Percutaneous Fiberoptic Cardioscopy of the Left Ventricle

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SUMMARY

The feasibility of percutaneous transluminal cardioscopy of the left ventricle was examined in 35 patients with or without various heart diseases. A guiding balloon catheter (7 or 9 French) was introduced through the right femoral artery into the left ventricle. The balloon was inflated, and a fiberscope (1.6 or 4.3 French) was advanced to the distal tip of the catheter. The balloon was then manipulated against the portion of the ventricle targeted for examination, and heparinized saline (10 U/ml) at body temperature was infused through the catheter at 5 ml/sec for 3 to 6 sec. The images were recorded on videotape and 16 mm cinefilm. In 4 patients without demonstrable heart disease, the endocardial surface of the left ventricle was brown and the trabeculae became prominent during systole. The chordae connected to the mitral leaflets were white. In 3 of 5 patients with dilated cardiomyopathy, the endocardium was light yellow with thin trabeculae which barely contracted during systole. The endocardium was red or reddish-brown in 3 patients with acute myocarditis. In patients with rheumatic mitral stenosis white patches were scattered on the endocardial surface. In 7 of 8 patients the akinetic or dyskinetic segments representing prior infarctions were white. No complications other than transient ventricular arrhythmias were noted. We conclude that percutaneous fiberoptic imaging with a guiding balloon catheter is feasible and safe, and yields highly detailed images of the endocardium.

Additional Indexing Words:

Cardioscopy Dilated cardiomyopathy Ischemic heart disease

THE morphology and function of the cardiac chambers have been evaluated clinically using cineventriculography, computed tomography, magnetic resonance imaging and percutaneous endomyocardial biopsy. Excluding the invasive technique of biopsy where tissue is actually removed,

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these other non-invasive techniques reveal only indirect evidence of endocardial pathology and therefore allow the potential for misdiagnosis from insufficient data. Fiberoptic examinations, as recently demonstrated in coronary,¹⁾⁻⁴⁾ pulmonary^{5),6)} and peripheral arteries,^{7),8)} allow direct observation of pathology otherwise unobtainable. Recently, similar techniques have been applied to examine all the cardiac chambers of the dog⁹⁾ and the right heart of humans.¹⁰⁾ In this study, we examine the feasibility and safety of percutaneous fiberoptic cardioscopy of the left ventricle in patients with various categories of heart disease.

PATIENTS AND METHODS

Fiberscope:

The fiberscope used in this study was either 1.6 French in diameter with 2,000 image fibers and 100 illumination fibers, or 4.2 French with 3,000 image fibers and 200 illumination fibers (Olympus Corp., Tokyo, Japan).

Guiding balloon catheter and its manipulation:

The two guiding balloon catheters have 7 and 9 French external diameters of a 'J', 'L' or 'U' tip configuration and both have a distal tip balloon diameter of 20.7 mm when completely inflated (Clinical Supply Co., Gifu, Japan). Three to 3.5 ml of CO₂ were required to completely inflate the balloon. The diameter of the visual field obtained by these catheters and fiberscope was 5-10 mm in water. The guiding balloon catheter was selected with a 'J', 'L' or 'U' tip according to the location of the site targeted for examination. Namely, a catheter of 'J' configuration was selected for inferior and posterior segments, and a catheter of 'U' configuration for high lateral and high septal segments. The guiding balloon catheter was introduced through a sheath and advanced into the left ventricle over a 0.035 inch wire (Terumo Corporation, Tokyo). Ventricular pressure was monitored through the distal lumen to determine whether the distal tip was located in the left ventricle. The wire was removed, the catheter's lumen was flushed with heparinized saline, and the balloon was inflated manually with CO₂. One of the fiberscopes was then advanced through the guiding catheter to its most distal tip without protruding from the tip of the guiding catheter. The guiding balloon catheter was manipulated under fluoroscopy so that the balloon was directly contiguous with the portion of endocardium targeted for examination. Also, saline was infused to identify whether the distance between the endocardium and fiberscope was appropriate for observation. Usually, a 9F guiding balloon catheter and 4.2F fiberscope were used. How-

ever, when stenosis in the iliac artery disturbed introduction of a 9F catheter, a 7F catheter and 1.6F fiberscope were used.

