EXPERIMENTAL STUDY ON THE SURGICAL TREATMENT FOR CORONARY INSUFFICIENCY

by

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INTRODUCTION

There have been three principal approaches to the surgical treatment for coronary insufficiency. (1) Thyroidectomy is performed in order to lower the body metabolism to reduce the work load of the heart. This is now accomplished chemically or surgically, but commonly associated with myxedema producing hypercholesteremia which unfortunately might cause the underlying arteriosclerosis to advance more rapidly. (2) Interruption of the nervous innervation of the heart, namely paravertebral alcohol injection, upper dorsal sympathectomy, pericoronary neurectomy etc.,[12)15)] are carried out for the relief of the anginal syndrome. However, these procedures afford only symptomatic relief from the pain of angina pectoris. (3) Revascularization of the ischemic myocardium are attempted by: (i) the production of adhesions between peri- and epicardium ;[13)31)] (ii) grafts, using omentum,[29)] lung,[10)16)21)] muscle,[3)] skin[38)] and pedicles from upper intestinal organs ;[22)] (iii) implantation of the internal mammary artery into the left ventricular myocardium ;[35)36)37)] (iv) ligation of the great cardiac vein[15)30)] or the coronary sinus ;[20)] (v) arterialization of the coronary sinus by insertion of the vein graft between sinus and aorta;[4)5)6)25)] (vi) ligation of both internal mammary arteries at the level of the second interspace,[1)2)17)] and (vii) a combination of some of the above mentioned procedures.

The third approach to the problem, revascularization of the ischemic myocardium, has seemed most attractive to us. At the present time, however, none of these surgical procedures has gained general acceptance. The surgical operation for coronary insufficiency should be especially simple as well as effective. The purpose of this study is to pick up some simpler methods designed for myocardial revascularization in order to determine which one is the most beneficial.

EXPERIMENT I

1. METHOD

Healthy mongrel dogs weighing about 10 kg were divided into the following six groups.

(i) No surgery

This group was used as the control group.

(ii) Pericardiotomy

The pericardium was widely opened parallel to the left phrenic nerve and then loosely closed after intrapericardial fluid was wiped away with gauze.

(iii) Cardio-pericardiopexy

Accoding to THOMPSON, 0.2 g of asbestos powder were applied to the surface of the heart after the pericardiotomy was done in the same manner as (ii).

(iv) Cardio-pneumonopexy without talc powder

Two longitudinal pericardial incisions, respectively, anterior and posterior to the left phrenic nerve about 2 cm apart were made. A portion of the middle lobe of the left lung was pulled in beneath the pericardial bridge and sutured in this position after de-epicardialization with 95 per cent phenol, but without application of talc powder.

(v) Cardio-pneumonopexy with talc powder

Exactly the same as (iv) except for the application of talc powder (HARKEN's Method).

(vi) BECK I Operation

Two pericardial incisions were made in the same manner as (iv). The lining of the parietal pericardium and the epicardium were abraded by a tooth brush. Powdered asbestos in amounts of 0.2 g was placed upon the heart. A ligature was placed around the coronary sinus just distal to its opening into the right auricle and then tied down on a stylet 2 mm in diameter. The stylet was removed to produce partial occlusion of the sinus. The pericardium was loosely closed. All available pericardial fat was brought into direct contact with the heart.

All operations were performed with sterile technique by the same team, under anesthesia with sodium pentobarbital and positive pressure breathing with 100 per cent oxygen through an endotracheal tube. Thoracotomy was done through the left fourth interspace immediately after induction of anesthesia. After the operation the chest wall was firmly closed with two layers suture and no drainage was practised. All animals received antibiotics postoperatively.

Three months later the animals were subjected to ligation of the circumflex branch of the left coronary artery. Thoracotomy was done in the same manner as previously. The pericardium was opened as little as possible and then the degree and extent of adhesions between the peri- and epicardium were checked. A SATINSKY clamp was used to make traction on the left auricular appendage for feasibility of subsequent procedures. The circumflex branch was isolated at its origin for a small distance and then ligated, taking care to include the uppermost small branches. For comparison, ligation of the anterior descending branch in the control series was also carried out.

In order to analyze possible benefits derived from each surgical procedure against the ligation test, subsequent examinations were performed. Control electrocardiographic tracings in lead III were taken with the left thorax uppermost before the thoracotomy and then changes of the electrocardiogram following the ligation were followed up at suitable intervals during a fifteen minute period. Lead III

was used for the reason that the infarct due to such a ligation is to be caused in the left posterior ventricular wall. Mortality study was also done. The surviving animals were killed a week or more after the operation. Post-mortem examination of the heart was carried out; each heart was removed en masse and sliced into several transverse sections to measure the size of infarct after it was ckecked to see whether the ligature had been placed in the proper place.

2. RESULTS

Seventy-five dogs were used for this experiment.

(1) *Mortality Study*

Table 1.-Mortalities Following the Circumflex-ligation Performed Three Months after the Foregoing Surgical Procedures.

Surgical approach	Survival	Immediate Death	Late Death	Total	Mortality (%)
Pericardiotomy	6	2	3	11	45.5
Cardio-pericardiopexy	6	2	2	10	40.0
Cardio-pneumonopexy (no application of talc powder	6	1	3	10	40.0
Cardio-pneumonopexy (application of talc powder)	6	1	3	10	40.0
Beck I Operation	8	2	0	10	20.0
No surgery	3	6	3	12	75.0
Mortality Following the Anterior Descending-Ligation					
No surgery	8	2	1	11	27.0

"Immediate Death" is used to indicate the dogs that died, soon after the ligation test, of ventricular fibrillation, and "Late Death" to indicate those that died on and after the day following the surgery.

In a series of Beck I Operation, as shown in Table 1, the lowest mortality following the circumflex-ligation, i. e., 20% (2 of the 10 dogs died) was obtained. With the exception of this series, mortalities in all series having undergone surgery were almost the same (40~45.5%), fairly lower than the mortality of the control series (75%). Even simple pericardiotomy can protect the animal, to some degree, from the ligation test.

Out of 11 intact dogs in which the anterior descending branch was ligated only 3 died (27%). Therefore, it seems that such a ligation is not a suitable method to evaluate possible benefits resulting from the surgical procedure designed for revascularization of the ischemic myocardium.

In the control group far more immediate deaths were obtained, whereas the number of late deaths was almost the same in all groups except the Beck I Operation group.

The time which elapsed from ligation to death in each group was summarized in Table 2. From these data, it is impossible to discuss the comparative merits of the foregoing surgical procedures.

All dogs, in which irritant agent, asbestos or talc, had been placed upon the heart, had severe and extensive adhesions between the peri- and epicardium, whereas those which had not received one of these agents had no adhesions or easily broken

Table 2.-Time Elapsed from the Moment of the Circumflex-ligation to the Death of Dogs in Each Group.

Group of dogs	Immediate Death (Minutes)		Late Death (Hours)	
No surgery	3.0 1.5 3.25 7.92 17.5 25.0	7.0 (mean)	12 18 41	23.6 (mean)
Pericardiotomy	15.0 30.0	22.5 (mean)	24 54 127	68.3 (mean)
Cardio-pericardiopexy	6.75 31.0	18.87(mean)	11 56	33.5 (mean)
Cardio-pneumonopexy (no application of talc powder)	2.0		11 53 55	39.6 (mean)
Cardio-pneumonopexy (application of talc powder)	2.5		31 2 55	29.3 (mean)
Beck I Operation	4.0 30.0	17.0 (mean)		

Table 3.-Relation between the Survival Following the Circumflex-ligation and the Adhesions Caused by the Foregoing Surgical Procedures between the Peri- and Epicardium

	Pericardiotomy		Cardiopneumonopexy (no application of talc powder)		
	No. of dogs	Adhesions		No. of dogs	Adhesions
Death	1	+	Death	48	−
	51	++		10	+
	4	+		34	−
	25	++		46	−
	72	++			
Survival	2	++	Survival	28	−
	6	+		29	+
	8	++		30	−
	32	+		38	−
	73	++		41	−
	74	++		47	−

Key: (−)···No adhesions; (+)···Adhesions limited in the area of pericardiotomy; (++)··· Adhesions extending more widely, but limited partially; (+++)···Adhesions extending over the eintire surface of the heart.

Table 4.-Extent of Infarct in the Layer of Myocardium Resulting from the Circumflex-ligation Performed Three Months after the Foregoing Surgeries

	Entire	Almost entire	Innner two-thirds	Inner half	Total
No surgery	3	0	0	0	3
Pericardiotomy	2	4	0	1	7
Cardiopericardiopexy	3	1	1	1	6
Cardiopneumonopexy (no application of talc powder)	4	0	1	1	6
Cardiopneumonopexy (application of talc powder)	2	1	2	1	6
Beck I Operation	0	1	2	5	8

This examination was carried out on dogs which were killed seven days or more after the ligation test.

ones, if any, along the line of the pericardial incision. The latter animals were able to survive the ligation test fairly well (Table 3).

Out of 10 dogs subjected to cardio-pneumonopexy without talc powder, only one had a few avascular adhesions between the lung pulled in beneath the pericardium and the heart.

(2) *Gross Pathologic Examinations*

The infarct resulting from the circumflex-ligation was able to be distinguished in dogs killed a week or more after this procedure. As shown in Table 4, it was restricted within the inner layer of the myocardium in almost all which had been subjected to Beck I Operation, and was transmural in a half or more of animals which had been subjected to the other surgical procedures and in all which had undergone no surgery (Fig. 1, 2, 3, 4, 5).

Fig. 1

Fig. 2

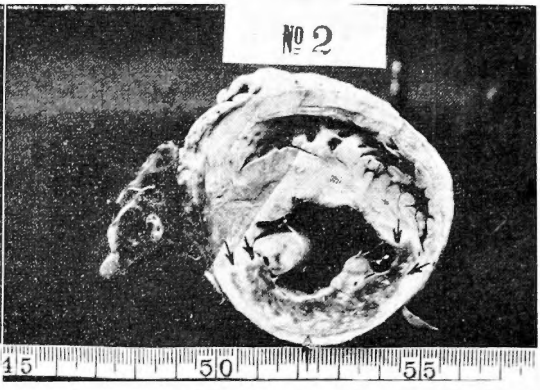


Fig. 1- A transverse section of the heart showing a transmural infarct from dog No. 60 which was previously subjected to no surgery and then killed 7 days after the circumflex-ligation.

Fig. 2- A transverse section of the heart showing an almost transmural infarct from dog No. 2 which was previously subjected to pericardiotomy and then killed 7 days after the circumflex-ligation.

Fig. 3

Fig. 4

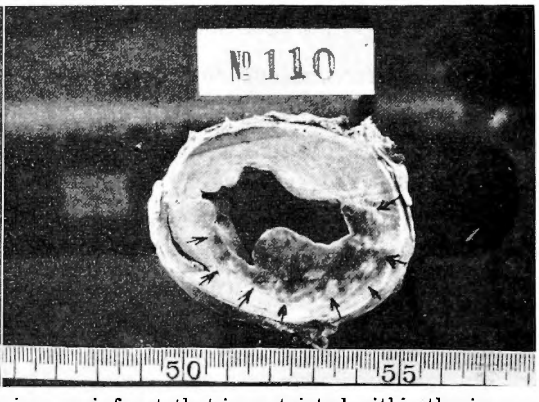


Fig. 3- A transverse section of the heart showing an infarct that is restricted within the inner half layer of myocardium from dog No. 38 which was previously subjected to cardiopneumonopexy with phenol de-epicardialization but no application of talc powder, and then killed 7 days after the circumflex-ligation.

Fig. 4- A transverse section of the heart showing an infarct that is restricted within the inner two-thirds layer of myocardium from dog No. 110 which was previously subjected to Beck I Operation and then killed 7 days after the circumflex-ligation.

Table 5.-Electrocardiographic Changes in Lead Ⅲ Following the Circumflex-ligation Performed Three Months after the Foregoing Surgical Procedures

	Before the ligation	Immediately after	After 30″-40″	1′	3′-15′
No surgery	T negative.	T increased progressively in depth. ST shifted downwards.	T and ST became isoelectric.	T became positive.	ST shifted markedly.
Pericardiotomy	T mostly diphasic.	T became negative. No sagging of ST.	ST began to shift upwards. Bigeminy appeared in most cases.	T became positive.	ST shifted markedly. Bigeminy disappeared.
Cardiopericardiopexy	T mostly positive.	T unchanged, diphasic and negative for each case. No sagging of ST. R became taller.	Bigeminy appeared in a half of cases.	T became positive. ST began to shift upwards.	ST shifted markedly. Bigeminy disappeared.
Cardiopneumonopexy (no application of talc power)	T positive, diphasic and negative.	T became negative or increased in depth in most cases.	Bigeminy appeared in a third of cases.	T became positive. ST began to shift upwards.	ST shifted markedly. Bigeminy disappeared.
Cardiopeunmonopexy (application of talc powder)	T mostly positive.	T unchanged, increased in height and negative. Bigeminy appeared temporarily in more than a half of cases.	ST shifted gradually upwards.	T became positive. ST stopped to shift further more.	Shifting of ST remained mostly unchanged.
Beck I Operation	T positive and diphasic, respectively, in a half of cases.	T diphasic and negative. ST shifted up-or downwards. Bigeminy appeared temporarily.	T became mostly positive. ST shifted progressively upwards.		ST showed a downward shifting after once elevated in some cases.

