beyond the normal predicted contour of the ventricle. In terms of the definition paradoxical motion means centrifugal motion during systole, and the predicted contour of the ventricle in the given area is the contour that would be predicted by interpolation between

normal anatomical landmarks (for example, the aortic and mitral valves) and the contour of the normally contracting myocardium.

Left ventricular aneurysms interfere with the mechanical function of the remaining viable myocardium. Despite their frequency and functional importance, however, there is no easy clinical method of recognising them. Occasionally, the presence of an aneurysm may result in haemodynamic deterioration, repeated embolism, or resistant arrhythmias. In such cases aneurysectomy may be considered. Not all aneurysms are amenable to surgery, and a reliable technique is, therefore, necessary to assess resectability. At present, decisions on the feasibility of surgery are based on left ventricular angiography. Although cardiac catheterisation is an invasive technique it is always likely to be required before surgery in order to demonstrate detailed coronary artery anatomy. Nevertheless, there is a great need for a non-invasive screening procedure to select those patients requiring further invasive investigations. It would be advantageous if such a procedure could also provide detailed information of the extent and distribution of both the aneurysm and remaining viable myocardium.

Recent reports have suggested that computed tomography can demonstrate left ventricular aneur-

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Accepted for publication 5 April 1984

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ysms well.^{5,6} In all cases a definite change in the contour of the ventricle has been observed and is a feature not detected in any other condition. Without electrocardiographic gating the function of the left ventricle cannot be assessed by computed tomography, but information may be provided on the amount of remaining viable myocardium and the size of the remaining ventricle at end diastole.

This study aimed to compare the relative merits of computed tomography and left ventricular angiography in determining the operability of left ventricular aneurysms and to see if computed tomography would be an accurate technique for identifying unresectable aneurysms.

Patients and methods

Eighteen patients with a history of myocardial infarct and in whom a left ventricular aneurysm was detected at angiography were studied by computed tomography. An additional two patients suspected clinically of having a left ventricular aneurysm were studied by computed tomography before angiography. In all patients angiography and computed tomography were performed within two months of each other. Left heart catheterisation with left ventricular angiography in the 40° right anterior oblique and 50° left anterior oblique projections together with coronary arteriography was undertaken in all patients.

COMPUTED TOMOGRAPHY

Computed tomography without electrocardiographic gating was performed in all patients using an IGE CT/T 8800 scanner with a 5.6 s scan time and 2.4 s interscan time. A scanned projection radiograph was first performed to identify the anatomical levels for a dynamic incremental series of scans of the heart. Each scan was of 1 cm thickness and was recorded at 1 cm intervals. From this series the appropriate anatomical levels for intravenous contrast study were selected. An intravenous infusion of 40 ml of iodinated contrast medium (Conray 280) at 2 ml/s was started 15 s before the first scan, and four scans of the left ventricle at 1 cm intervals were then obtained starting at the level of the aortic root. A further 2–4 scans during a second infusion of 20–40 ml of contrast were obtained to complete the series of the left ventricle. All scans were performed during fixed maximal inspiration.

EVALUATION

The computed tomographs and the left ventricular angiograms were assessed both qualitatively and quantitatively. These assessments were performed blind by independent experienced observers. To evaluate residual functioning myocardium in the left ventricle we decided to calculate the percentage of

non-aneurysmal myocardium remaining in the left ventricle. The angiographic assessment was made using a segmental system. The left ventricle was divided into seven segments as proposed by the American Heart Association,⁷ each segment being assumed to represent 14.3% of the whole. The percentage of non-aneurysmal myocardium was then estimated. The computed tomograms were directly measured using commercially available computer software with a tracker ball. The length of non-aneurysmal and aneurysmal myocardium was directly measured on each computed tomographic section, the measurements being made to the point of change of contour of the left ventricular outline (Fig. 1). Measurements were made on each computed tomographic section and the results in each patient summed. The percentage of non-aneurysmal myocardium was then calculated and the percentages obtained by the two methods compared. Where possible the maximum short axis diameter of the non-aneurysmal ventricle was measured from the left ventricular angiograms in the left anterior oblique projection using calibration

Fig. 1 Computed tomogram of an anterior left ventricular aneurysm showing method of measuring non-aneurysmal (broken line) and aneurysmal myocardium (solid line) to calculate percentage of non-aneurysmal myocardium. An, aneurysm; LV, left ventricle.

markers. The maximum short axis measurement from the computed tomograms was taken perpendicular to the septum (approximately left anterior oblique). A right anterior oblique measurement is not possible with computed tomography as the sections are not perpendicular to the long axis in this plane. A qualitative assessment of the size of the remaining ventricle was also made with both techniques and recorded as normal or dilated.