Patients:

The 35 patients in the current study were as follows: 9 females and 24 males whose age ranged from 35–76 years (mean=57). The indications for cardiac catheterization in these patients were as follows: chest pain syndrome (n=4), ASD (n=1), idiopathic dilated cardiomyopathy (n=5), acute idiopathic myocarditis (n=4), rheumatic aortic regurgitation (n=3), rheumatic aortic stenosis and regurgitation (n=2), rheumatic mitral regurgitation (n=2), rheumatic mitral stenosis (n=3), old myocardial infarction without angina pectoris (n=8), and angina pectoris (n=3).

The procedure:

In view of the experimental nature of the procedure, informed consent was obtained from all patients undergoing the study. After premedication with oral diazepam (10 mg), the patients were transported to the cardiac catheterization laboratory. Routine cardiac catheterization was performed by standard techniques using an 8 French sheath in the right femoral artery. For the current procedure, the sheath was exchanged for that of a 9 French sheath. The patients then received 5,000 U intravenous heparin and 50 mg intravenous lidocaine. A guiding balloon catheter and fiberscope were introduced into the left ventricle by the method described above. The balloon was inflated and saline warmed to body temperature was infused by a power injector through the end hole of the guiding catheter. It was predetermined that 3–4 atmospheres of proximal pressure were required to maintain a distal saline flush rate of 5 ml per second. A maximum of 30 ml of fluid was used during each examination to displace the blood located between the expanded balloon and the endocardium. The images were recorded on either 16 mm color cinefilm at 16 or 25 frames per second and/or 1 inch video tape. After each examination, contrast medium (Urographin 76) was injected through the guiding balloon catheter in order to document the site of inspection (Figs. 1A and 2A).

RESULTS

1. Patients without Obvious Myocardial Disease (chest pain syndrome and ASD)

As a normal control, Fig. 1A shows selected frames from the ventriculogram of a patient with chest pain syndrome of uncertain etiology. Figure 1B

Table I. Cardioscopic Features of Left

	Chest pain	ASD	DCM
No. of patients	4	1	5
No. of observed LV segments per patient	2-4	1	2-5
Total No. of segments examined	14	1	22
Endocardium			
brown	12*	1	3
light brown	2		3
white			12
white and brown or reddish-brown in mosaic			2
light yellow			2
rose			
reddish-brown			
red			
Trabecula			
thin			5
thick			
Bleeding			
Thrombi			1
Neovascularization			
Chorda white	3		
LVDDVI (ml/m ²)	76±8		168±20
LVESVI (ml/m ²)	30±3		122±23
EF (mean±SE)	0.6±0.09		0.28±0.05
Time from onset of symptoms (months)	2.4±0.3	no symptom	19.4 ±7.8

ASD=atrial septal defect; DCM=idiopathic dilated cardiomyopathy; AM=idiopathic acute myocarditis; AR=rheumatic aortic regurgitation; ASR=rheumatic aortic steno-regurgitation; MS=rheumatic mitral stenosis; MR=rheumatic mitral regurgitation; OMI=old myocardial

shows cardioscopic images from this same patient. These are typical observations from all patients with this syndrome presenting attacks of chest pain and exercise induced depression of the ST segment of the electrocardiogram without significant coronary stenosis and inducible coronary vasospasm. In patients in this category, the endocardium from the apical to basal segments was brown in color due to ergonovine (Table I). In the apical, inferior and lateral segments, the trabeculae were prominent, forming networks, and they became more prominent during systole (B and D in Fig. 1B).

Ventricle in Patients with Heart Disease

Diseases					
AM	AR, ASR	MS	MR	OMI	AP
4	5	3	2	8	3
2-4	1-2	1-2	1-2	2-4	1-2
11	8	6	3	24	4
	3	2	2	6	2
4	2	1		4	1
	2	1		12	1
	1	2	1		
1					
2				2†	
4					
3					
	4				
2					1
2				2	
				2	
				1	
130±27	189±29	68±10	128±20	99±10	71±9
64±20	63±7	34±7	54±9	59±4	34±5
0.52±0.07	0.58±0.16	0.5±0.1	0.59±0.1	0.41±0.1	0.52±0.0
1.0 ±0.4	4.8 ±1.0	6.0±0.9	7.1 ±2.2	0.9 ±0.2	2.8 ±0.7

infarction; AP=angina pectoris.

* Number of segments which showed changes/number of segments examined. † Border zone between ventriculographically hypo- to dyskinetic segments and normal segments.