(3) *Electrocardiographic Examinations*

An electrocardiographic tracing was taken in lead III for the reason previously mentioned. Its findings were summarized in Table 5.

(i) Group of no surgery (Fig. 6)

The electrocardiographic examination was carried out on 4 dogs. Results obtained from each dog were almost the same. An inverted T wave already existed. Immediately after the circumflex branch had been ligated, the T wave continued to increase in depth, but it converted into a positive one after about one minute. Simultaneously with the alteration of T wave the ST segment deflected down wards at first and thereafter changed the direction of its shifting from negative to positive; after 30 to 40 seconds ST became isoelectric and after 3 minutes deviated markedly upwards, remaining almost unchanged for 15 minutes. There were no changes of the R wave. The "deep Q wave" was noted in one case.

Out of 4 animals 2 died, soon after, of ventricular fibrillation and the others

Fig. 6

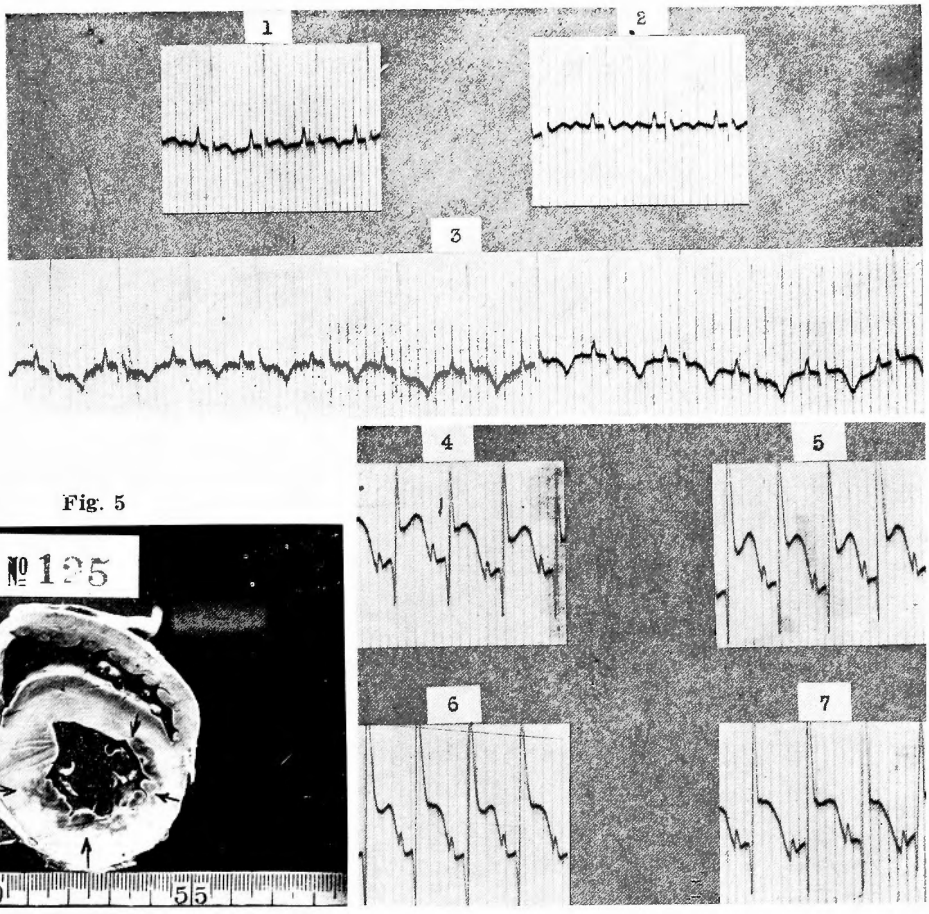


Fig. 5

Fig. 5- A transverse section of the heart showing an infarct that is restricted within the inner half layer of myocardium from dog No. 125 which was previously subjected to Beck I Operation and then killed 7 days after the circumflex-ligation.

Fig. 6-Electrocardiograms in lead III of dog No. 65 having undergone no surgery. 1, Before thoracotomy the T wave was already negative. 2, After isolation of the circumflex branch the ST segment shifted downwards. 3, Immediately after the circumflex-ligation the T wave increased progressively in depth associated with sagging of the ST segment. 4, Three minutes after the ST segment shifted markedly upwards. 5, Five minutes after the "deep Q wave" appeared. 6 and 7, Electrocardiographic tracings, respectively, ten and fifteen minutes after. The dog died twelve hours after operation.

died about ten hours afterwards. It was impossible to measure the infarcts in all cases, because they did not live long enough to develop an infarct.

(ii) Group of pericardiotomy (Fig. 7, 8)

In 3 of 5 dogs which received electrocardiographic examination, the T wave was originally diphasic and in 2, positive and negative, respectively. Just after the ligation the diphasic T wave became negative and the negative increased in negativity associated with no sagging of the ST segment. After one minute all T waves became positive. The ST segment began to shift upwards after 30 to 40

Fig. 7.

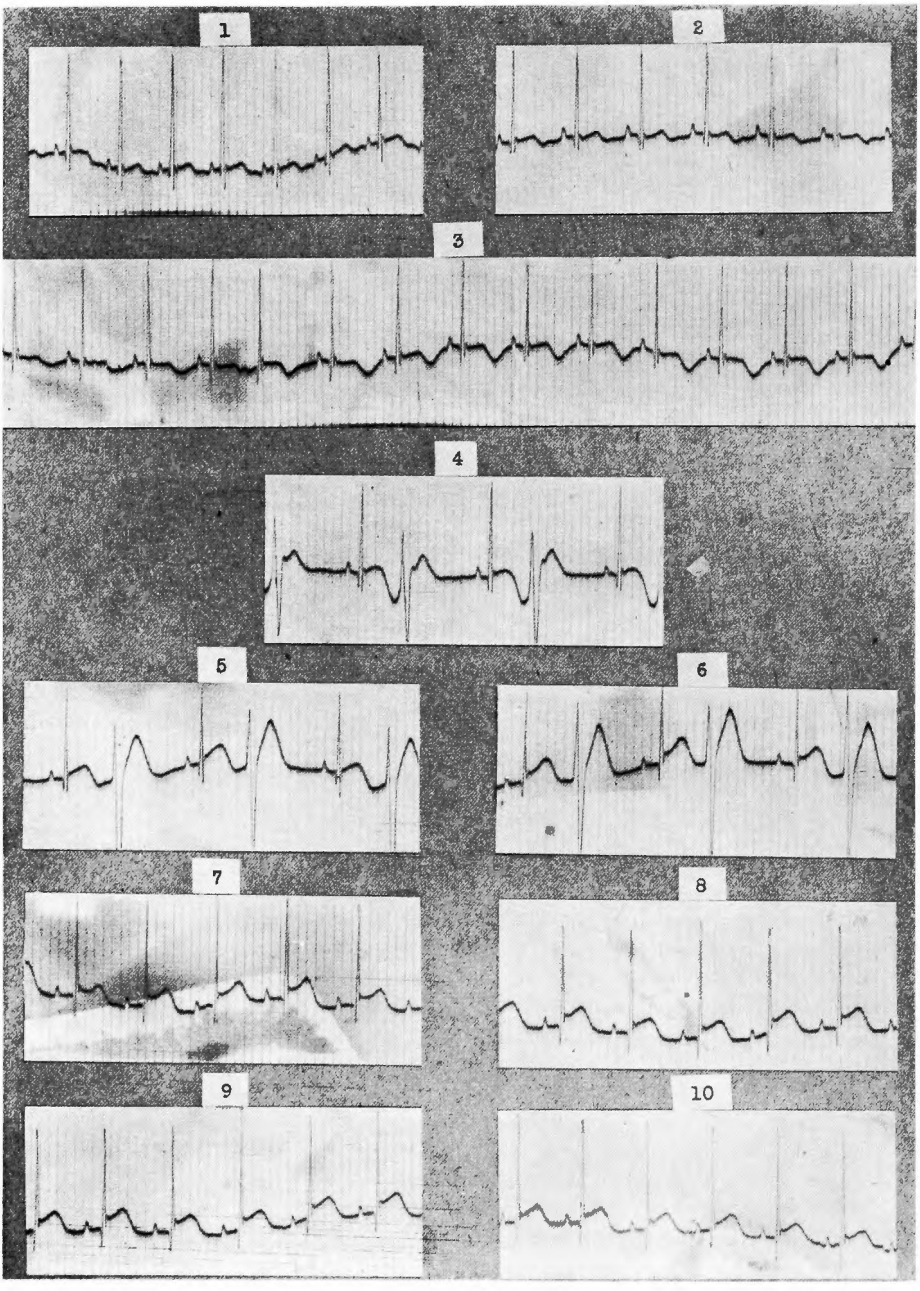


Fig. 7-Electrocardiograms in lead III of dog No. 25 having undergone pericardiotomy. 1, Before thoracotomy the T wave was diphasic. 2, After isolation of the circumflex branch the electrocardiogram remained unchanged. 3, Immediately after the circumflex-ligation the T wave was transformed into a negative phase, increasing progressively in depth accompanied by no sagging of the ST segment. 4, Twenty seconds after bigeminy appeared accompanied by a slight elevation of the ST segment. 5 and 6, Electrocardiographic tracings, respectively, fifty seconds and two minutes after, show that the ST segment shifted progressively upwards and bigeminy was yet noted. 7, Two minutes and fifty-five seconds after bigeminy disappeared and the ST segment shifted more upwards. 8, 9 and 10, Electrocardiographic changes, respectively, five, ten and fifteen minutes after were almost the same as 7.

The dog died 24 hours after operation.

Fig. 8

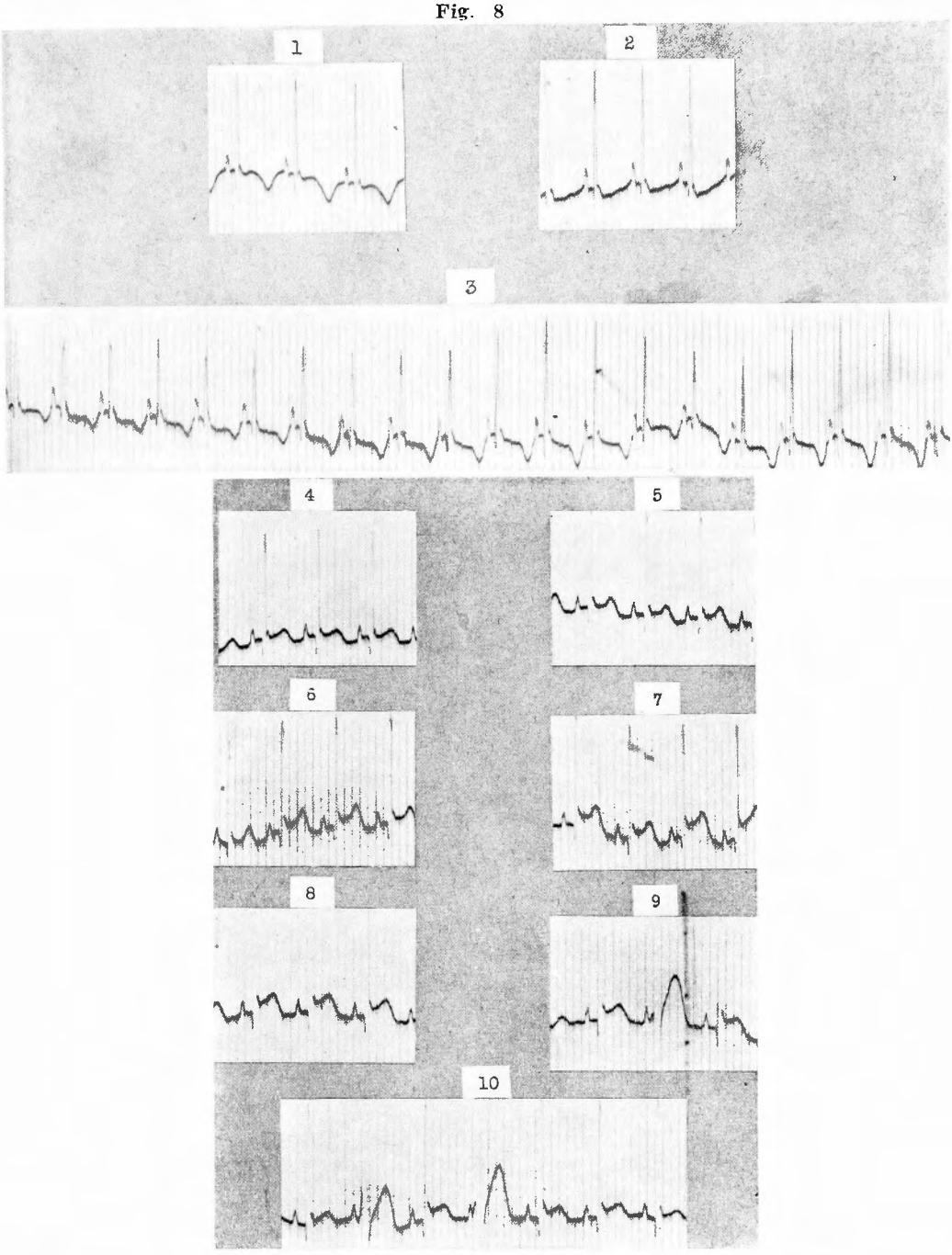


Fig. 8-Electrocardiograms in lead III of dog No. 2 having undergone pericardiotomy. 1, Before thoracotomy the T wave diphasic. 2, After isolation of the circumflex branch the electrocardiogram remained unchanged. 3, Immediately after the circumflex-ligation the T wave converted into a negative phase, increasing progressively in depth. 4, One minute after the T wave became positive and the ST segment elevated slightly. 5, Two minutes after the electrocardiographic changes became more markedly. 6, Three minutes after the R wave increased in voltage. 7, Five minutes after the ST segment shifted upper-most. 8, Ten minutes after electrocardiographic changes were almost the same as before. 9, Thirteen minutes after extra systole appeared. 10, Fifteen minutes after almost the same as 9.

