Arch. Jap. Chir. 40 (1), 15~27, May 1971

Clinical Studies of Selective Cine Coronary Arteriography and Surgical Revascularization of Ischemic Myocardium

BY

OSAMU SHIRAI

The 2nd Surgical Division, Kyoto University Medical School
(Director : Prof. Dr. CHUJI KIMURA)

Received for Publication Apr. 15, 1971

Part 1 Selective Coronary Cine Arteriography

I. Introduction

The management of the patients with ischemic heart disease has presented one of the most difficult problems in clinical medicine in the recent past. The ischemic heart disease can be defined as a variety of disorders characterized by the undoubted presence of angina pectoris or myocardial infarction, or both.

The most common cause of ischemic heart disease is believed to be atherosclerosis. Hypertensive disease, rheumatic heart disease with aortic stenosis or insufficiency, and luetic heart disease with coronary osteal stenosis may also be implicated.

Pathophysiologically, anginal pain is generally produced by myocardial ischemia when the coronary blood flow fails to meet the myocardial oxygen demand. The coronary flow is under the control of many mechanical, metabolic, and neurohumoral factors. Any increase in myocardial mass or significant obstruction of the coronary artery may upset these regulatory mechanisms and be responsible for myocardial ischemia.

However, exact mechanism responsible for anginal pain remains to be solved.

For the diagnosis of ischemic heart disease, the careful inquiry of symptoms and analysis of electrocardiographic changes still deserve their orginal values. Recently, the technique of coronary arteriography has been developed rapidly by many investigators to visualize accurate location and grade of coronary artery obstruction.

This study was undertaken to evaluate the clinical application of coronary arteriography.

II. History of the development of coronary arteriography

The pathological studies of SCHLESINGER[1] revealed that most zones of coronary occlusion were less than five millimeters in length and within three centimeters

from the orifice of the main vessels.

In 1933, ROUSTHÖI[2] for the first time demonstrated the coronary arteries of the experimental animals by direct puncture of the ascending aorta from back and by catheterization of systemic artery.

Since then, much efforts have been devoted for better coronary visualization.

In 1945, RADNER[3] used the sternal aortic puncture method on 4 patients to get very faint visualization of the coronary artery. GUGLIELMO[4] injected radiopaque material through a catheter placed in the ascending aorta. In his series, however, the coronary artery could not be visualized in approximately one third of patients due to the uncertainties in filling of the coronary cusps by means of the flushing technique.

Many modifications have been added to GUGLIELMO's method to overcome this difficulty. DOTTER and FRISCHE[5] employed baloon occlusion of the ascending aorta to retard flushing out of contrast medium. ARNULF[6] induced bradycardia or cardiac arrest with the administration of acetylcholine. THAL[7] applied timed diastolic injections by means of phase selector. A looped polyethylene catheter was designed by WILLIAM[8] in 1960, aiming to flush the aortic sinus so that a high proportion of the medium might perfuse the coronary artery.

NORDERSTÖM[9] expected to obtain good opacification of coronary artery under increased intrabronchial pressure when contrast medium was injected into aortic root. He could decrease aortic systolic blood pressure to about 70mmHg under intrabronchial pressure of 40mmH_2O.

These methods were so often far from what they thought to be satisfactory.

In 1958, SONES[10] initiated selective catheterization of the coronary artery via right brachial artery by means of cinefluorography with the image intensifier. In this method, the special catheter tapered in its distal end allowed coronary artery to be constantly perfused with the blood during the procedure. Selective catheterization of the coronary artery is particularly useful for cinefluorographic demonstration of the coronary arteries with multiple small manual injections of contrast medium. SONES suggested that distal radicles of the coronary artery tree as small as 100 microns in diameter might be routinely demonstrated with his selective coronary arteriography.

RICKETTS[11] and AMPLATZ[12] modified SONES's technique by adapting percutaneous puncture of femoral artery instead of arteriotomy in brachial artery.

In this study, SONES's technique was adopted for reason why the tip of catheter could not be manipulated so easily with femoral approach as with brachial approach.