The size of the aneurysm was assessed by both left ventricular angiography and computed tomography as small (<2 cm diameter), medium (2–4 cm), or large (>4 cm). The anatomical relation of the aneurysm to the left ventricle was noted and also whether the aneurysm had a neck and if so whether it was wide or narrow.

An aneurysm was regarded as being resectable by the following criteria: (a) the amount of functioning myocardium remaining in the left ventricle, (b) the size of the left ventricle, and (c) the ability to repair the left ventricle after resection. In addition left ventricular function was included in the angiographic analysis.

Results

In all patients a left ventricular aneurysm was demonstrated by both computed tomography and angiography. A distinct change in the predicted contour of the ventricle was readily apparent on the computed tomograms of all the patients studied, and this change in contour has not been observed in any other condition (Fig. 2). There was agreement on the site of the

Fig. 2 (a) Left ventricular angiogram (right anterior oblique projection) of a large anterior aneurysm with a wide neck. (b) Computed tomogram of the same patient showing the distinct change in contour of the ventricle (arrowed). (c) Computed tomogram of a patient with an old anterior myocardial infarct but no aneurysm, demonstrating no change in contour. The infarcted area (arrowed) shows myocardial thinning. An, aneurysm; LV, left ventricle; RV, right ventricle; LA, left atrium; D, diaphragm.

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aneurysm in all cases. In view of the small numbers studied it is not possible to comment critically on the distribution of the different sites of the aneurysms, but as might be expected anterior and apical aneurysms (19) were much commoner than posterior ones (1).

ASSESSMENT OF FUNCTIONING MYOCARDIUM

A comparison of the two sets of data gives a coefficient of correlation of 0.52 ($p < 0.01$) (Fig. 3). When compared for difference by Wilcoxon's matched pairs signed ranks test there was no significant difference between the two pairs of data ($p > 0.88$).

LEFT VENTRICULAR SHORT AXIS MEASUREMENT

The left anterior oblique short axis could be measured by both techniques in 17 of the 20 cases. In all but two, computed tomography underestimated the short axis measurement ($p < 0.001$). A comparison of the two measurements gave a coefficient of correlation of 0.61 ($p < 0.004$) (Fig. 4).

LEFT VENTRICULAR SIZE (Table)

In 18 of the cases there was agreement between the two techniques on the left ventricular size. In the remaining two, reported as normal by computed tomography, the angiographic short axis measurements (5.5 cm and 6.2 cm) were only just outside the normal limits.

SIZE OF ANEURYSM AND PRESENCE OF A NECK

In 17 cases both techniques agreed on the size of the aneurysm (one small, three medium, and thirteen

Fig. 3 Percentage of non-aneurysmal myocardium measured by computed tomography and angiography.

Fig. 4 Left ventricular left anterior oblique short axis measurement by computed tomography and angiography. *Two patients.

large). The remaining three cases were reported as large by angiography and medium by computed tomography.

In 12 cases there was agreement on the presence of a neck (three narrow (Fig. 5), seven wide (Fig. 2), and two no neck). The remaining eight cases were reported as having a wide neck by computed tomography and no neck at angiography.

RESECTABILITY OF ANEURYSM

Seven aneurysms were considered resectable by angiography, and all of these were reported as resectable by computed tomography (Table). An additional five aneurysms were considered resectable by computed tomography, and, although reported as unresectable by angiography, two were successfully resected. In eight cases resection was not thought feasible by computed tomography. All had dilated ventricles and large aneurysms demonstrated by both techniques. None of these eight were considered resectable at angiography, and none were resected.

Discussion

Although there is a relatively high incidence of left ventricular aneurysms after acute myocardial infarction most patients have no referable symptoms. When symptoms are present, however, aneurysectomy should be considered. The most common indications for surgery are heart failure and angina, although occasionally surgery is performed for recurrent

Table Qualitative assessment of left ventricular size and the resectability of the aneurysms by the two techniques

Angiography	Computed tomography			
	Left ventricle		Aneurysm	
	Normal	Dilated	Resectable	Non-resectable
Left ventricle:				
Normal	6	0		
Dilated	2	12		
Aneurysm				
Resectable			7	0
Non-resectable			5	8

emboli from mural thrombi and rarely for uncontrollable life threatening arrhythmias.

The decision on whether a left ventricular aneurysm is resectable or not is based mainly on the amount and function of the remaining myocardium in the left ventricle. If these are adequate then resection should be considered. When the aneurysm has a narrow neck its size is usually of little importance. When there is no neck, however, or the neck is wide the extent of the aneurysm in addition to the size and function of the remaining left ventricle becomes important, particularly in relation to ventricular repair after aneurysectomy.