The dog survived the test and then was killed 7 days after. Post-mortem examination reaveled that the infarct was almost transmural (Fig. 2).

Fig. 9.

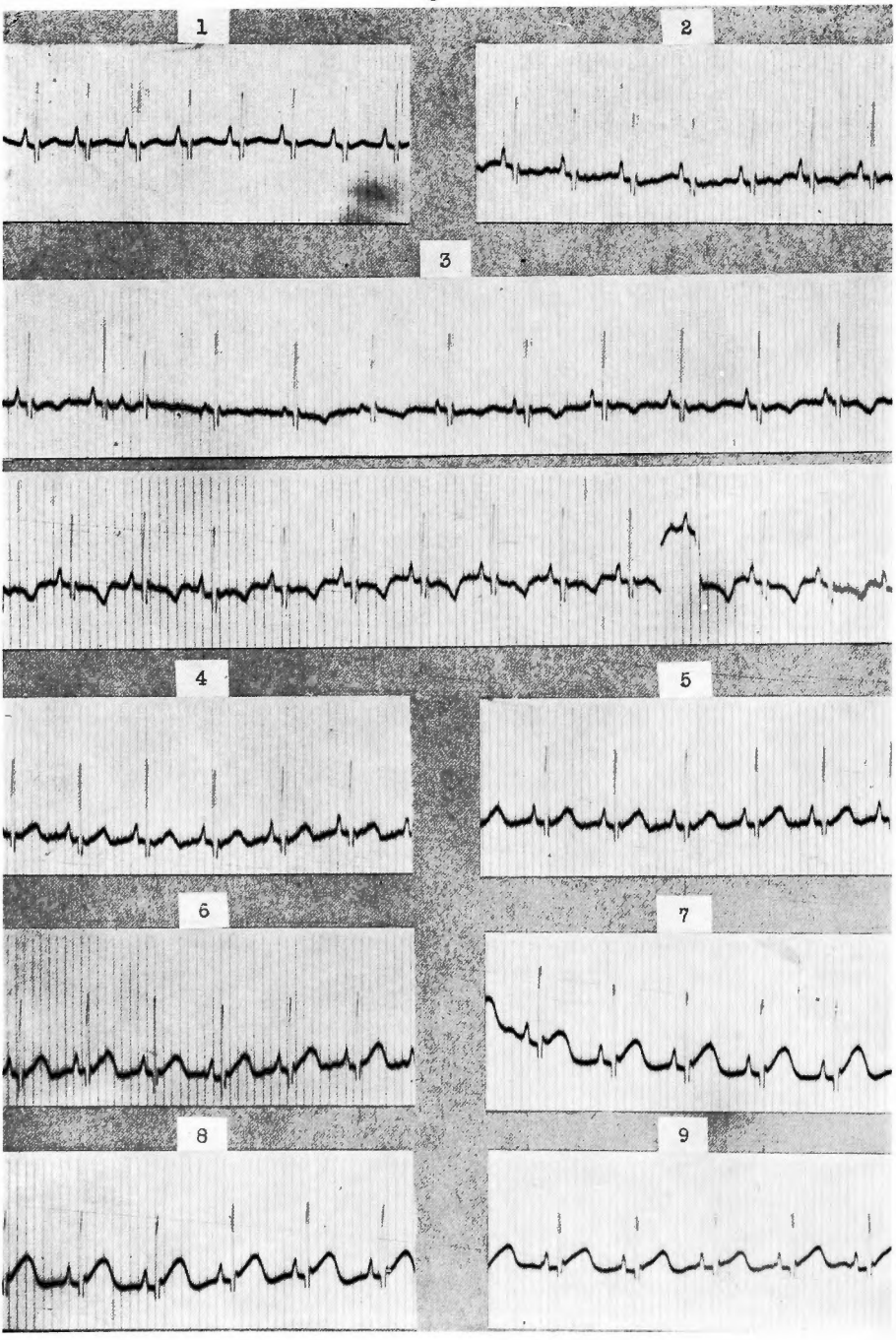


Fig. 9-Electrocardiograms in lead III of dog No. 50 having undergone cardiopericardiopexy (THOMPSON's Method). 1, Before thoracotomy the T wave was positive. 2, After isolation of the circumflex branch the ST segment became depressed. 3, Immediately after the circumflex-ligation the T wave became diphasic, isoelectric, negative, and finally, typical of the "ischemic T wave" with coving and R wave became somewhat taller. 4, One minute after the T wave was converted again into a positive phase. 5, Two minutes after almost the same as 4. 6, Three minutes after the ST segment began to shift upwards. 7, Five minutes after its shifting became more marked. 8 and 9, Electrocardiogrphic changes ten and fifteen minutes after, respectively, were almost the same as before.

The dog died 31 minutes after operation of ventricular fibrillation.

Fig. 10.

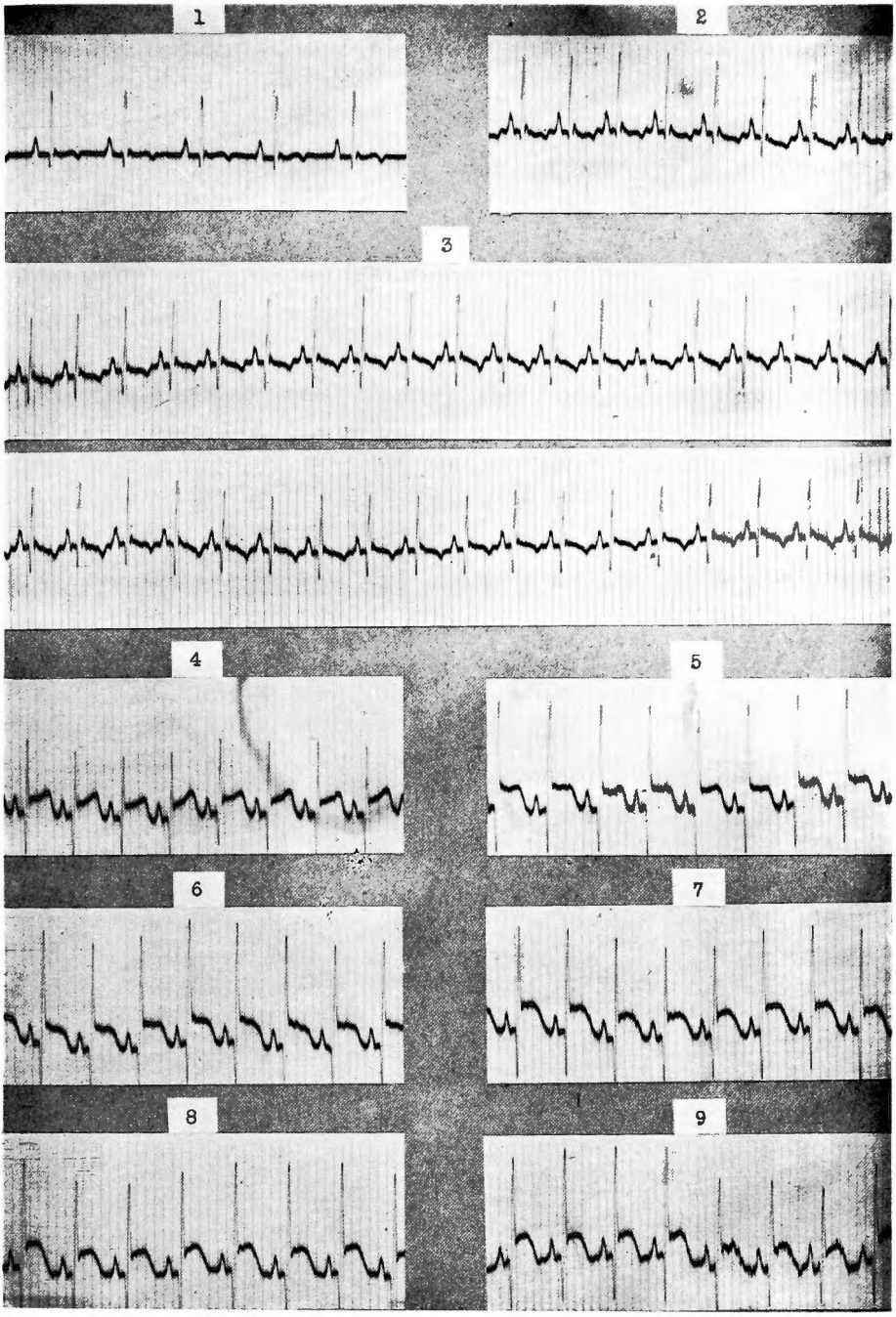


Fig. 10-Electrocardiograms in lead III of dog No. 38 having undergone cardiopneumonopexy with phenol de-epicardialization but no application of talc powder. 1, Before thoracotomy the T wave was already diphasic. 2, After isolation of the circumflex branch the T wave became negative. 3, Immediately after the circumflex-ligation the T wave increased progressively in depth. 4, One minute after the ST segment shifted upwards accompanied by the "deep Q wave". 5, Two minutes after the former changes became more marked and the R wave increased in voltage twice as large as before. 6, 7, 8 and 9, Electrocardiographic tracings, respectively, three, five, ten and fifteen minutes after, were almost the same as 5.

The dog was killed 7 days after and it was confirmed that the infarct was restricted within the inner half layer of myocardium (Fig. 3).

Fig. 11.

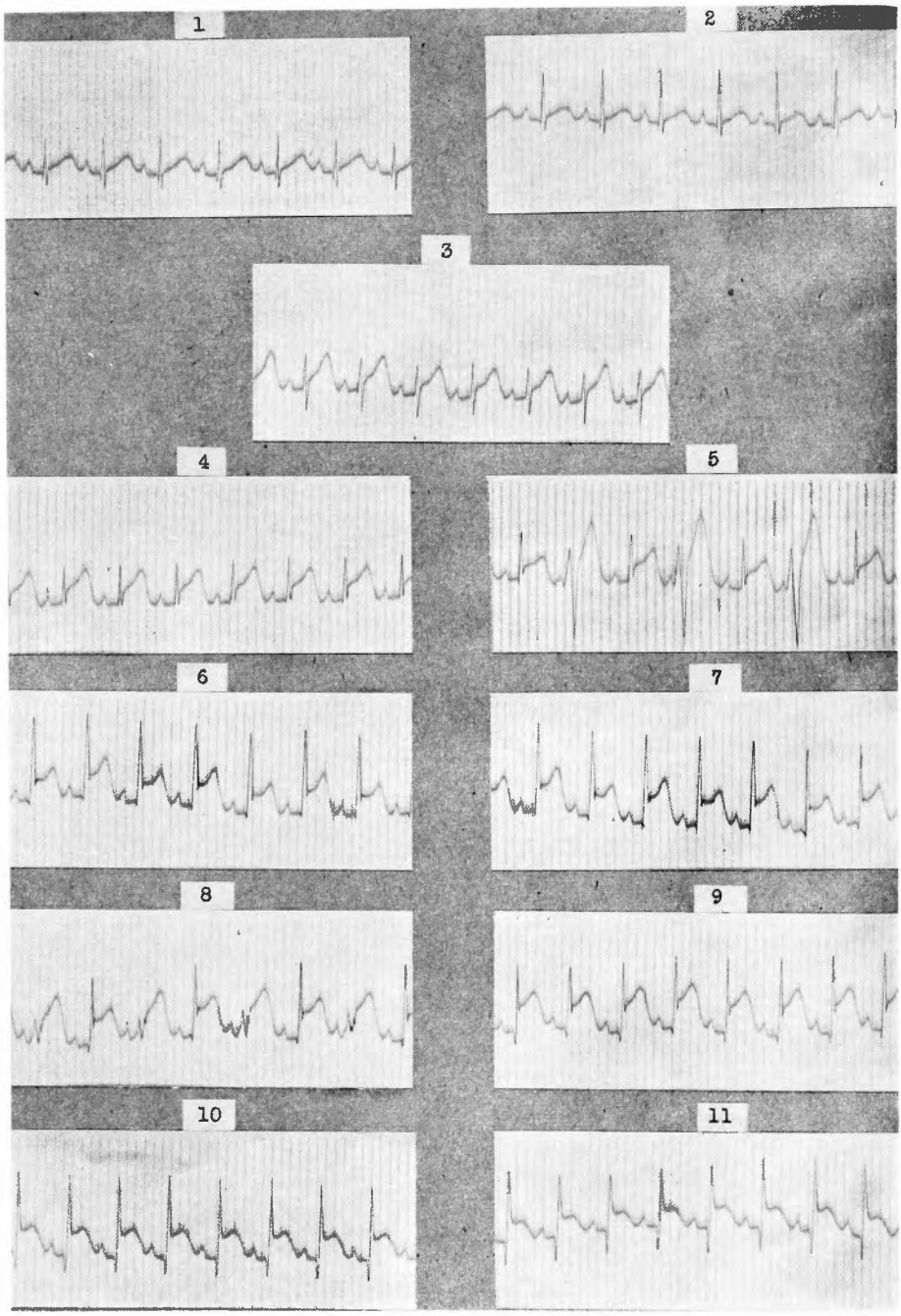


Fig. 11-Electrocardiograms in lead III of dog No. 98 having undergone cardio-pneumonopexy (HARKEN's Method). 1, Before thoracotomy the T wave was positive. 2, After isolation of the circumflex branch the electrocardiogram remained unchanged. 3, Immediately after the circumflex-ligation the T wave increased in height accompanied by upward deflection of the ST segment. 4, After twenty seconds the ST segment shifted more upwards. 5, After forty seconds bigeminy appeared. 6, After one minute, bigeminy disappeared, the ST segment shifted upper-most and the R wave became twice as large as before. 7, 8 and 9, Electrocardiograms, respectively, two, three, and five minutes after, were similar to each other. 10, After ten minutes the "deep Q wave" appeared. 11, After fifteen minutes, electrocardiographic changes were almost the same as 10.
The dog died 73 hours after operation.