III. Materials and methods

Siemens fluorographic apparatus and Arriflex 35mm cinecamera were used for this study (Figure 1).

The 80cm long Sones's catheters ranging in size 6.5F to 8F were employed. This thin-walled, radiopaque, woven-dacron catheter tapers in its distal 5cm to size 5F, and has an end-hole as well as four side holes in its distal 1cm.

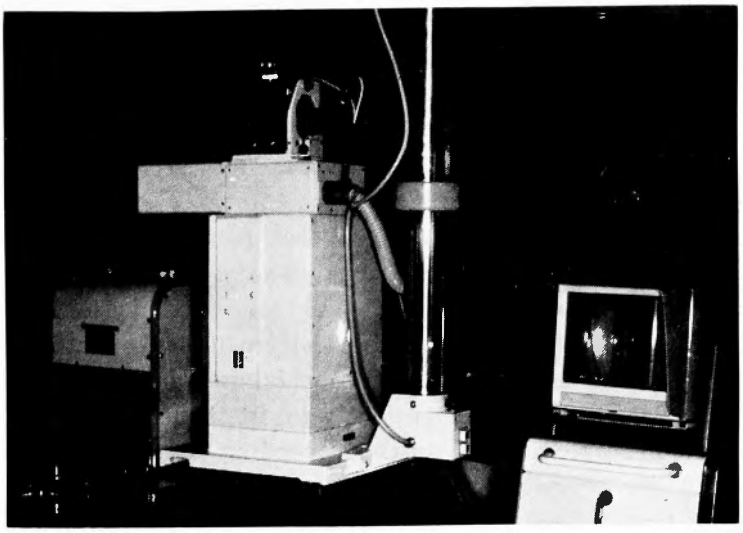

Fig. 1 Siemens fluoroscopic apparatus and 35mm Arriflex cinecamera.

The catheter is attached by interposition of rotating adaptor to three stopcocks to which a 20cc syringe for contrast medium injection, a tubing to contrast medium reservoir, a 50cc syringe for flushing catheter and a tubing to pressure transducer are connected. This 50cc syringe is filled with physiological saline containing 10mg of Heparin per 100cc. This arrangement permits continuous monitoring of aortic pressure at the tip of the catheter except periods of contrast medium or physiological saline injection (Figure 2).

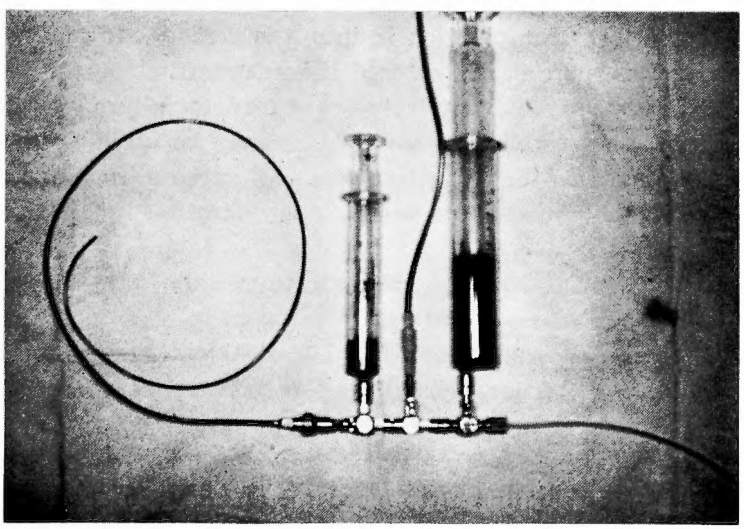

Fig. 2 Diagram of the stopcock and transducer system used for coronary arteriography.

The arteriograms are filmed with a 35mm cinecamera at the speed of 80 frames per second through 10 inch or 6 inch image intensifier. Thirty five mm double X

cinefilm is used. The contrast medium employed are 80% Conraxin H and 80% Angioconray.