To avoid unnecessary invasive investigation in those patients who are not surgical candidates, a reliable non-invasive screening technique would be of

value. Such a technique would not only demonstrate the aneurysm but would also provide information on the size and function of the remaining left ventricle. At present several non-invasive techniques that will detect left ventricular aneurysms are available. So far none have been able to provide all the information required to permit selection of patients for aneurysectomy.

Fluoroscopy is insensitive: not all aneurysms, especially those arising from the posterior wall, can be detected.^{3 8} The method does not permit assessment of size or function of the remaining left ventricle or of whether the aneurysm has a neck. Radionuclide angiography can demonstrate most left ventricular aneurysms⁹ and also differentiate them from diffuse hypokinetic areas of the left ventricle.^{10 11} The size and function of the remaining left ventricle can also be assessed.^{12 13} It is difficult by this technique, however, to determine whether an aneurysm has a neck or not, and it is rarely possible to determine whether the aneurysm is resectable.

M mode echocardiography can detect the presence of a dilated area of ventricle and give some information on the function of the remaining left ventricle.¹⁴ It is not usually possible, however, to determine whether such a dilated area is an aneurysm or not.¹⁴ Cross sectional echocardiography permits ready identification of left ventricular aneurysms,^{13 15 16} although difficulties may be encountered in obtaining adequate data in certain situations such as obesity and lung disease, which occurs in an appreciable number of patients. The size of the aneurysm and the function of the remaining left ventricle can usually be assessed, but to date there are no published studies proposing echocardiography as a method to evaluate operability.

Cardiac computed tomography without electrocardiographic gating provides images of the cardiac chambers at their largest dimensions—that is, in diastole. Left ventricular aneurysms either increase in volume in systole or project beyond the normal contour of the left ventricle during diastole. The image produced during ungated computed tomography will, therefore, show a change in contour at the point of

Fig. 5 Computed tomogram of a patient with a posterior narrow necked aneurysm. An, aneurysm; LV, left ventricle, RV, right ventricle.

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origin of the aneurysm. If a dynamic series of computed tomograms through the left ventricle is obtained during intravenous contrast infusion not only may a left ventricular aneurysm and its anatomical relation to the ventricle be identified but also its size may be assessed.

Although most patients (18) in this study had been diagnosed angiographically as having left ventricular aneurysms before computed tomography, the computed tomographic appearances assessed without knowledge of the angiographic appearances were characteristic in all patients.

The images produced by computed tomography and left ventricular angiography cannot be compared directly, but this study, nevertheless, has attempted to relate these two techniques. Each computed tomographic section can be regarded as a 1 cm thick transverse slice of a left ventricular angiogram. Both quantitative and qualitative assessments can, therefore, be made and compared. Computed tomographic information is digitally derived, and numerical data are available in each section on the whole circumference of the left ventricle. Quantitative measurements should, therefore, provide more accurate information than angiography, which is not so derived, is difficult to calibrate, and also provides data only on single projections of the left ventricle.

Non-gated computed tomographic images are produced from data acquired during the whole cardiac cycle. Since most of this acquisition time is during diastole that portion from systole will be relatively less prominent and blurred out and the image produced, therefore, more representative of diastole.¹⁷ This will not, however, be a true end diastolic image and will, therefore, underestimate angiographic measurements, a feature demonstrated in this study. It may be possible to produce a correction formula for this error when more data are available from a larger number of patients.

The main disadvantage of computed tomography is its inability to view the inferior surface of the heart which is parallel to the scanning beam. This fact may explain some of the differences observed between the two techniques. It should not, however, preclude the identification of inferior aneurysms which will extend beyond the predicted border of the ventricle. In addition, computed tomography does not appear to be an accurate method for differentiating aneurysms with wide necks from those with no neck, but this information is unlikely to have clinical importance.

In all eight cases considered unresectable by computed tomography this was confirmed at angiography. Computed tomography incorrectly identified five aneurysms as being resectable; this may be explained by the fact that the function of the residual left ventricle could be assessed by angiography but not by com-

puted tomography.

From this series of patients it would appear that ungated computed tomography is a sensitive non-invasive method for diagnosing left ventricular aneurysms. It compares favourably with left ventricular angiography in the estimation of non-aneurysmal myocardium and provides a reasonably accurate, although slightly underestimated, measurement of the end diastolic short axis. In addition, it provides information on the anatomy of the aneurysm and its relation to the left ventricle. Furthermore, using this information a group of patients who would not be suitable for aneurysectomy may be selected. These patients would, therefore, not require invasive investigation. Electrocardiographic gated computed tomography permits some assessment of left ventricular function.^{18,19} With this technique, therefore, the number of patients requiring invasive investigations may be further reduced.

We thank Mr J Yates, senior radiographer, for his assistance.

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