Fgi. 12.

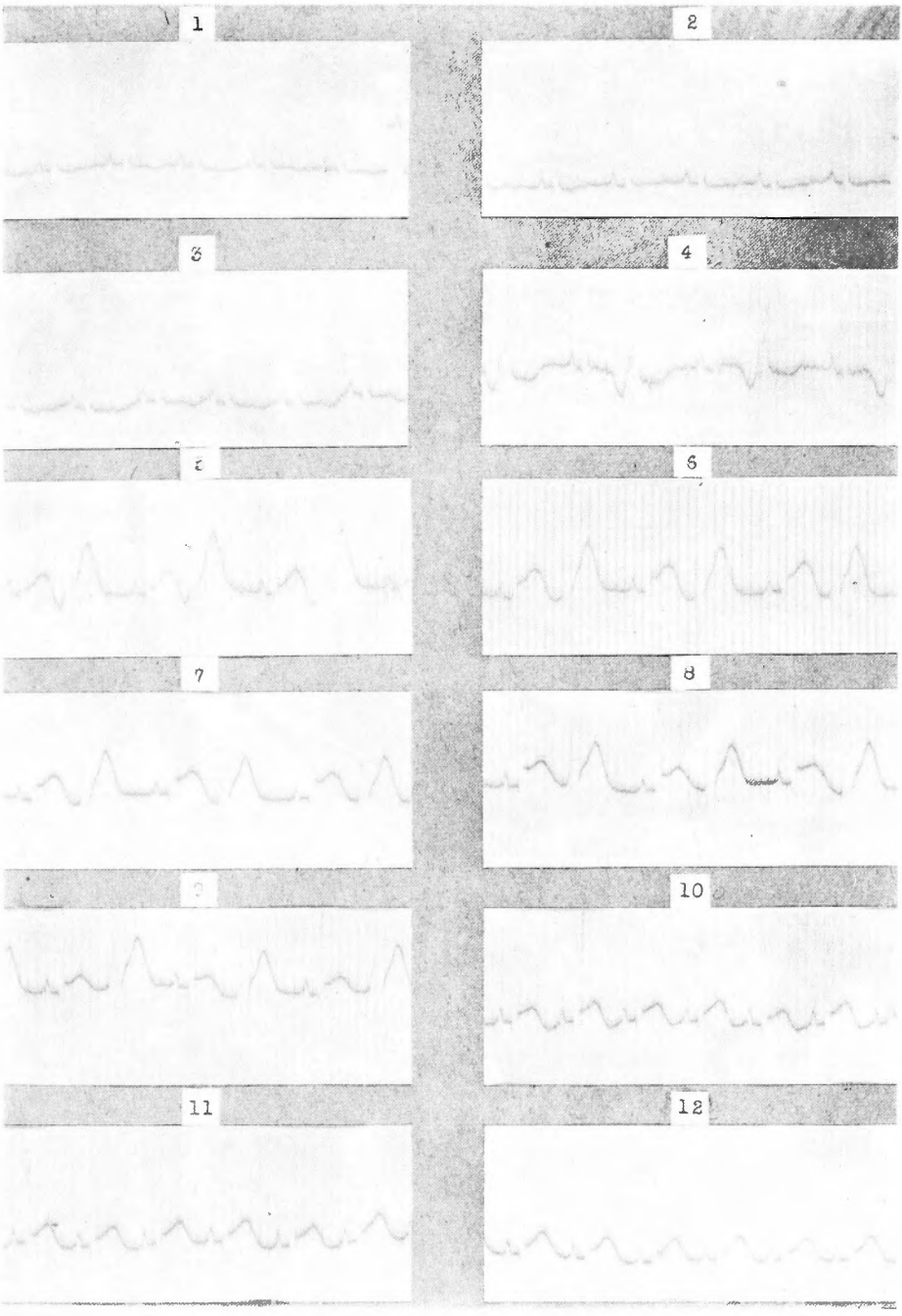


Fig. 12-Electrocardiograms in lead III of dog No. 81 having undergone cardiopneumonopexy (HARKEN's Method). 1, Before thoracotomy the T wave was flat. 2, After isolation of the circumflex branch the electrocardiogram remained unchanged. 3, Immediately after the circumflex-ligation the T wave became negative, increasing progressively in depth following slight sagging of the ST segment. 4, After eight seconds bigeminy was noted. 5, After twenty seconds the ST segment shifted upwards. 6, After forty seconds it shifted more markedly. 7, The electrocardiogram after one minute. 8, After two minutes the ST segment shifted upper-most. 9, After three minutes it shifted slightly downwards and yet begeminy was noted. 10, 11 and 12, Electrocardiographic tracings, respectively, five, ten and fifteen minutes after, show that the ST segement having once elevated shifted downwards increasingly, i. e., a tendency to restore the original state.

The dog survived the ligation test and then was killed 9 days after operation. Post-mortem exam- revealed that the infarct was restricted within the inner half layer of myocardium.

Fig. 13.

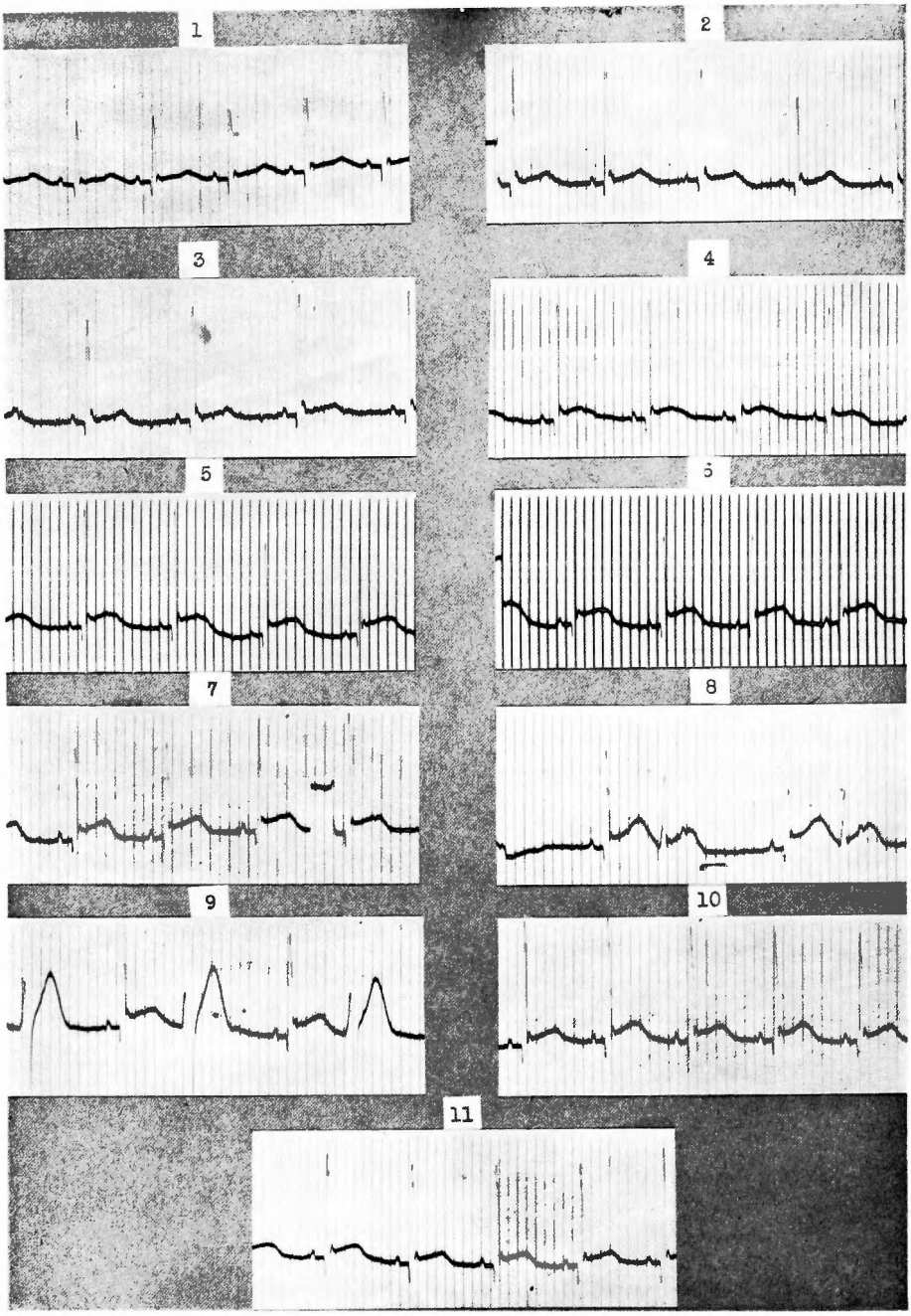


Fig. 13-Electrocardiograms in lead III of dog No. 110 having undergone Beck I Operation. 1, Before thoracotomy the T wave was positive. 2, After isolation of the circumflex branch the electrocardiogram remained almost unchanged. 3, Immediately after the R wave became taller than before. 4, After twenty seconds the ST segment shifted slightly upwards. 5, 6 and 7, Electrocardiograms. respectively, forty seconds, one minute and two minutes after, show that the ST segment shifted upwards progressively. 8, After three minutes bigeminy appeared. 9, After five minutes bigeminy was yet noted. 10 and 15, Electrocardiograms, respectively, ten and fifteen minutes after, show that the ST segment shifted downwards gradually, i. e., a tendency to restore the initial state.

The dog survived the ligation test and then was killed 7 days after operation. Post-mortem examination revealed that infarct was restricted within the inner two-thirds layer of myocardium (Fig. 4).

Fig. 14.