Fifty mg of Pethilorfan is routinely administered 30 minutes prior to selective coronary arteriography

The basic technique adopted is that of SONES with slight modification. Four limbs electrodes are connected for continuous oscilloscopic monitoring of the electrocardiogram. Under local anaesthesia with 2% Xylocain, a longitudinal 3cm long incision is made in the right antecubital fossa. The right brachial artery is exposed for about 2cm. Arteriotomy is made by a small transverse incision, which is slightly spread with mosquito's forceps to facilitate the introduction of the catheter.

Ten mg of Heparin is injected to distal brachial artery to minimize the incidence of arterial thrombosis. The catheter is gently inserted into the arterial lumen and advanced under fluoroscopic control to the ascending aorta. Ten mg of Heparin is again injected into the ascending aorta.

The patient is then turned into the left anterior oblique position. In this position the heart usually clears the most of spine. The origins of right and left coronary arteries are almost tangential to the projected image of the ascending aorta.

Gentle advancement of the catheter curves the tip into J-shape. Intermittent injections of 1 to 2cc of contrast medium, identify the position of the catheter and visualize the ostium of coronary artery. The catheter is then manipulated until the tip enters the ostium of the coronary artery.

It is important to advance no more than 1cm into the coronary artery to avoid wedging of the artery. Evidence of complete wedging is recognized by damping of the monitoring pressure.

For right coronary catheterization, the catheter is manipulated into the right aortic sinus. For the left, manipulation is into the left aortic sinus. Usually the right coronary artery is more easily entered than the left.

Sclerotic and tortuous subclavian artery may lead to failure to catheterize the coronary artery. But the injection in aortic sinus may be utilized in the hopes of successful opacification. During manipulation, the catheter may occasionally slip through the aortic valve into the left ventricle as indicated by ventricular pressure curve.

With manual injection of 7 to 10cc of contrast medium, the course of coronary artery can be visualized. Cine arteriography is taken in deep inspiration to remove the diaphragmatic shadows from the heart. For complete study, multiple injections of contrast medium are sometimes carried out in each coronary artery and a total of 70 to 150cc of contrast medium is employed as an average dosage.

After completion of the procedure, the catheter is removed and brachial artery proximal to the incision was allowed to bleed for a second in order to flush out any clots. The arteriotomy was closed with the silk initially, but with the 6-0 Tevdek in the recent series. If the pulsation of the brachial artery is confirmed, the skin is closed with silk.

IV. Indication and Contraindication

Although there are many controversies on the indication, coronary arteriography is believed to be indicated in the following patients;

1) In spite of normal resting and exercise electrocardiograms, the patient is clinically suspected to have ischemic heart disease.

2) The patient with clinically established ischemic heart disease is considered as a candidate for surgery of coronary revascularization.

3) The patient with aortic valvular disease is suspected to have anginal pain associated with coronary artery disease.

4) The patient with congenital heart disease is suspected of abnormal distribution of the coronary artery.

5) The patient with electrocardiograms suggesting ischemic heart disease is required to differentiate from some type of myocardial disease.

6) The patient is suspected of coronary arteriovenous fistula.

Severe refractory congestive heart failure, insufficient cardiopulmonary reserve, uncontrolled atrial or ventricular tachycardia, complete heart block, and associated uncurable diseases are believed to be contraindication.

Angina decubitus is not considered as contraindication.

It seems reasonable to require a waiting period of several months after acute myocardial infarction that is severe enough to cause changes in the electrocardiogram and blood enzymes. Nevertheless, coronary arteriography has been performed in a patient within 4 weeks after acute myocardial infarction without any difficulty in this study.

V. Result

A total of 52 patients, 44 men and 8 women ranging in age from 14 to 63 years old, has been studied by selective coronary arteriography during past 3 years (Table 1).

Good coronary opacifications were achieved in 47 right coronary arteries (90.4%) and 46 left coronary arteries (88.7%). In the last 25 patients, 25 right coronary arteries (100%) and 24 left coronary arteries (96.0%) were opacified successfully.

Photographs printed from frame of cine films are showed in Figures 3 and 4. Figure 3 shows normal coronary arteriographic pattern. Figure 4 shows the occlusion in distal half of anterior descending artery.

