Noninvasive Diagnosis of Thrombus in the Heart and Large Vessels — Usefulness of Two-dimensional Echocardiography and X-ray CT —

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The usefulness of two dimensional echocardiography (2-D echocardiography) and x-ray computed tomography (CT) for the diagnosis of thrombi in the cardiac cavity and large vessels was studied by comparing them with the findings of invasive methods. Among 56 subjects with mitral stenosis, left atrial thrombi were noted in 12 cases (16 regions) by CT and 8 cases (9 regions) by 2-D echocardiography. In 16 subjects who underwent operations, one false negative case by CT and 3 false negative and one false positive cases by 2-D echocardiography were found. In 80 subjects with myocardial infarction 2-D echocardiography, CT and left ventriculography (LVG) were performed at approximately the same time. Thrombi were detected in 10 subjects (12.5%) by 2-D echocardiography, in 15 (18.8%) by CT and in 14 (17.5%) by LVG. Although mural thrombi in abdominal aortic aneurysm were detected very easily, thin thrombi surrounding the false lumen of the dissecting aneurysm were not detected ultrasonographically. These thrombi were only detected by the enhanced CT.

Our results show the usefulness of both methods for detecting thrombi in the heart and large vessels. CT can distinguish the thrombi more clearly than 2-D echocardiography, but 2-D echocardiography is performed more easily, safely and economically than CT.

IT was relatively difficult to detect thrombi in the heart and large vessels until several years ago¹. Recently many techniques using medical electronics have been available to detect them safely and noninvasively. These techniques, such as echocardiography, computed tomography, nuclear cardiology and NMR are changing the diagnostic concept of thrombi. Accordingly, we decided to study the diagnostic values of two main noninvasive methods, two dimensional echocardiography (2-D echocardiography) and X-ray computed tomography (CT) in detecting

thrombi in the heart and large vessels.

SUBJECTS AND METHODS

The subjects in this study included 56 patients with mitral stenosis, 144 patients with transmural myocardial infarction, 15 patients with congestive cardiomyopathy, one patient with Behçet's disease with a right ventricular thrombus, 20 patients with abdominal aortic aneurysm and 36 patients with dissecting aortic aneurysm.

Two-dimensional echocardiography and enhanced CT were performed successively within a week on most of the subjects, and the others underwent one of the two procedures. Left ventriculography (LVG) or other angiocardiology was also performed on many subjects to confirm the diagnosis. Some subjects underwent surgical

Key Words:

Thrombus
Two-dimensional echocardiography
Computed tomography
Mitral stenosis
Myocardial infarction

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Fig.1. A large left atrial thrombus (TH) in the 2-D echocardiogram and enhanced cardiac CT image of a patient with mitral stenosis.

Ao: aortic root, RVOT: right ventricular outflow tract, LA: left atrium, RA: right atrium, RV: right ventricle, LV: left ventricle.

Mitral stenosis 43 m

Fig.2. Enhanced cardiac CT image and 2-D echocardiogram of a patient with mitral stenosis.

Both left atrial and auricular thrombi (TH) which were confirmed by surgery are shown with the filling defects in the CT image. On the other hand, the thrombus in the left auricle is not shown on the 2-D echocardiogram.

RA: right atrium, RVOT: right ventricular outflow tract, Ao: aortic root, LA: left atrium, LAA: left auricle.

procedures.

Two-dimensional echocardiography was performed with an electronic sector scanner (Toshiba Model 11A) using the parasternal long and short axis views and the apical four chamber views obtained at the standard transducer position for cardiac observation. An electronic linear scanner (Toshiba Model 53H) was also used for the long and short axis observation of the abdominal aorta.