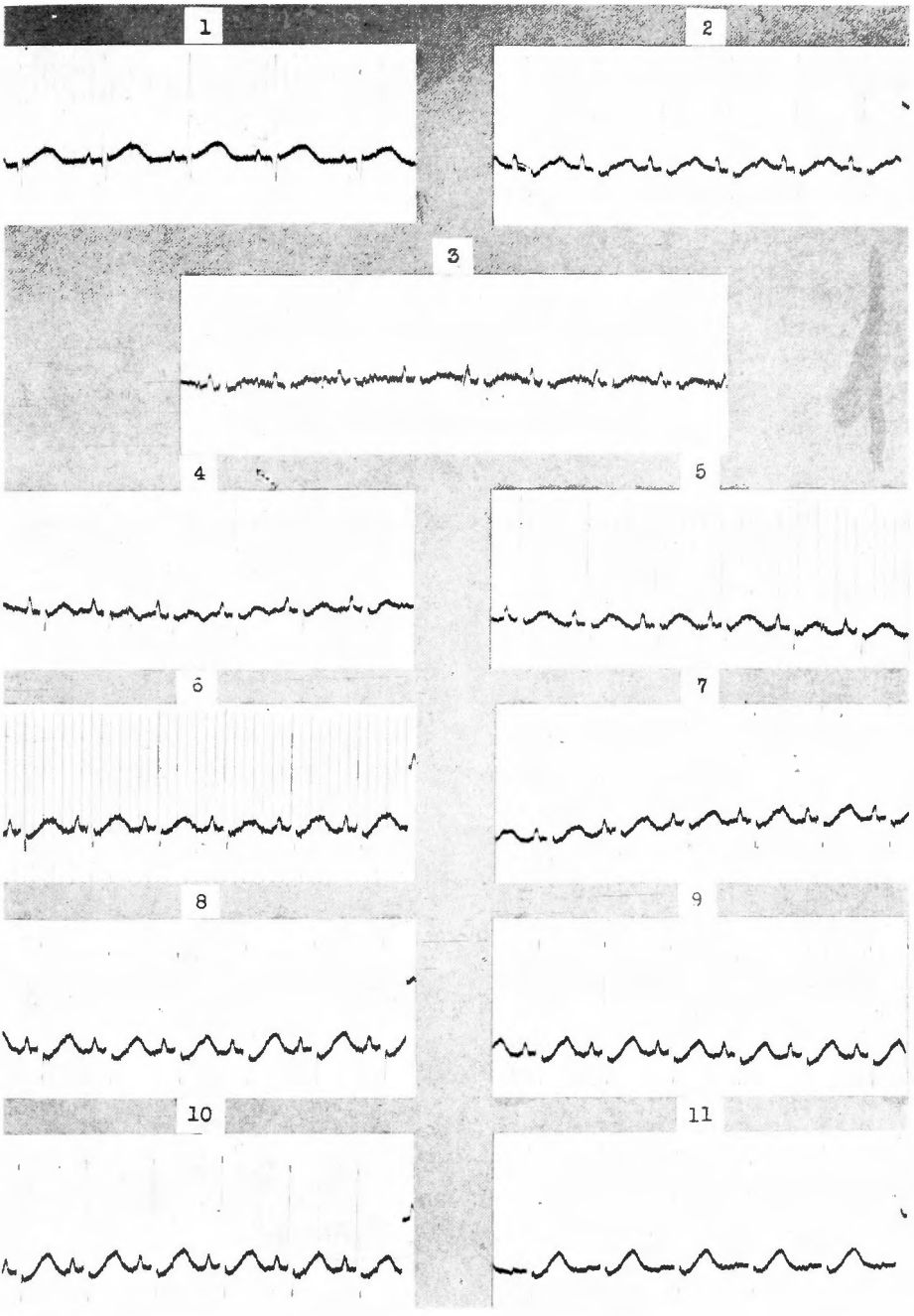


Fig. 14-Electrocardiograms in lead III of dog No. 125 having undergone Beck I Operation. 1, Before thoracotomy the T wave was positive. 2, After isolation of the circumflex branch the ST segment sagged slightly. 3, Immediately after the circumflex-ligation the ST shifted gradually downward. 4, After twenty seconds the T wave was transformed into a diphasic phase. 5, After forty seconds the T wave became again positive. 6 and 7, Electrocardiograms, respectively, one minute and two minutes after, were almost the same as 5. 8, After three minutes the ST segment shifted somewhat more downwards. 9, 10 and 11, Electrocardiograms, respectively, after five, ten and fifteen minutes, were almost the same as 8.

The dog survived the ligation test and then was killed 7 days after. At autopsy, it was found that the infarct was restricted within the inner half layer of myocardium (Fig. 5).

seconds. Its shifting reached the maximum in 3 to 5 minutes, remaining unchanged thereafter. On the other hand, the originally positive T wave became taller, associated with upward deflection of the ST segment. In 3, bigeminy appeared just after or a half minute after and disappeared after 3 minutes. The R wave increased mainly just after or a few minutes after in voltage, becoming occasionally one and a half or two times as large as before. Only in 1, the "deep Q wave" was noted temporarily after 10 minutes.

Out of the 5 dogs, 2 were killed, respectively, one and two weeks after operation in which the infarcts were transmural, 1 died 30 minutes after operation and 2 on the next day.

(iii) Group of cardio-pericardiopexy (Fig. 9)

The T wave was initially positive in 5 dogs and negative in 1.

Immediately after the ligation the originally positive T wave remained unchanged in 2 and became diphasic and negative, respectively in 2 and 1. In a case which died soon after of ventricular fibrillation, the initially positive T wave became diphasic and then afterwards negative. With the exception of this case, all the T waves changed, both diphasic and negative, becoming positive about one minute after and remaining in this state. In cases in which the T wave was originally positive, the ST segment began after about 1 minute to shift upwards. Its shifting was at a maximum in 3 to 5 minutes, remaining unchanged until the end of the examination. Out of these cases, 2 in which the T wave was not changed into other phases by the ligation survived this test, and then after about 10 days were killed to show transmural infarcts and 3 died soon after operation or on the next day.

The originally negative T wave increased immediately after operation in negativity associated with no sagging of the ST segment and after 1 minute changed the direction of its alteration to become isoelectric and then after 5 minutes diphasic. The ST segment deflected downwards temporarily after 2 minutes. These changes were restored almost to the initial states in 15 minutes. An animal having shown such electrocardiographic changes were killed after 7 days and then it was confirmed that the infarct was restricted within the inner half of the layer of myocardium.

The R wave became taller soon after in all 6 animals which were subjected to the electrocardiographic examination. It is noticeable that this change was restored to the original state after 5 minutes in a dog which had the infarct restricted within the inner half of the layer of myocardium.

The "deep Q wave" was not noted in any case. Bigeminy appeared temporarily after 20 seconds to 1 minute in a half of 6.

(iv) Group of cardio-pneumonopexy without application of talc powder (Fig. 10)

Ten dogs received the electrocardiographic examination.

Initially the T wave was positive in 3, diphasic in 4, and negative in 3. Immediately after the ligation the positive T wave was transformed into a diphasic or negative phase, the diphasic into a negative one except a case in which the T

wave remained unchanged, and the negative increased in negativity. About 1 minute after the ST segment began to shift upwards, associated with the T wave change to positive, and after several minutes its shifting reached to the maximum state, which was maintained during examination. The R wave became taller in 5 and smaller in 1. In 3, however, this wave became again somewhat smaller and in 2 of them finally returned to the original state. The "deep Q wave" was noted only in 1. Bigeminy appeared temporarily in 3.

As to electrocardiographic changes in this group, there were no significant differences between dogs which survived the ligation and those which did not.

(v) Group of cardio-pneumonopexy with application of talc powder (Fig. 11, 12)

Seven dogs were subjected to the electrocardiographic examination.

The T wave was originally positive in all the animals except one case in which it was negative. Changes of the positive T wave after the circumflex-ligation were as follows: a) unchanged (2 cases): b) immediately increased in height and thereafter unchanged (2 cases): c) immediately changed into a negative phase and then returned to the former state about a half minute after (2 cases). The initially negative T wave increased immediately after the ligation in negativity and then was trasformed into a positive phase after about a half minute.

The ST segment began to shift upwards about 20 seconds afterwards, whether it sagged previously or not, and then reached to the maximum about 1 minute after. Its shifting was maintained almost unchanged in all cases, except one in which the ST elevation decreased gradually in height, i. e., the electrocardiogram showed a tendency to restore the initial state. This animal had the infarct restricted within the inner layer of myocardium. Compared with the foregoing groups, there were seen somewhat slighter changes of the T wave and ST segment in this group.

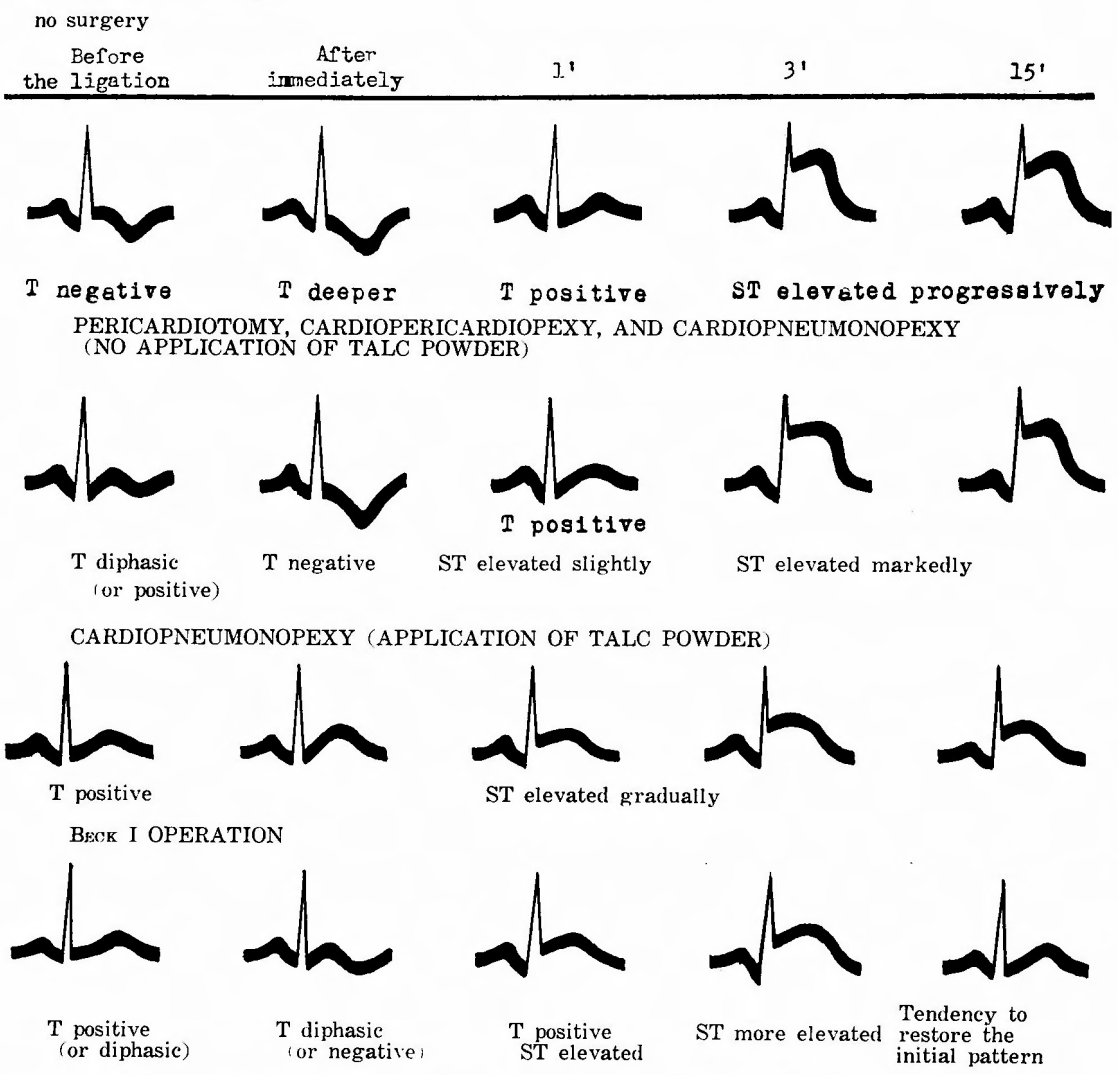
The "deep Q wave" was noted only in 1 which died on the third day after operation. The R wave became taller in 5, smaller in 1 and remained unchanged in 1. Bigeminy was temporarily noted in 4.

(vi) Group of Beck I Operation (Fig. 13, 14)

Before the circumflex-ligation, the T wave was positive in half of the 6 dogs and diphasic in the others. In each animal, the originally positive T wave was transformed into a diphasic phase immediately after the ligation and then returned to the original state after 30 to 40 seconds. The originally diphasic T wave became positive after change to negative in 2, and furthermore, in 1 of them progressively negative, whereas in the remaining 1 this wave remained unchanged for a little while after the ligation and then became also increasingly negative.

In 4 upward shifting of the ST segment reached to the maximum after about 2 minutes and then decreased gradually in height in 2 of them, but in the others remained almost unchanged. In 2 the ST segment shifted gradually downwards to be under the base line. Compared with the other groups, displacement of the ST segment after the ligation was somewhat slighter. In some cases, its elevation did

Fig. 15-Diagrammatic Illustration of Electrocardiographic Changes in Lead III after the Circumflex-ligation



not occur, or occasionally decreased gradually in height to return to the initial state. The R wave became taller in 2. The "deep Q wave" was not noted in any case.

To sum up, electrocardiographic changes following the circumflex-ligation were almost the same in four groups, no surgery, pericardiotomy, cardiopericardiopexy and cardiopneumonopexy without application of talc powder, although before the ligation the T wave was negative in the group of no surgery and positive or diphasic in most cases of the other groups. Immediately after the ligation the T wave increased in negativity, when it was originally negative, and became negative, in most cases, when it was originally positive or diphasic, accompanied or

unacompanied by sagging of the ST segment. About one minute after, change to positive of the T wave and upward shifting of the ST segment developed. Three to five minutes after, its shifting became upper-most and then this level remained unchanged until the end of the examination. In the group of cardiopneumonopexy with application of talc powder (HARKEN's Method) change to negative of the T wave immediately after the ligation did not occur in most cases and shifting of the ST segment was, generally speaking, less marked. In the group of BECK I Operation, the ST segment which had once elevated after the ligation, shifted in some cases again downwards and occasionally an inverted T wave and sagging of the ST segment were noted within fifteen minutes (Fig. 15), i. e., the electrocardiogram showed a tendency to restore the original pattern. Consequently, it may be said that, based on the electrocardiographic findings, BECK I Operation is the most beneficial procedure, and next it is cardiopneumonopexy with application of talc powder.

In Experiment I, ligation of the circumflex branch of the left coronary artery was used as a method for analysis of possible benefits derived from surgical procedures. From the data obtained from statistical evaluation of mortality, measurements of infarct and electrocardiographic examinations, it is concluded that BECK I Operation is the most beneficial among the tested surgical procedures.