Table 1

Selective Cine Coronary Arteriography

Disease	No. of patients
angina pectoris	27
myocardial infarction	11
coronary arteriovenous fistula	2
suspected myocardiopathy	2
mitral valve disease	3
atrial septal defect	2
aortic valve disease	1
others	4
Total	52

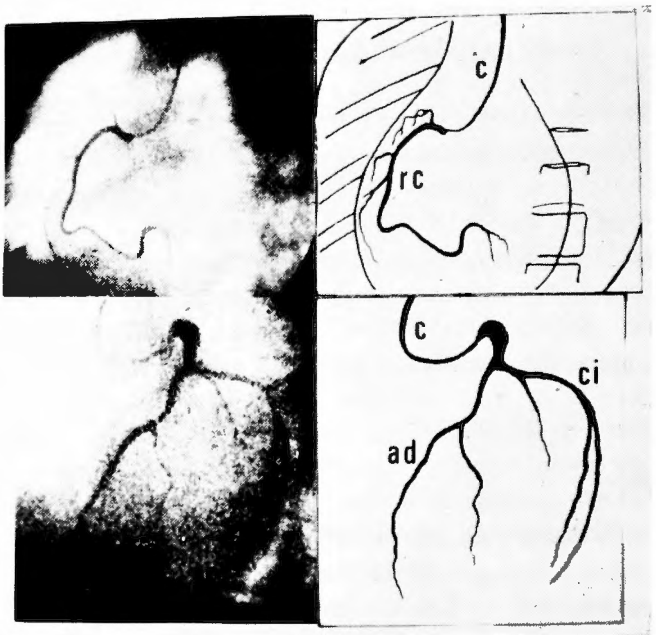

Fig. 3 Normal right and left coronary arteries in left anterior oblique position.

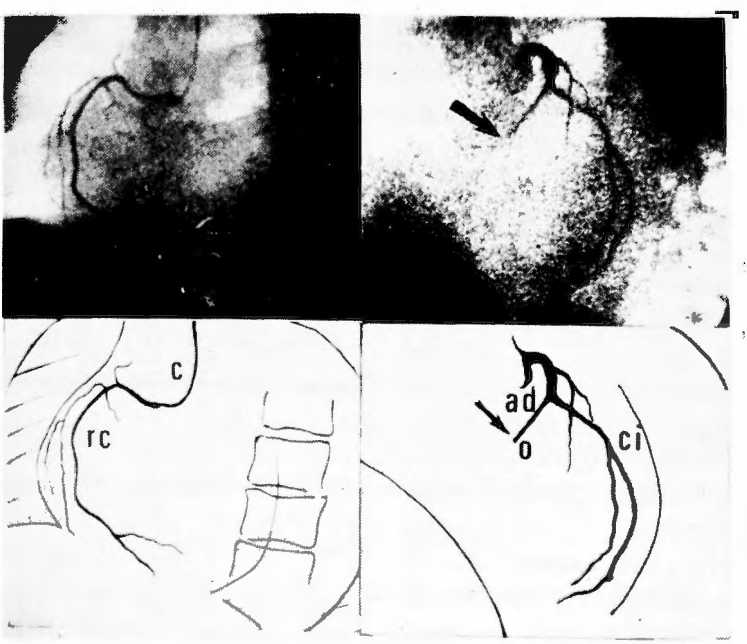

Fig. 4 Single frame from the coronary arteriography of a patient with typical angina. The arrow marks the severe obstruction in distal part of anterior descending artery.

At the injection of contrast medium into coronary artery, momentary QRS and T wave changes were observed in almost all patients. Typical QRS changes consist of left axis shifts at left coronary injection and right axis shifts at right coronary injection. The inversion of T wave at right coronary injection and its elevation at left coronary injection were routinely observed.

Such changes returned to previous electrocardiogram after persistence of 30 to 120 seconds without any accompanying symptom. Whenever typical T wave changes were observed at the injection of contrast medium, good coronary opacifications were routinely obtained in this study.