The trabeculae in the posterior and septal portions were different from these segments in that they were low and their contraction during systole was not prominent. The chordae connected to the posterior leaflet of the mitral valve, also observed in the 3 patients with chest pain syndrome, were white and reflected the scope's illuminations (Fig. 1C). They were stretched during systole and were somewhat relaxed during diastole.

In the patient with ASD, the left ventricular endocardium could be observed by introducing the same balloon catheter and fiberscope through

Fig. 1A. T.T. 51-year-old female. Chest pain syndrome. Left ventriculogram at a right anterior oblique projection at end-diastole (A), end-systole (B) and during cardioscopic observation (C). Arrow: guiding balloon catheter.

the femoral vein, across the ASD and then across the mitral valve. Similar to those in patients with chest pain syndrome, the endocardium was brown. The endocardium was examined with a segment by segment analysis, since the visual field obtained by a single observation was small, namely 0.5 to 1 cm in diameter.

2. Patients with Idiopathic Dilated Cardiomyopathy

The left ventricular endocardium was observed in all 5 patients with idiopathic dilated cardiomyopathy. In 3 of these patients, the endocardium was white or light yellow in color. The trabeculae were thin and stretched, and contraction was not observed (Figs. 2A and 2B and Table I). In 1 patient, the apical segment was light brown and the inferior segment was white. In this patient, the light brown segment contracted vigorously while the white segment scarcely contracted. In the remaining patient, the apical portion was white or reddish-brown while the lateral portion was white or brown in mosaic fashion. No obvious relationship was observable between endocardial changes and subjective symptoms in this small number of patients.

3. Patients with Idiopathic Acute Myocarditis

When cardioscopy was performed 15 to 60 days after the onset of subjective symptoms, the endocardium was white or reddish-brown in 2 pa-

Fig. 1B. The same patient as in Fig. 1A. Cardioscopic features of the apical segment of the left ventricle during diastole (A) and systole (B), and inferior segment during diastole (C) and systole (D). The endocardial surface was brown in color. Small black spots which are visible in this and in other figures are due to fractures of the glass fibers of the fiberscope.

tients with acute myocarditis (Fig. 3). In a third patient, cardioscopy performed 30 days after the onset of symptoms revealed that the endocardium of the apical and posterior segments was red in color. Moreover, bleeding and thrombi were scattered on the lateral and posterior segments (Fig. 4 and Table I). The blood was ejected from the wall into the lumen during systole. The thrombi were streamer-like and fluttered synchronously with each cardiac beat. In a fourth patient whose endocardium was rose colored, thrombi attached to the apical segment could be observed (Fig. 4).

4. Patients with Valvular Disease

The endocardium was brown and the trabeculae were thick and became prominent during systole in 2 patients with aortic regurgitation. In

Fig. 1C. The same patient as in Fig. 1A. A: cardioscopic features of the chordae connected to the posterior papillary muscle (arrow). B: closer observation of the same chordae. Arrows: chordae.

Fig. 2A. S.M. 64-year-old female. Idiopathic dilated cardiomyopathy. Left ventriculograms at end-diastole (A), end-systole (B) and during cardioscopic observation (C). Arrow: guiding balloon catheter.

2 patients with rheumatic mitral stenosis the endocardium was brown in color with scattered white patches (Fig. 5 and Table I). Also, white patches were scattered on the luminal surface in 1 patient with rheumatic mitral regurgitation (Fig. 6 and Table I).

5. Patients with Ischemic Heart Disease

The endocardium of infarct sites at least 30 days old were examined

Fig. 2B. The same patient as in Fig. 2A. Cardioscopic features of the lateral segments of the left ventricle during diastole (A) and systole (B), and posterior segment during diastole (C) and systole (D). Both segments were light yellow in color.

in 8 patients. All sites except 1, either akinetic or dyskinetic, appeared white by cardioscopy (Fig. 7). Non-infarcted segments in the same patients were usually brown in color. In 2 patients the border zones of infarcted and non-infarcted segments were hyperemic (Fig. 8). In 2 patients yellow mural thrombi with small vessels on them were detected. The thrombi were not identified by echocardiography or cineventriculography. In patients with angina pectoris, the endocardium was brown or light brown in color (Fig. 9).