EXPERIMENT II

Now it is known from the comparative study, in which experimental circumflex artery ligation was used as the evaluating means, that BECK I Operation is the most beneficial surgical procedure. Clinically, however, coronary insufficiency develops gradually and progressively, being part of a generalized arteriosclerotic process. In order to create experimentally a more realistic type of this disease, we devised a new method consisting in gradual constriction of both main branches of the left coronary artery, suggested by VINEBERG and others.[24] With this test, the comparative study was also done.

1. METHOD

Small plastic sleeves with an internal diameter of 6 mm and a length of 5 mm were previously prepared and prior to operation sterilized by boiling. A 1 mm logitudinal slot and a fine circular groove were cut in the sleeve to facilitate slipping it over the artery and placing a circular ligature around it.

Anesthesia and thoracotomy were carried out in the same manner as in Experiment I. The pericardium was incised anterior to the left phrenic nerve from the level of the great vessels to a point near the diaphragm. The heart was then delivered through this incision out of the pericardial sac. A SATINSKY clamp was used to make traction on the left auricular appendage. A small incision was made in the epicardium overlying the area where the left coronary artery branches divide into the anterior descending and circumflex. A blunt probe was used to isolate these vessels for a distance of approximately 2 cm at their origins. The tip of a small curved clamp was passed through under the anterior descending and

circumflex branches, respectively, and utilized to maintain elevation for a few seconds while the plastic sleeves were slipped on. Ligatures were placed around them. A small stick of Laminaria for gynecological use was inserted into each sleeve and fixed in this place with a silk-thread (Fig. 16). No attempt was made to repair the epicardium. The heart was replaced in the pericardial sac and the pericardium was closed with interrupted sutures. Routine closure of the thorax was then completed after careful reinflation of the lung. Thus, it was expected that the gradual constriction of both main branches of the left coronary artery would be brought about by the expansion of Laminaria.

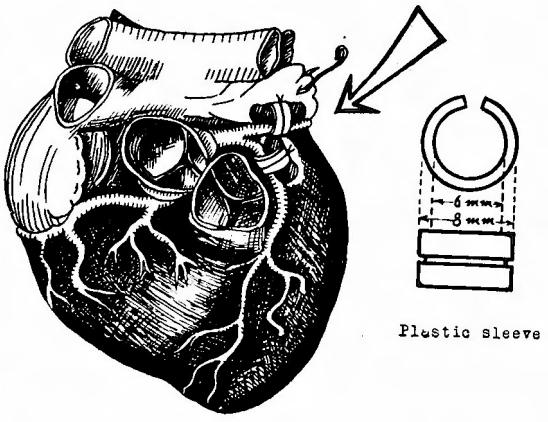


Fig. 16-Illustration showing location of plastic sleeves around the anterior descending and circumflex branches of the left coronary artery. Laminaria sticks are inserted into the sleeves.

2. RESULTS

1. *Preliminary Study*

This study was carried out to know the suitable size of a Laminaria stick for the production of coronary insufficiency in a realistic manner.

(i) Clinical Observations

As shown in Table 6., animals in which Laminaria sticks with a diameter of more than 1.2 mm had been used, died soon after operation. Dog No. 101 died suddenly a "mechanism" death 6 days after application of Laminaria sticks with a diameter of 1.2 mm, in spite of its complete recovery from operation. Two dogs, No. 102 and 97, having received the sticks of the same size recovered completely and then were killed 24 and 40 days after, respectively.

Table 6-The Sizes of Laminaria and the Times of Survival after Operation

Dog Number	Diameters of Laminaria Sticks (mm)	Times of Survival
93	2	Hours 13 (died)
100	1.5	17 (〃)
101	1.2	Days 6 (〃)
102	〃	24 (sacrificed)
97	〃	40 (〃)

(ii) Electrocardiographic Examinations

In two of the dogs that were killed, electrocardiographic tracings were taken prior to death, while they were anesthetized with sodium pentobarbital and intubated to breathe 100 per cent oxygen.

As evidenced by Fig. 17, in dog No. 102 diphasic T waves and slight ST

Fig. 17

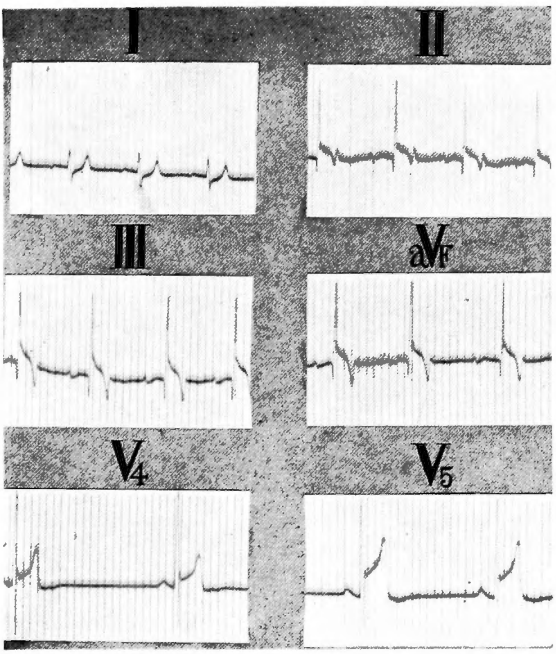


Fig. 18

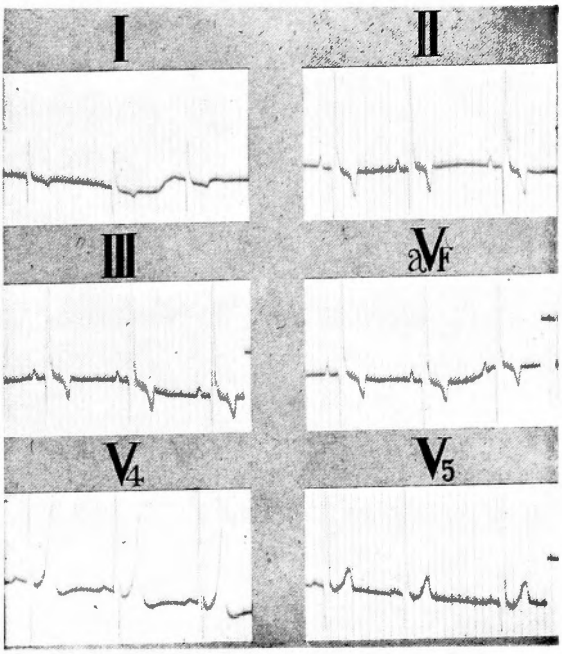


Fig. 17-Electrocardiographic tracings taken in dog No.102, 24 days after gradual constriction of both main branches of the left cornary artery.

Fig. 18-Electrocardiographic tracings taken in dog No. 97, 40 days after gradual constriction of both main branches of the left coronary artery.

elevations in lead II, inverted T waves with covings and fair ST elevations in lead III and $_aV_F$ and marked ST elevations in V_4 and V_5 were observed. For convenience, the exploring electrode was placed on the left fifth rib adjacent to the sternum for V_4 and from there laterally about two transverse finger breadths for V_5. As shown in Fig. 18, in dog No. 97 inverted T waves with covings and ST saggings in lead II, III and $_aV_F$, splitted P waves in V_4 and V_5, and abnormally tall T waves and ST saggings in V_5 were noted.

Histological examination revealed in both dogs myocardial degeneration due to gradual constriction of the main branches of the left coronary artery, as will be mentioned later on.

(iii) Contrastmedia Injection Studies and Gross Pathologic Examinations

Shortly after death, the heart was removed en masse and then both coronary ostia were cannulated with blunt syringes of comparable size. The syringes were attached in place by circular ligatures around the ostia and their free ends attached to perfusion apparatus. Injections with contrastmedia (Abrodil) were completed, and then radiographs were taken to determine the degree of patency of the coronary arteries and existence of any other changes.

In most cases, the left coronary trunks were demonstrable, but their small peripheral branches were not visible. The circumflex artery was, generally, less constricted than the anterior descending (Fig. 19).

Thereafter, each heart was sliced like a loaf of bread into sections measuring

Fig. 19 Fig. 20.

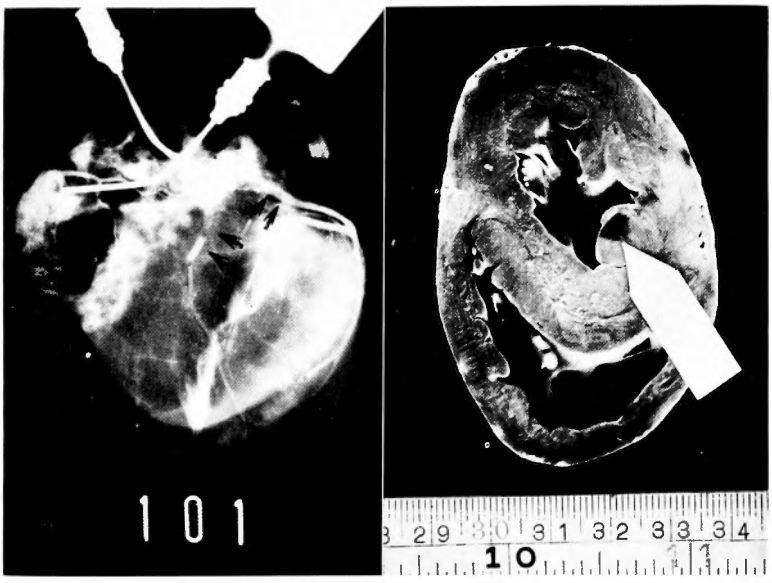


Fig. 19-Photograph of x-ray taken following perfusion of contrastmedia through syringes into the coronary ostia (dog No. 101). The arows point out the anterior descending and circumflex branches.

Fig. 20-Photograph of a transverse section obtained from the heart of dog No. 101 which died a "mechanism" death 6 days after operation. The arow indicates the infarct occupying an anterior position in the left ventricular wall.

approximately 2 cm in thickness, for inspection. Only one (dog No. 101) of the five showed the gross infarcted area occupying an anterior position in the left ventricular wall (Fig. 20).

(iv) Histopathological Examinations

Three hearts (No. 101, 102 and 97) were subjected to the histological examination. Pieces of cardiac tissue were stained with hematoxylin-eosin.

Transverse sections of the plastic sleeve-encased vessels became in all cases

Fig. 21-A Fig. 21-B

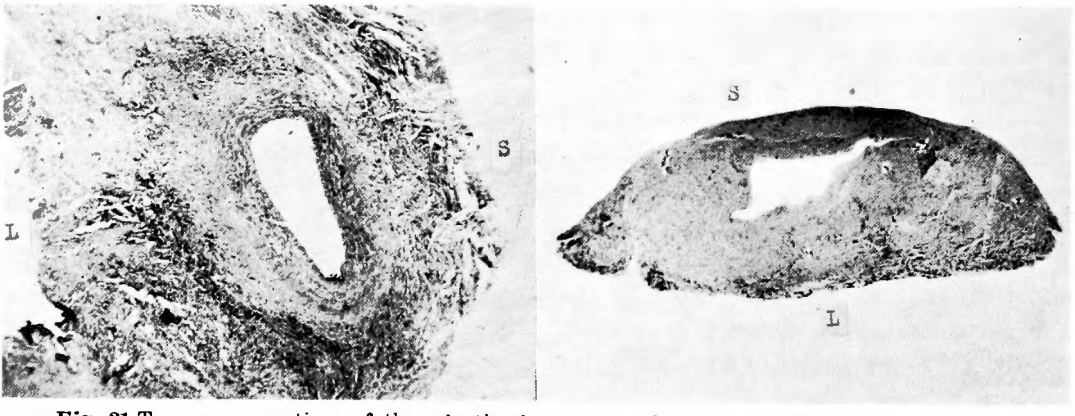


Fig. 21-Transverse sections of the plastic sleeve-encased vessels. A. The circumflex branch from dog No. 102. B. The anterior descending branch from dog No. 97. Note the intimal hyperplasia in B. L···The Laminaria side. S···The plastic sleeve side.

oval by the expansion of Laminaria. Furthermore, their constrictions were promoted by the fibrous tissue reaction in the tunica adventitia, and hyperplastic involvement of the medial and intimal tunicae (Fig. 21).

In dog No. 101 which died a "mechanism" death after complete recovery, pathological changes of myocardium were found in the left side; cloudy swelling of protoplasm all over and focal necrosis with inflammatory reaction in the inner layer (Fig. 22). In the gross infarcted area, focal necrosis with marked granulocyte infiltration and myocardial degeneration (pycnosis, vacuolization and granular degeneration of protoplasm) were evidenced (Fig. 23).