Momentary bradycardia was recognized rather frequently at right and left coronary injections. This bradycardia was observed in 14 of 19 patients at right coronary injection and 15 of 19 patients at left coronary injection. Asystole lasting four to six seconds has occurred in four patients at the left coronary injection and none has required treatment. Short runs of ventricular tachycardia lasting 10 beats were observed in two patients. One of them occurred at right coronary injection and another at left coronary injection (Figure 5).

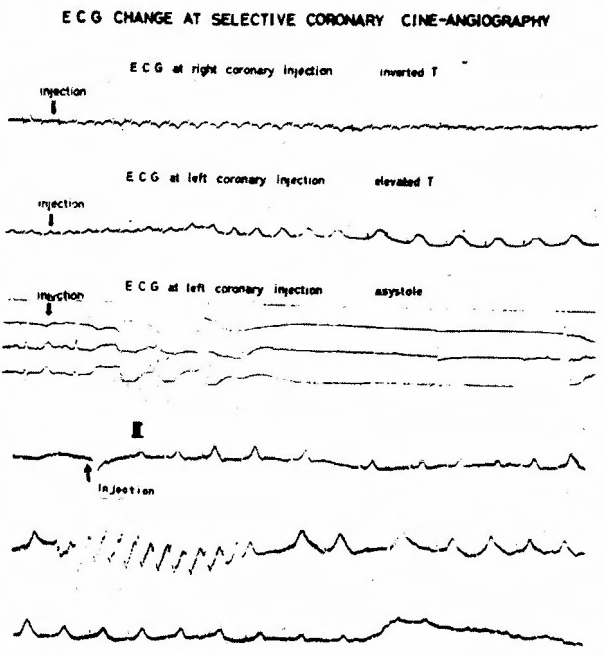

Fig. 5

The attacks of anginal pain and nausea at the injection have occurred in 5 patients. These attacks occurred more frequently in the patient with advanced coronary artery disease. These episodes have been relieved upon the administration of Nitrol and inhalation of the oxygen, and the studies were continued without any interruption.

The radial pulse was lost in 3 patients whose arteriotomies were closed with the silk. Collateral circulations were adequate to prevent loss of tissue in these cases, and all of them remained asymptomatic.

Urticaria was observed in 3 patients, but disappeared spontaneously without any subsequent treatment.

Ventricular fibrillation or the dissection of the wall of coronary artery as result of the direct injection of contrast medium has not been experienced.

The character of anginal pain, electrocardiographic changes and coronary arteriographic findings in 24 patients with suspected angina pectoris are summarized in Table 2.

Table 2

Correlation of Chest Pain and Electrocardiographic Changes with Coronary Arteriography in 24 Patients with Angina Pectoris

Case No.	Age Sex	Chest Pain	Electrocardiogram		Arteriography			
			Rest	Postexercise	RCA	LMCA	ADA	LCA
1	51M	typical	ST depression	further ST depression	1	1	2	3
2	41M	typical	ST depression	further ST depression	0	1	3	1
3	56F	typical	ST depression inverted T	ST depression inverted T	1	1	2	2
4	36F	atypical	ST depression	further ST depression	1	0	2	2
5	53M	typical	normal	ST depression	1	1	2	3
6	50M	typical	flat T	flat T	1	0	1	3
7	45M	atypical	normal	ST depression	0	0	2	1
8	40M	typical	ST depression	further ST depression	0	1	2	2
9	60M	typical	inverted T	inverted T	0	1	3	1
10	41M	typical	normal	normal	0	0	3	0
11	44M	typical	ST depression	further ST depression	0	1	3	3
12	46M	typical	ST depression	further ST depression	0	0	3	1
13	56M	atypical	ST depression	further ST depression	0	0	1	0
14	38M	typical	normal	normal	2	0	2	1
15	51M	typical	normal	ST depression	0	1	2	2
16	54M	typical	ST depression	further ST depression Extrasystole	0	0	2	0
17	52M	atypical	normal	ST depression	0	0	1	1
18	63M	typical	ST elevation	ST elevation	3	0	2	1
19	29F	atypical	ST depression	further ST depression	0	0	2	1
20	42F	typical	normal	Extrasystole	0	0	2	0
21	57M	typical	ST elevation	ST elevation	1	1	2	1
22	30M	typical	normal	Extrasystole	0	0	2	1
23	51F	atypical	inverted T	inverted T	0	1	3	1
24	57M	typical	ST elevation inverted T	ST elevation inverted T	2	1	3	2