A GE CT/T 8800 was used mainly for the CT scan, but a Siemens Somatom 2 was also used in some cases. All patients were examined in the supine position during a full inspiratory breath hold. The enhanced CT scan were performed with 1 cm slice thick after a bolus intravenous injection of 20 ml of urografin-76 (76% Methylglucamine diatrizoate). In some cases, dynamic CT scanning with a contrast material was done to demonstrate the blood perfusion in

Fig.3. 2-D echocardiogram, enhanced CT image and LVG of a patient with anterior myocardial infarction.

Although, it is difficult to determine the boundaries of the thrombus (TH and arrow) and the wall by 2-D echocardiography and LVG, CT can distinguish the thrombus from the blood and the ventricular wall.

RV: right ventricle, RA: right atrium, LV: left ventricle, S: interventricular septum.

TABLE I VALIDITY OF CT AND 2-D ECHOCARDIOGRAPHY IN SURGICAL CASES

Case No.	Age	Sex	CT	2D echo	Operation findings
1	49	F	+	+	ls PV-OS, 3 g LAU, a little
2	38	M	+	+	ls PV-OS, 3 g
3	43	M	+	+	LW, 4 g LAU, 1 g
4	56	M	+	+	PW, 20 g
5	37	F	—	—	LAU, 5 g
6	50	M	—	—	—
7	57	F	—	+	—
8	59	F	—	—	—
9	32	F	—	—	—
10	50	M	—	—	—
11	52	F	—	—	—
12	33	F	—	—	—
13	48	F	—	—	—
14	43	F	±	—	—
15	69	M	—	—	—
16	34	M	—	—	—

LAU: left auricula, PV-OS: pulmonary vein ostium, PW: posterior wall of left atrium, LW: left lateral wall of left atrium.

the heart and aorta.

The criteria for the diagnosis of thrombus with 2-D echocardiography and CT used in this study were as follows:

A thrombus was defined by 2-D echocardiography as a distinct mass of echos in the cardiac

cavity or in the aortic lumen that was clearly seen throughout the cardiac cycle from at least two different echocardiographic views. On the other hand, thrombi were determined by CT as filling defects in the cardiac cavity or in the aortic lumen after the administration of the contrast material. Thrombi could be differentiated from the papillary muscle and the trabecula, because the CT values of the thrombi were not increased by contrast enhancement, while those of the papillary muscle and the trabecula were increased moderately. A small filling defect of less than 25 mm² in size which was seen only in one slice of the CT scan was not considered a thrombus, because a low density fleck owing to artifacts might confuse the diagnosis.

Echocardiogram, CT and LVG images were interpreted by well-trained observers. The diagnosis of the presence or absence of thrombus was agreed on by all observers, and when agreement was not possible, the diagnosis of the thrombus was classified as a questionable case.

RESULTS

1. Left atrial thrombus

Among the 56 subjects with mitral stenosis, left atrial thrombi were found in 9 regions in 8 cases (14%) by 2-D echocardiography and in 16 regions in 12 cases (20%) by CT. All the cases with thrombi had atrial fibrillation. Out of these 16 thrombi detected by CT, 2-D echocardiography discovered 9 thrombi. Five of the other 7 thrombi were located in the left auricula and 2 were located near the entrance of the left

TABLE II THE DETECTION RATE OF THE MURAL THROMBI BY CT, 2-D ECHOCARDIOGRAPHY AND LVG

(A)

		2-DE			Total
		+	±	—	
CT	+	15	2	5	22
	±	0	0	2	2
	—	0	1	85	86
	Total	15	3	92	110

(B)

		CT			Total
		+	±	—	
LVG	+	13	0	1	14
	±	0	1	1	2
	—	2	1	66	69
	Total	15	2	68	85

(C)

		2-DE			Total
		+	±	—	
LVG	+	10	0	5	15
	±	0	0	2	2
	—	0	1	77	78
	Total	10	1	84	95

pulmonary vein (Fig. 1 and 2).