6. Complications

In a patient with chest pain syndrome, a small amount of endocardial bleeding was observed at the portion where the balloon was placed. We induced ventricular arrhythmias such as ventricular premature beats and/or

Fig. 3. O.H. 50-year-old male. Acute myocarditis (20 days after onset). A: apical segment. The trabeculae were white and thin (white arrow) and the portions between the trabeculae were reddish-brown. Black arrow: catheter tip. B: inferior segment. Black arrow: reddish-brown portion.

Fig. 4. A: A.I. 48-year-old female. Acute myocarditis (30 days after onset). Red endocardial surface and multiple bleeding points (arrows) in the inferior segment of the left ventricle during systole. B: K.Y. 50-year-old male. Acute myocarditis (60 days after the onset of subjective symptoms). Apical segment during systole. Endocardium was rose in color, and thrombus was observed (arrow).

short runs of ventricular tachycardia in all examinations on pushing the balloon against the endocardium. However, they subsided spontaneously within a few seconds although the balloon remained pushed against the targeted segment. These arrhythmias occurred upon infusion of saline in

Fig. 5. Y.K. 70-year-old female. Rheumatic mitral stenosis. Apical portion of the left ventricle during diastole (A) and systole (B). Arrows: scattered white patches.

a few patients. In these patients, the targeted segment was changed or saline flush rate was reduced, with resultant disappearance of the arrhythmias. Balloon rupture did not occur in any of the patients. The amount of saline required for completion of one observation ranged from 20 to 30 ml and the observation time ranged from 3 to 8 sec. The total amount of saline infused ranged from 350 to 550 ml. However, no signs or symptoms indicating congestive heart failure occurred in any of the patients during the stay in the catheterization laboratory. Since left ventricular end-diastolic pressure was not measured during or immediately after observation it was unclear how much left ventricular end-diastolic pressure rose. Furosemide (20 mg) was injected intravenously in all of the patients with valvular disease and dilated cardiomyopathy. Congestive heart failure did not occur in any patient after their departure from the cardiac catheterization laboratory.

DISCUSSION

In 1956, Sakakibara et al were the first to observe the interior of the heart using a rigid cardioscope during open heart surgery in patients with atrial septal defect.¹¹⁾ More recently, these investigators have also observed native aortic valves during aortic valve replacement.¹²⁾ Subsequently, intraoperative observations of the vessels have been performed by many phy-

Fig. 6. K.M. 58-year-old male. Rheumatic mitral stenosis. Apical segment during diastole (C) and systole (D). Arrows: catheter tip. Apical segment was white and inferior segment was light brown in color.

sicians using rigid or flexible angioscopes.^{13),14)}

Recent advances in fiberscope technology enable us to observe percutaneously not only peripheral vessels but also coronary and pulmonary arteries.¹⁾⁻¹⁰⁾ However, percutaneous cardioscopy has not been pursued due to a lack of an effective method to displace the blood. The results in this study show that a guiding catheter with an inflatable balloon at the tip is effective in displacing the blood between the endocardium and the balloon to allow examinations. In addition, cardioscopy is useful for documentation of the pathological changes examined in this study; the left ventricular endocardial surface was brown in color and the trabeculae became prominent and the chordae were stretched during systole. In anesthetized dogs, the endocardial surface is also brown in color.^{9),15)} Also, the endocardial surface in autopsied human cases without heart disease is brown in color. Since organic changes were not demonstrated in this study, the brown color of the

Fig. 7. T.O. 53-year-old male. Old myocardial infarction. Posterior segment of the left ventricle with angiographically normal contraction (A) and akinetic inferior segment (B). Posterior segment was brown and inferior wall was white in color.

Fig. 8. H.K. 45-year-old male. Old myocardial infarction. Hyperemic lateral segment and chordae (arrow) during diastole (A) and systole (B). Posterior segment was brown and inferior wall was white in color.

Fig. 9. S.K. 59-year-old male. Old myocardial infarction. A: light brown posterior segment during systole. This segment contracted normally angiographically. B: white dyskinetic inferior segment during systole. C: yellow thrombi with newly developed vessels (arrows) in the inferior segment during systole.

endocardium in patients with chest pain syndrome in this study was considered to be almost a normal control. In contrast to these patients, the endocardial surface was white or light yellow in 3 patients with dilated cardiomyopathy. In 2 of these patients, endomyocardial fibroelastosis was demonstrated by biopsy. Therefore, white or light yellow coloration can be used as an indicator of fibrosis. This is also supported by the fact that the endocardial surface is frequently white in autopsied cases with dilated cardiomyopathy.¹⁶⁾ In other patients with dilated cardiomyopathy, the endocardium was light brown or brown and biopsy revealed that the endocardium was not fibrotic.