RCA = right coronary artery
LMCA = left main coronary artery
ADA = anterior descending artery
LCA = left circumflex artery

0 = normally patent
1 = less than 50% luminal obstruction
2 = from 50% to 75% luminal obstruction
3 = more than 75% luminal obstruction

In 22 of 24 patients, single or multiple obstructions of more than 50% in diameter of coronary artery were observed. Seven of 24 patients with angina pectoris showed normal resting electrocardiograms. However, exercise electrocardiograms showed abnormal findings in 22 patients and was normal in only 2 patients. Of 18 patients with typical pain, 9 patients were recognized coronary obstruction of more than 75% in diameter. In only one of 6 patients with atypical pain, obstruction of more than 75% was observed. This fact suggests that obstructive change of coronary artery tends to be more severe in the patient with typical pain than with atypical pain.

Correlation of electrocardiographic diagnosis and arteriographic findings in the patients with myocardial infarction are showed in Table 3.

Table 3

Correlation of Electrocardiographic and Arteriographic Location in 11 Patients with Myocardial Infarction

Case No.	Age Sex	Electrocardiographic Location	Arteriography				Correlation
			RCA	LMCA	ADA	LCA	
1	44M	DMI	3	2	3	3	+
2	33M	AMI	0	0	0	3	−
3	38M	AMI	1	1	3	1	+
4	35M	AMI	3	1	1	3	+
5	56M	DMI, PMI	3	2	2	3	±
6	51M	AMI	3	2	3	2	−
7	38M	PMI	0	0	1	2	+
8	42M	PMI	0	1	2	3	+
9	49M	AMI	3	1	3	1	+
10	31M	AMI	0	0	3	1	+
11	25M	PMI	0	0	0	3	+

AMI=Anterior myocardial infarction
PMI=Posterior myocardial infarction
DMI=Diaphragmatic myocardial infarction

The obstruction of more than 75% in diameter was more common in the patient with myocardial infarction than in the patient with angina pectoris.

The area of ischemic myocardium suggested by the electrocardiographic changes was not always correlated to the site of the obstructive lesions of the coronary artery.

Of 11 patients with myocardial infarction, 8 patients had definite correlation between electrocardiogram and arteriogram. In other 3 patients, such correlation could not be confirmed.

The obstructive changes were most frequently recognized in left anterior descending artery which was followed in order of incidence by left circumflex, left main, and right coronary artery. The right coronary artery was least involved. Severe obstruction, however, was observed in each artery in the frequency of following order; anterior descending, left circumflex, right, and left main coronary artery (Table 4).

Table 4

Location and Degree of Obstructed Coronary Branches in 35 Patients with Ischemic Heart Disease

Degree of Obstruction	Coronary Branches			
	RCA	LMCA	ADA	LCA
more than 25% in diameter	15/35	18/35	34/35	31/35
more than 50% in diameter	8/35	3/35	28/35	17/35
more than 75% in diameter	6/35	0/35	12/35	10/35

Thus it appears that anterior descending artery is involved in nearly all patients, and that ischemic heart disease is rarely symptomatic when single coronary branch is involved.

Among these 35 patients with obstructive coronary disease, surgical procedures were performed in 20 patients, including 15 patients with frequent anginal pain and 5 patients with previous myocardial infarction.

VI. Discussion

1. Electrocardiographic changes following the injection of contrast medium

Momentary T wave changes described by Ross[15] and Hale[16] were most commonly observed at the injection of contrast medium into coronary artery. These T wave changes were its inversion at the injection into right coronary artery and its elevation at the injection into left coronary artery.

Right and left axis shifts at the injection were observed in almost all patients. Maytin[22] recognized that left axis shifts at left coronary injection were more significant than right axis shifts at right coronary injection.