Fig. 22

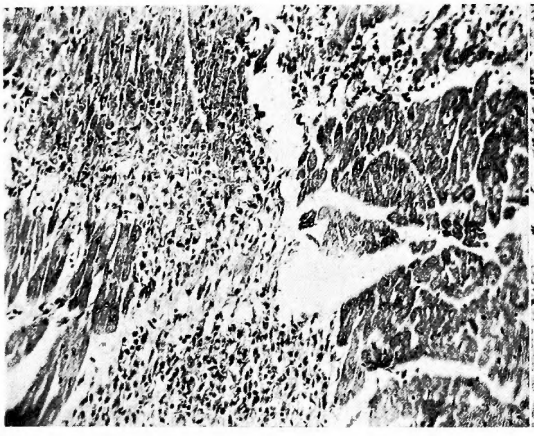


Fig. 23

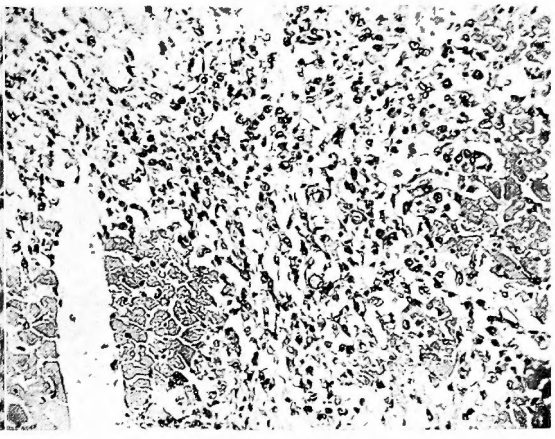


Fig. 22-Focal myocardial necrosis with inflammatory reaction in the left ventricular wall from dog No. 101.

Fig. 23-Microphotograph of the gross infarcted area showing focal necrosis and myocardial degeneration with inflammatory reaction from dog No. 101.

Fig. 24

Fig. 24-Myocardial degeneration(vacuolization and cloudy swelling of protoplasma) and interstitial edema in the anterior wall of the left ventricle from dog No.. 102.

In one (No. 102) of the two which were killed, myocardial degeneration (vacuolization and cloudy swelling of protoplasm) and interstitial edema were noted only in the anterior wall of the left ventricle (Fig. 24). In the other (No. 97), almost the same changes were found more or less in both ventricular walls.

After all, it has been shown that, if Laminaria sticks of suitable size, 1.2 mm in diameter, are used, the gradual constriction method devised by us in order to test the efficacy of myocardial revascularization procedures do create a more realistic type of coronary insufficiency than the ligation of the main coronary arteries. Accordingly, sticks with this diameter will be used in the next experiment.

(2) *Comparative Study*

A comparative study on the same surgical procedures was also done by the constriction of the coronary arteries instead of the ligation. Eight dogs were divided two by two into four groups; pericardiotomy, cardiopericardiopexy (THOMPSON's Method), cardiopneumonopexy (HARKEN's Method) and BECK I Operation. Simultaneously with each surgical procedure the gradual constriction of the coronary arteries was carried out, using Laminaria sticks of 1.2 mm in diameter. Immediately prior to operation, control electrocardiographic tracings were taken. Three months later, the animals were killed after electrocardiographic examination and then the hearts were removed en masse in order to perform gross pathologic as well as pathohistological examinations.

(i) Electrocardiographic Examinations

The results of electrocardiographic examinations were summarized in Table 7.

Table 7.-Electrocardiographic Changes Three Months After the Gradual Constriction of the Coronary Arteries Associated with the Myocardial Revascularization Procedures

Revascularization Procedures	Dog No.	Lead I	Lead II	Lead III	aVR	aVL	aVF
Pericardiotomy	126	T flat→ negative	T negative→ unchanged	T negative→ increased in depth	T positive→ unchanged	T positive→ unchanged	T negative→ increased in depth ST sagging
	127*	T negative→ positiv	T flat→ negative	T positive→ negative ST sagging	T flat→ negative ST sagging	T positive→ unchanged	T positive→ negative ST sagging
Cardio-pericardiopexy	129*	T negative→ flat	T diphasic→ negative	T diphasic→ negative	T positive→ unchanged	T diphasic→ positive	T diphasic→ negative ST sagging
	135	T diphasic→ flat	T diphasic→ negative ST sagging	T diphasic→ negative ST sagging	T diphasic→ positive	T negative→ positive ST elevation	T diphasic→ negative ST sagging
Cardio-pneumonopexy (HARKEN's) Method)	130*	T flat→ positive	T negative→ increased in depth ST sagging	T diphasic→ increased in depth ST sagging	T positive→ taller	T diphasic→ positive	T negattive→ increased in depth ST sagging
	136	T flat→ positive	T diphasic→ negative	T diphasic→ negative	T diphasic→ unchanged	T diphasic→ positive	T diphasic→ negative ST sagging
BECK I Operation	132*	T negative→ unchanged	T diphasic→ unchanged	T diphasic→ unchanged	T positive→ unchanged	T diphasic→ unchanged	T diphasic→ unchanged
	139*	T flat→ positive	T positive→ lower	T positive→ lower	T negative→ unchanged	T negative→ flat	T positive→ unchanged

* After operation bigminy appeared.

In the BECK I Operation group, the electrocardiogram taken three months after operation showed no detectable changes of T wave and ST segment from the preoperative tracing (Fig. 25). In the other groups, T waves became typical of the "ischemic T wave" with coving, mostly accompanied by downward shifting of ST segments in lead II, III and aVF (Fig. 26, 27, 28).

Before Operation **Fig. 25.** After Operation

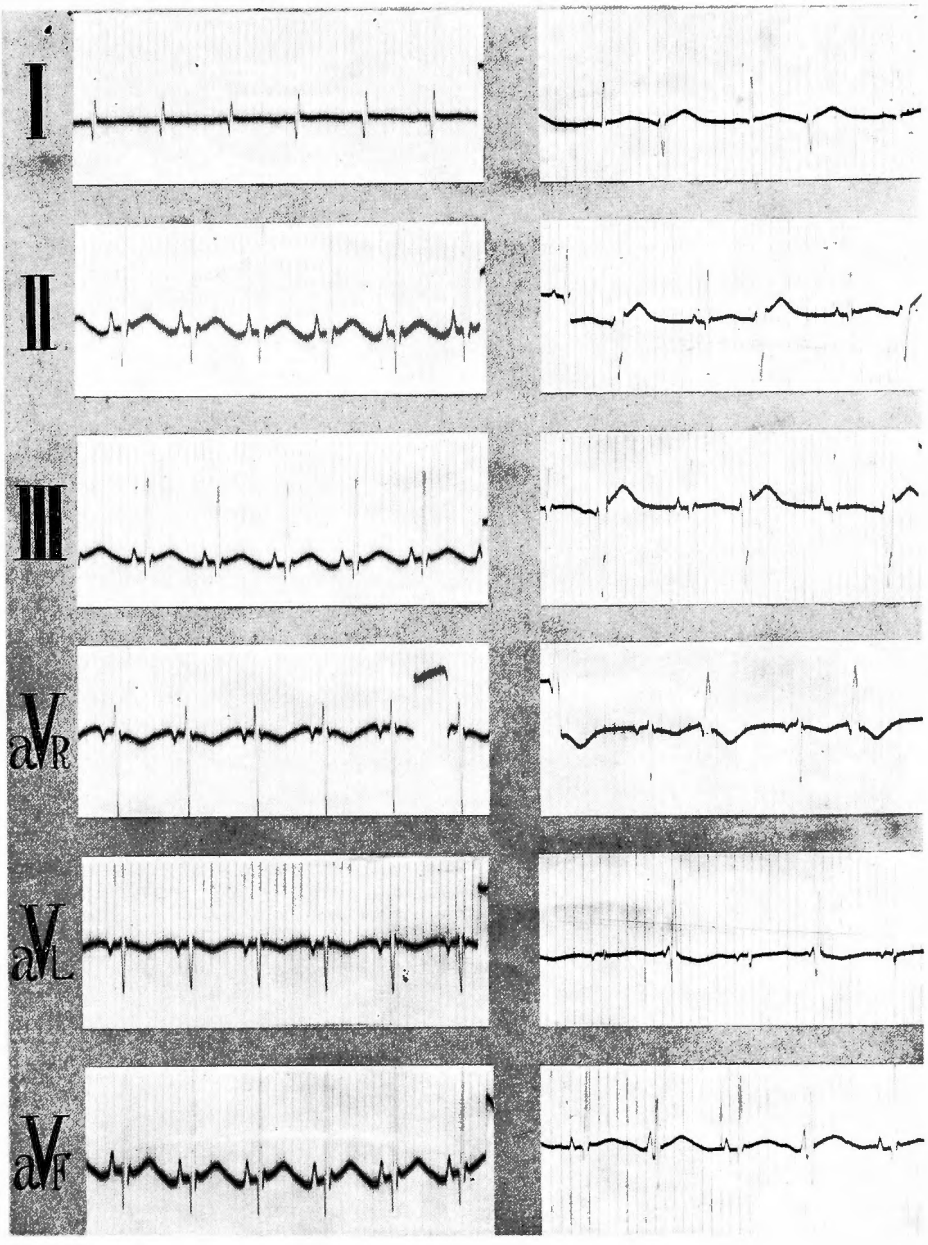


Fig. 25-Electrocardiograms taken before and three months after gradual constriction of the coronary arteries associated with Beck I Operation in dog No. 139. After operation bigeminy was noted.

(ii) Gross Pathologic and Histopathological Examinations

No gross infarcted area was found in any heart. The plastic sleeve encased areas of the coronary arteries showed the same histological appearances as described in the preliminary study. However, more marked intimal hyperplasia and, occa-

Before Operation **Fig. 26.** After Operation

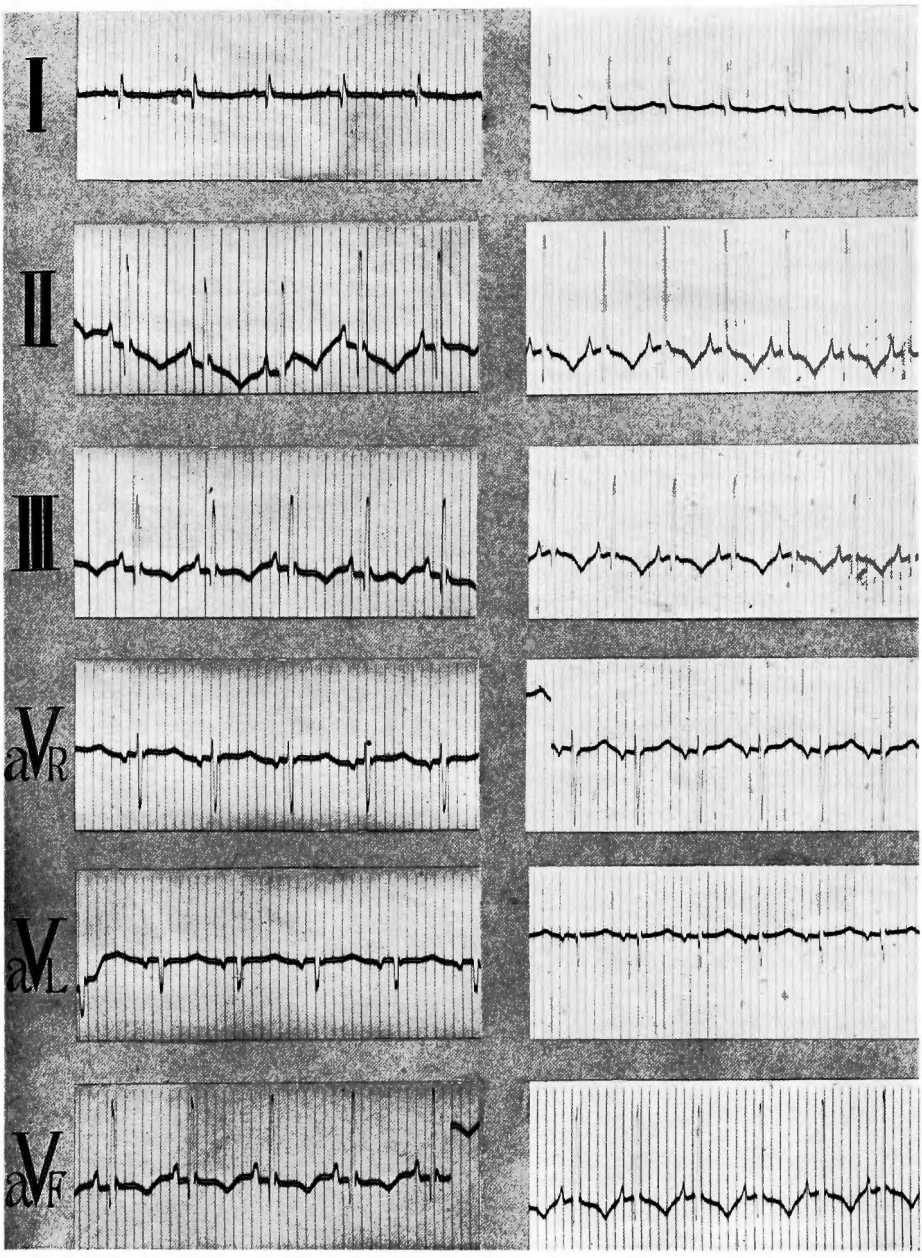


Fig. 26-Electrocardiograms taken before and three months after gradual constriction of the coronary arteries associated with pericardiotomy in dog No. 126.

sionally, thrombosis were found (Fig. 29). Myocardial tissue showed a normal appearance in almost cases. Only in one (No. 135), subendocardial necrosis with granulocytes infiltration in the anterior wall of the left ventricle was found.