Although there was no obvious relation between endocardial coloration and left ventricular function or time from onset of subjective symptoms, the differences in endocardial coloration may be due to the difference in stage or magnitude of endocardial and/or subendocardial tissue involvement. In this study, patients with ventriculographically demonstrated mild to moderate impairment were used, since routine cardiac catheterization and angiography themselves or volume overload during cardioscopy might result in congestive heart failure. Therefore, it remains to be clarified whether the cardioscopic features observed in this study are also common to severely impaired patients. The endocardial surface was reddish-brown, rose or red in patients with acute myocarditis who underwent cardioscopy 15 to 60 days after the onset of subjective symptoms. In 2 patients whose endocardial surface was red or rose, mononuclear cell infiltrations and myocardial degeneration without fibrosis, indicating acute inflammation, were revealed by biopsy. Therefore, red or rose endocardium may indicate acute inflamma-

tion. In 1 patient with acute myocarditis, multiple small thrombi and spotty bleeding were observed. Since such changes were not observed in other patients, it is likely that these changes were induced by endomyocarditis and not by balloon manipulation. In patients with rheumatic aortic regurgitation, the trabeculae were thick, probably due to volume and/or pressure loads. In patients with rheumatic mitral stenosis or mitral regurgitation, white patches were scattered on the endocardial surface, or the endocardium was white. It is likely that these changes indicate fibrosis after endocarditis. In patients with mural thrombi, the thrombi did not disappear on flushing with saline and no symptoms suggesting systemic embolism were observable. Therefore, the thrombi may have been firmly attached to the luminal surface. Although thrombo-embolism did not occur in these patients, this fact does not mean that cardioscopy of thrombi does not cause detachment of thrombi and subsequent embolism, especially in cases of fresh thrombi which are usually loosely attached to the luminal surface. Therefore, careful manipulation of the fiberscope and guiding catheter is recommended. In patients with old myocardial infarction, the endocardial surface of the segment with impaired contraction frequently showed white coloration. It is likely that this change also indicated fibrosis. In 2 patients, the border zone between the infarcted and non-infarcted segments was hyperemic, suggesting development of subendocardial collaterals from non-ischemic to ischemic segments. Yellow thrombi and small vessels on the thrombi could be detected in the infarcted segment. It is likely that the vessels developed after formation of the thrombi. They were not identified by echocardiography and ventriculography. This fact suggests that cardioscopy is feasible for detection of thrombi and neovascularization.

In this study, the fiberscope could not be directed to the high segment of the anterior wall and septum. Also, it was sometimes necessary to change the catheter to observe different segments. Therefore, development of a new balloon catheter with a tip deflector which enables the catheter tip to be directed toward the desired portion is necessary. Ventricular arrhythmias occurred on pushing the balloon catheter against the wall in all patients. However, they disappeared spontaneously within a few seconds although the balloon remained pushed against the endocardial surface. Therefore, endocardial motion synchronous to the cardiac beat could be observed undisturbed by the ventricular arrhythmias. In this study, endocardial motion was expressed semiquantitatively since a method of cardioscopic calibration has not been established. Endocardial damage attributable to manipulation of the balloon catheter or fiberscope was not observed in the majority of patients. Moreover, although up to 550 ml of saline were in-

fused to replace blood, congestive heart failure was not induced, or was prevented by furosemide administration. This cardioscopic method has other potentials such as use as a guiding tool for percutaneous endomyocardial biopsy and percutaneous cardiac surgery.¹⁷⁾ Further examinations using many patients are required to clarify whether there are any relationships between cardioscopic features and left ventricular function or clinical course, and whether percutaneous cardioscopy can create a new method to diagnose heart disease or improve therapeutic decision making.

We conclude that percutaneous cardioscopy using a guiding balloon catheter is a safe method for direct visual observation of the left ventricle, at least in patients who can undergo routine cardiac catheterization and angiography. It allows observation of pathological changes and contraction relaxation sequences, although only semiquantitatively at present, from inside the left ventricle.

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