Sewell[19] reported that momentary bradycardia were more frequently observed at right coronary injection than at left coronary injection. In this study, however, there was no difference in the incidence of bradycardia between right and left coronary injection.

McAlpin[17] supposed that electrocardiographic changes accompanied by selective injection into one coronary artery might be the result of differences in potential between area of myocardium perfused with contrast medium and area containing no contrast medium.

Gensini[18] suggested that electrocardiographic changes might be related to the high concentration of sodium in the contrast medium. He claimed that methylglucamin salts in the contrast medium which are weakly ionized produced less change than the more strongly ionized sodium salts and the contrast medium containing a high proportion of methylglucamin salts should be used for coronary arteriography. Conraxin H employed in this study contains a high proportion of methylglucamin salts.

2. Complication

A variety of complications was reported by each investigator. Sones[27] reported

that 9 deaths occurred in the performance of more than 11,200 diagnostic studies. He also described that ventricular fibrillation during the passage of contrast medium through the coronary artery occurred in 1.5 to 2 per cent of total patients studied and these were routinely overcome within 15 to 20 seconds by the application of direct current countershock of 300 to 400 watt seconds.

The dissections of the wall of coronary artery were occurred in four cases by SONES[27] and in one case by LEHMAN[20].

Thrombotic occlusions of brachial artery at the site of catheterization have occurred in 1 to 2 per cent in SONES's series. SEWELL[19] suggested that the radial pulse was lost in 2 of 8 patients whose brachial arteriotomy was closed with the silk, although it was lost in one of 23 arteriotomies closed with Merseline and in none of 119 arteriotomies closed with Tevdek.

PARKER[21] performed right thoracic sympathectomy in a patient complaining of coldness and marked intermittent claudication in his right hand and forearm. PARKER also reported a case of osteomyelitis of the fifth right metacarpal after brachial arteriotomy.

In this study, any significant complication was not observed except loss of the pulse in 3 patients.

3. Analysis of coronary arteriographic findings

Analysis of single frame obtained from cinefilm is generally unsatisfactory owing to the granular nature of the recording film. The cinefilm must be viewed in motion to compensate for the lack of the details in the individual frames.

Due to the different criteria proposed by different authors for the selection of patients, for the estimation of degree of coronary artery obstruction and for the clinical diagnosis of ischemic heart disease, it is needless to say that the result of this study can not be directly compared with others without any interpretation.

PROUDFIT[14] found more frequent involvement of right coronary artery as compared with this study. In his reports, the right coronary artery were involved in 457 (72.9%) of total 627 patients. GENSINI[23] reported that right coronary artery was more frequently involved than other two main branches. In this study, however, obstructive regions were most commonly found in anterior descending artery and right coronary artery was least involved. It is recognized by many investigators that coronary obstructive disease had commonly revealed as multiple involvement. PROUDFIT[13] reported that there were evidence of moderate to severe obstructions of one or more coronary branches in 194 (93.7%) of 207 patients with suspected angina pectoris. CAMPEAU[26] found that 96% of patients presumed not to have coronary insufficiency had no arteriographic evidence of significant obstructive coronary disease, whereas 80% of the patients complaining of typical angina had significant stenosis of one to three major coronary arteries. In this study, single or multiple regions to the extent of 50% obstruction or more were observed in 22 of 24 patients.

COHEN[24] indicated that nearly two thirds of the patients with normal resting electrocardiograms developed ST, T abnormalities with two step exercise test.

HULTGREN[25] insists that the degree of abnormality of the electrocardiographic exercise test could be related to the severity of coronary artery disease.

In this study, 7 of 24 patients with angina pectoris showed normal resting electrocardiograms. However, exercise electrocardiograms showed abnormal findings in 22 patients and was normal in only 2 patients.

VII. Summary

The study of selective cine coronary arteriography with SONES's technique afforded sufficient details of coronary trunks and major branches for evaluation of degree of obstructive changes.

In this study, the following conclusion was drawn.

1) Single or multiple obstruction of more than 50% in diameter of coronary artery were recognized in 22 of 24 patients with angina pectoris.