Sixteen subjects with mitral stenosis underwent surgery, and thrombi were present in 5 cases (7 regions). Among the 7 thrombi, three were found in the left auricula. These three thrombi were undetectable by 2-D echocardiography, but one was detectable, one was questionable and the third one was undetectable by CT. The other 4 thrombi were verified according to the results of the operations (Table I). The smallest thrombus picked up at operation was about 1g and its size measured from CT images was about 1 ml. Among the 11 subjects who were not found to have a thrombus in the left atrium, one subject was considered a questionable case of thrombus by CT and another one subject determined as a case with left atrial

thrombus by 2-D echocardiography.

Left atrial thrombi were detected in 2 out of 144 subjects with myocardial infarction, and in one out of 15 subjects with cardiomyopathy by CT.

2. Left ventricular thrombus

Left ventricular thrombi were detected in 15 (11.6%) out of 129 subjects with myocardial infarction by 2-D echocardiography, in 25 (20%) out of 125 subjects by CT and in 15 (15.8%) out of 95 subjects by LVG. Among the 80 subjects performed using these 3 procedures at approximately the same time, 2-D echocardiography, CT and LVG demonstrated thrombi in 10 (12.5%), 15 (18.8%) and 14 (17.5%) subjects, respectively. Most of the thrombi were found at the apical portion of the left ventricle and half of them were found in the ventricular aneurysm (Fig. 3).

One hundred ten subjects with myocardial infarction were studied with 2-D echocardiography and CT at approximately the same time. Among them left ventricular thrombi were found in 15 subjects by 2-D echocardiography, in 22 subjects by CT but none were found in 85 subjects by both methods. There were 10 cases of discord (Table II-A). Eighty five subjects were studied with CT and LVG at approximately the same time. Among them CT indicated left ventricular thrombi in 15 subjects. LVG indicated thrombi in 14 subjects. In one subject thrombi was questionable by both methods and in 66 subjects thrombi were not found by both methods. The findings of CT and LVG were in discord in 5 cases (Table II-B). In 95 subjects studied with 2-D echocardiography and LVG at approximately the same time, thrombi were found in 10 subjects by 2-D echocardiography and 15 subjects by LVG. Thrombi were not found in 77 subjects by both methods. There were 8 cases of discord (Table II-C).

Left ventricular thrombi also frequently developed in the course of congestive cardiomyopathy. In 4 out of 15 subjects with congestive cardiomyopathy, thrombi were detected by 2-D echocardiography and CT.

3. Right ventricular thrombus

A 37-year-old man with cardio-vascular Behçet's disease with superior vena cava syndrome was performed with 2-D echocardiography, CT and right ventriculography. A two-dimensional echocardiogram in the 8 mm cine film of the patient demonstrated a moving echo mass in his

T.S. 61 F Aortic aneurysm

Fig.4. Longitudinal and horizontal views of abdominal aorta by 2-D echography and enhanced abdominal CT images of a patient with abdominal aortic aneurysm.

right ventricle. CT and right ventriculogram indicated a filling defect in the apex of his right ventricle.

4. Thrombus in the aorta

Two-dimensional abdominal echography was performed in 20 subjects with abdominal aortic aneurysm. CT and aortography were performed on 12 and 10 cases of them, respectively. The diameter of the aneurysm was 3 cm to 8 cm and mural thrombi were found in 19 cases (95%) out of 20 subjects by 2-D echography. The thrombi were located most frequently at the anterior and

distal site of the aneurysm. CT and aortographic findings were similar to those of 2-D echography (Fig. 4). Among these subjects, 10 underwent surgery for the aneurysm and 2 other subjects died. The operation and autopsic findings confirmed the results of these noninvasive methods.

Thirty six patients with dissecting aortic aneurysm were studied with CT. CT images of the aorta showed aortic dilatation in 30 subjects, intimal flap in 34 subjects and thrombi in 28 subjects. In 24 cases dynamic CT scan were performed to differentiate true and false lumina.