2) The obstructive changes were most frequently recognized in anterior descending artery which was followed in order of incidence by left circumflex, left main and right coronary artery.

3) The area of ischemic myocardium suggested by the electrocardiographic changes was not always correlated to the site of the obstructive lesion of the coronary artery.

Selective cine coronary arteriography is safe and reliable procedure for the diagnosis of ischemic heart disease, and moreover provides most useful information as to the selection of the candidate for myocardial revascularization.

References

1) Schlesinger and Blumgart: Studies on the relation of the clinical manifestations of angina pectoris, coronary thrombosis and myocardial infarction to the pathological findings. Amer. Heart. J., **19**: 1, 1940.
2) Rousthöi: Über Angiokardiographie. Vorläufige Mitteilung. Acta. Rodiol., **14**: 419, 1933.
3) Radner: An attempt at the roentgenologic visualization of the coronary blood vessels in man. Acta. Radiol., **26**: 497, 1945.
4) Guglielmo: A roentgenologic study of the coronary arteries in the living. Acta. Radiol., Suppl **97**, 1952.
5) Dotter: Visualization of coronary circulation by occlusion aortography; A practical method. Radiology. **71**: 502, 1958.
6) Arnulf: L'arteriographie methodique des arteres coronaires grâce a l' utilisation de l' acetylcholine; Donnees experimentales et cliniques. Bull. Acad. Nat. Med.. **142**: 661, 1958.
7) Thal: Arteriographic studies of the coronary arteries in ischemic heart disease. J. Amer. Med. Ass., **168**: 2104, 1958.
8) Williams: Coronary arteriography; II clinical experiences with the loop end catheter. New. Engl. J. Med., **268**: 328, 1960.
9) Nordenström: Coronary angiography in 100 cases of ischemic heart disease. Radiology. **78**: 714, 1962.
10) Sones: Cine-coronary arteriography. Mod. Conc. Cardiov. Dis., **31**: 735, 1962.
11) Ricketts: Percutaneous selective coronary cine arteriography. J. Amer. Med. Ass., **181**: 620, 1962.
12) Amplatz: Mechanics of selective coronary artery catheterization via femoral approach. Radiology. **89**: 1040, 1967.
13) Proudfit: Selective cine coronary arteriography; correlation with clinical findings in 1000 patients. Circulation. **33**: 901, 1966.

14) Proudfit: Distribution of arterial lesions demonstrated by selective cine coronary arteriography. Circulation. **36**: 54, 1967.
15) Ross: Clinical applications of coronary arteriography. Circulation. **27**: 107, 1963.
16) Hale: Technique and interpretation of selective coronary arteriography in man. Brit. Heart. J., **25**: 644, 1963.
17) MacAlpin: Electrocardiographic changes during selective coronary cinearteriography. Circulation. **34**: 627, 1966.
18) Gensini: myocardial toxity of contrast agents used in angiography. Radiology. **82**: 24, 1964.
19) Sewell: Coronary arteriography by Sones technique; technical considerations. Amer. J. Roentgen., **95**: 673, 1965.
20) Lehman: Selective coronary arteriography. Radiology. **83**: 846, 1964.
21) Parker: Selective coronary arteriography. Canad. Med. Ass. J., **94**: 425, 1966.
22) Maytin: The genesis of QRS changes produced by selective coronary arteriography. Circulation. **41**: 247, 1970.
23) Gensini: Coronary arteriography; Astudy of 100 cases with angiographically proved coronary artery disease. Dis. Chest. **54**; 10, 1968.
24) Cohen: Coronary heart disease; Clinical. cinearteriographic and metabolic correlations. Amer. J. Cardio.. **17**: 153, 1966.
25) Hultgren: A clinical evaluation of coronary arteriography. Amer. J. Med., **42**: 228, 1967.
26) Campeau: Clinical significance of selective coronary cinearteriography. Canad. Med. Ass. J., **99**: 1063, 1968.
27) Sones: Selective cine coronary arteriography in the dignosis and evaluation of medical and surgical treatment of coronary atherosclerosis. Nipp. Act. Radiol., **28**: 714, 1968.