The thrombi were always located in the false lumen in these subjects. Two-dimensional echography was performed on 20 of them. Aortic dilatation was demonstrated in the most of the subjects, but the thrombi surrounding thinly aortic lumen were hardly detected by 2-D echography, and thus thrombi were detected in only half of them. Among 36 subjects 8 underwent surgery while 2 others died and underwent an autopsy. The findings of the operation and autopsy confirmed the results of CT.

DISCUSSION

The diagnosis of thrombi is very important in determining the clinical treatment of anticoagulation, exercise restriction and surgery in various diseases. Recently, several reports have described the usefulness of 2-D echocardiography and enhanced CT for the detection of thrombi in the left atrium²⁻¹⁰. Some reports showed that most of the left atrial thrombi larger than the finger tip in size were detectable by 2-D echocardiography, but thrombi located in the left auricle were difficult to detect echocardiographically, because of the limitation of the direction of echo-beam projection^{4,9}. On the other hand, Tomoda et al have reported the usefulness of CT for detecting left atrial thrombi; In three out of 23 subjects with mitral valvular disease left atrial thrombi were delineated with CT and were confirmed by cardiac surgery or autopsy, and there were no false-positive or false-negative cases⁷.

Our results were similar to these findings. In 16 subjects who underwent surgery, there was one false-negative lesion by CT, three false negative lesions and one false positive lesion by 2-D echocardiography. It seems that the cause of failure to identify thrombi is mainly due to the poor resolution of the images owing to a low concentration of contrast material in the left atrium in case of CT and to the absorption of ultrasound in the lung surrounding the heart in the case of 2-D echocardiography.

Several investigators have also reported the detection of left ventricular thrombi by 2-D echocardiography¹⁰⁻¹⁹. These results show 2-D echocardiography is a useful method in detecting left ventricular thrombi, but false-positive and false-negative cases are relatively common. Nair et al, Godwin et al and Kanemitsu et al have shown that enhanced CT is more useful than 2-D

echocardiography^{16,20,21}. In our study 2-D echocardiography identified thrombi in 15 out of 129 subjects with myocardial infarction. However, it failed to identify left ventricular thrombi in 6 patients with a clearly defined left ventricular filling defect by CT and/or LVG. All of the 6 cases had thin mural thrombi at the apex of the left ventricle.

Two-dimensional echocardiography and CT could easily identify thrombi in the abdominal aortic aneurysm²²⁻²⁴ because there are usually large mural thrombi in the aortic aneurysm. Mural thrombi were detected in 95% of 20 subjects with aortic aneurysm in our study. The distribution of thrombi was most frequently at the antero-distal part of the aneurysm. Mural thrombi were also detected in 28 out of 36 subjects with dissecting aortic aneurysm. These thrombi were always found in the false lumen and in some cases thrombi completely filled the false lumen. The formation of the thrombi in the aortic aneurysm and the dissecting aneurysm seems to be caused by morphological change of the aortic wall and blood flow disturbance.

Two-dimensional echocardiography is an excellent method for the clinical evaluation of thrombi in the cardiovascular system. The echo images are produced in real time and the moving thrombi, which have a high risk to cause embolism, are easily detected^{17,23,25}. The transducer can be steered to any position on the body, with tomographic images being obtained from many planes such as the longitudinal or oblique. Echocardiographic equipment is less expensive and smaller in size than the apparatus for CT scan and cineangiography and can be portable. In addition to these advantages, echocardiography offers no known danger to the subjects. However, CT can more clearly distinguish thrombi from the blood and myocardium by a venous injection of contrast material. The detection rate of thrombi in the cardiac cavity and large vessels by CT is higher than that by 2-D echocardiography. Two-dimensional echocardiography and enhanced CT are the most useful noninvasive methods for detecting thrombi in the cardiovascular system. Each method has several advantages and disadvantages²⁶. The greatest difference between these methods is that 2-D echocardiography detects differences in the mechanical acoustic properties of tissue, while CT detects differences in x-ray absorption. Thus, by combining these methods, complementary information for im-

proved detection of thrombi can be obtained.

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