In Experiment II, it is also concluded that Beck I Operation is the most

Before Operation **Fig. 27.** After Operation

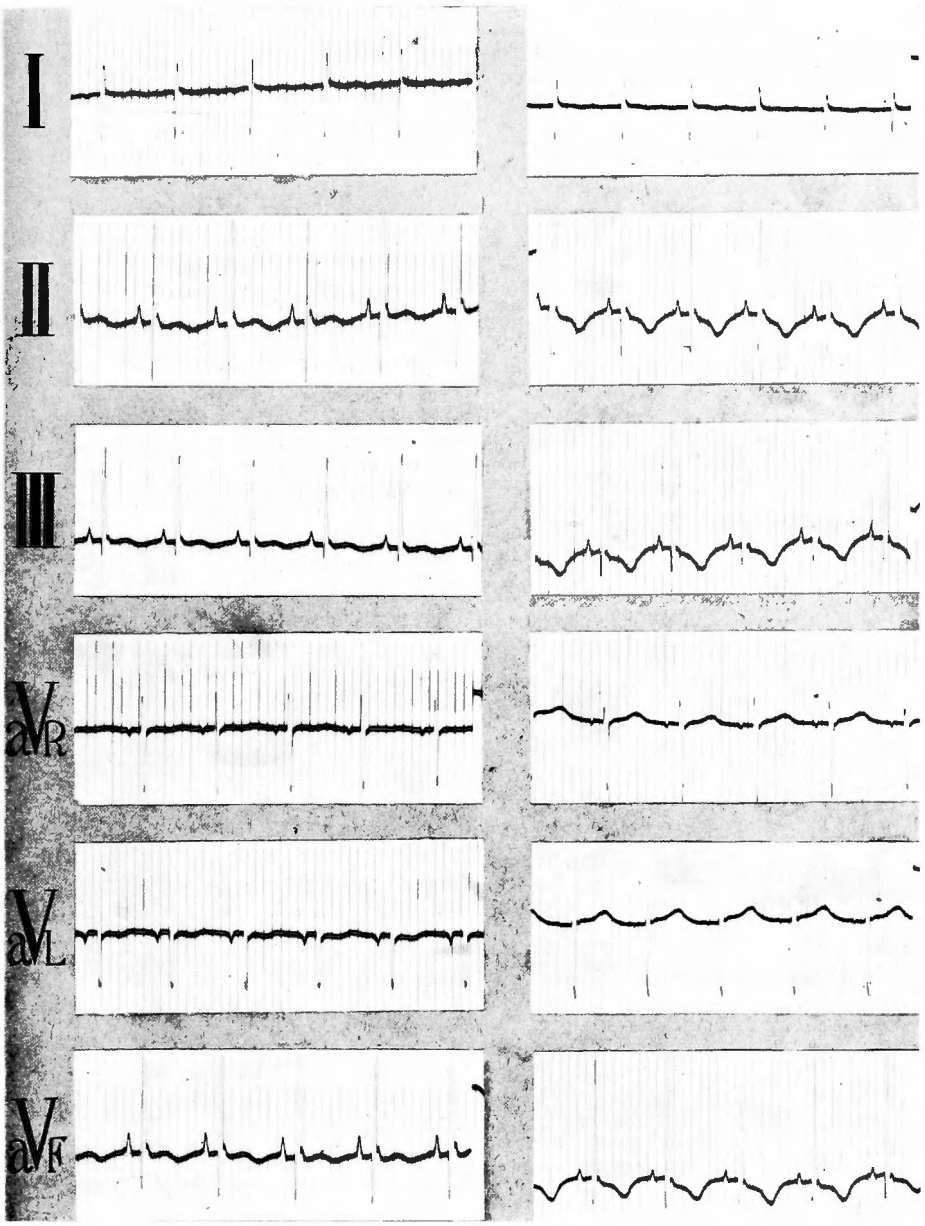


Fig. 27-Electrocardiograms taken before and three months after gradual constriction of the coronary arteries associated with cardiopericardiopexy (THOMSON'S Method) in dog No. 135.

beneficial and there are no significant differences between the other surgical procedures. Even if electrocardiographic changes are interpreted as showing myocardial ischemia, there are occasions when no pathological changes of myocardium are found.

Before Operation **Fig. 28.** After Operation

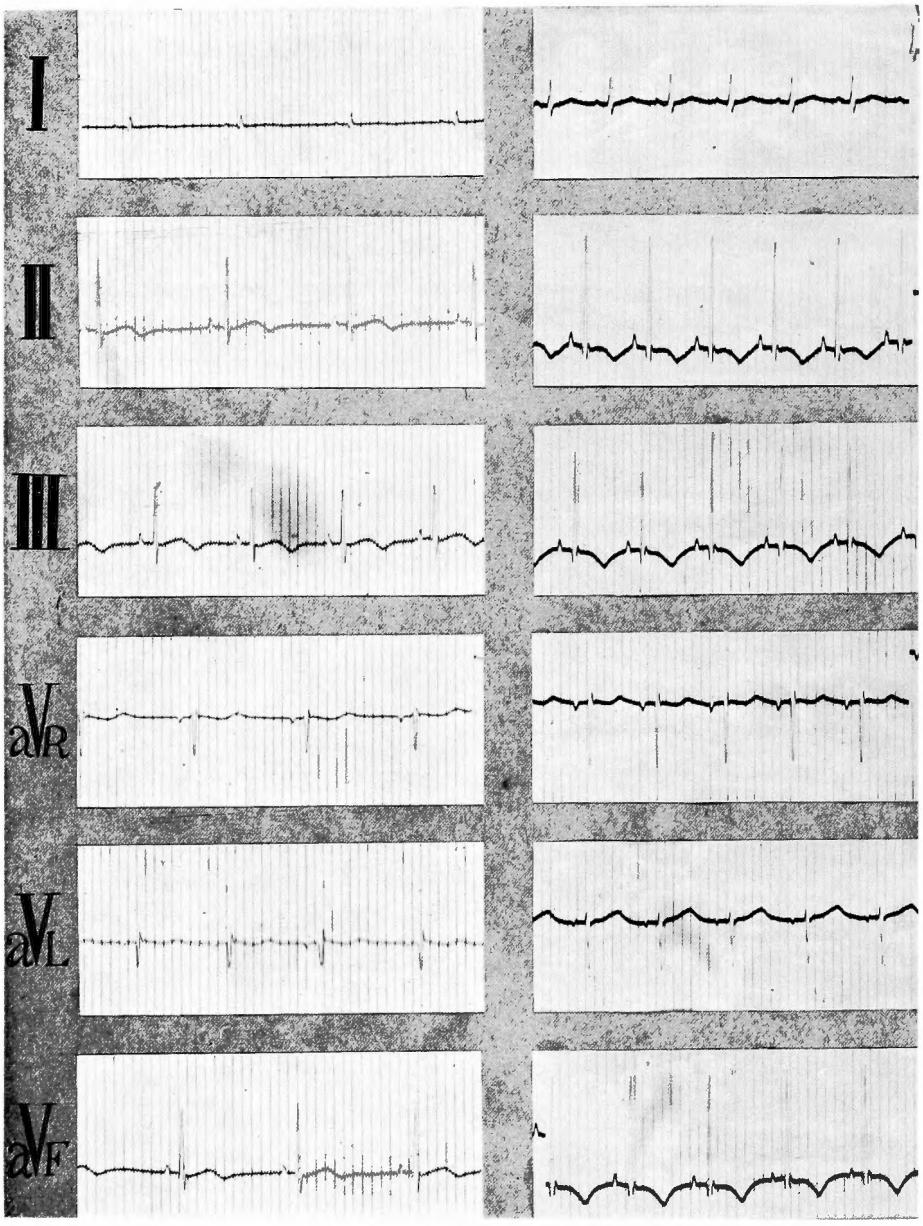


Fig. 28-Electrocardiograms taken before and three months after gradual constriction of the coronary arteries associated with cardiopneumonopexy (HARKEN's Method) in dog No. 36.

EXPERIMENT III

Even a simple procedure, such as pericardiotomy, reduced the mortality from the circumflex-ligation to some degree when it had been previously performed, as described in Experiment I. Under such circumstances, most animals had easily broken adhesions between the peri- and epicardium along the line of the pericardial

Fig. 30–An acrylic resin cast of the coronary arteries from dog No. 310 belonged to the control group. White……Anterior descending branch. Red…… Circumflex branch. Green……Right coronary artery.

Fig. 31–The main coronaries are easily separated one from another because of the absence of intercoronary channels (dog No. 310).

Fig. 32–The arrow pointing out fine and scanty channels between the main branches of the left coronary artery from dog No. 312 which belonged to the control group.

Fig. 33–A fine anastomosis between the main branches of the left coronary artery (dog No. 312).

Fig. 34–The arrows indicate many intercoronary channels from dog No. 309 subjected to pericardiotomy.

Fig. 35–Well developed intercoronary channels (dog No. 309).

Fig. 30

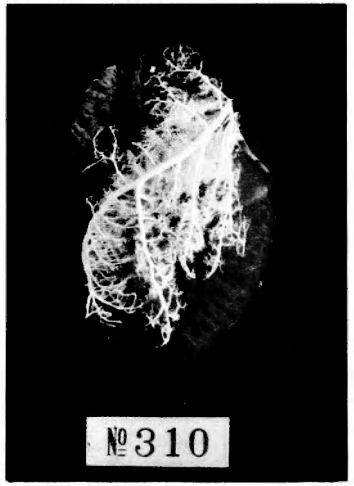


Fig. 31

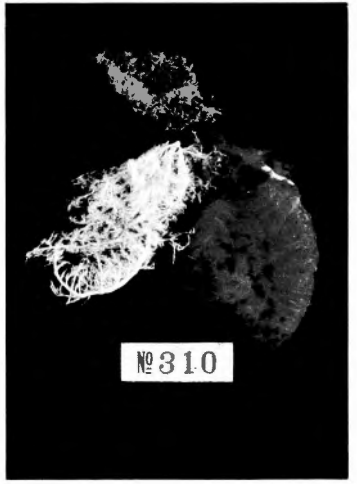


Fig. 32

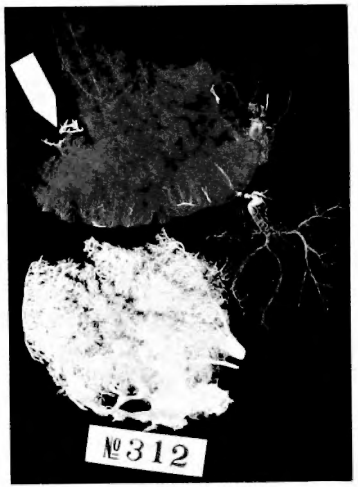


Fig. 33

Fig. 34

Fig. 35

incision.

What caused the beneficial effect ? In order to investigate this matter, the following experiments were done.

1. METHOD

Six dogs were divided into two groups. The first group of three dogs was used as a control. In the second group of the others, pericardiotomy was performed and then, one month later, these animals were killed. Each heart was removed en masse and acrylic resin casts of the coronary arteries were made according to DAY[14] and UCHINO[32] as follows:

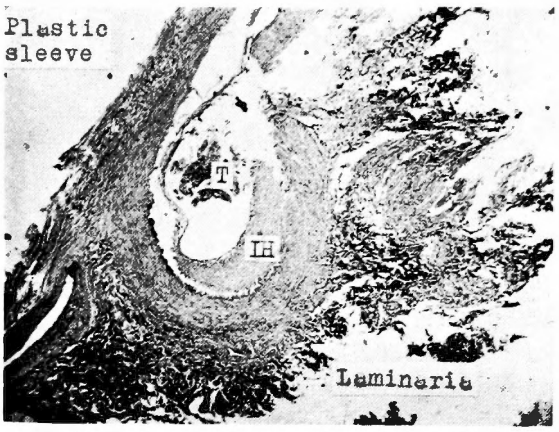


Fig. 29-A transverse section of the plastic sleeve-encased area of the circumflex artery (dog No. 135). IH···Intimal hyperplasia. Thrombus.

(i) For coronary perfusion of a saline solution in order to wash away the blood, a catheter was introduced into the ascending aorta around which a circular ligature was placed. The solution was made to flow out from the cut ends of the pulmonary trunk and caval veins.

(ii) The anterior descending and circumflex branches of the left coronary artery and the right coronary ostium were cannulated with blunt syringes, and then injected with white, red, and green plastic respectively. The specimen was allowed to harden.

(iii) The tissue was then made to corrod away in a 40% NaOH solution of 60°C, leaving a multicolored cast that exibits the vascular structures in three dimensions.

The plastic casts were examined macro- and microscopically.

2. RESULTS

In one of three hearts which belonged to the control group, there were found no intercoronary anastomoses (Fig. 30, 31), but in the remaining two, fine and scanty channels between the anterior descending and circumflex branches of the left coronary artery were evidenced (Fig. 32, 33). On the contrary, in all animals having undergone pericardiotomy, big and abundunt anastomoses between these vessels were found (Fig. 34, 35).

On the basis of these data, it is concluded that pericardiotomy produces the formation of new channels between the main coronaries as well as the dilatation and proliferation of already existing intercoronary anastomoses due to its irritating effect upon the heart, and thus protects the dog from the circumflex-ligation.

DISCUSSION

The comparative study on the relatively simple myocardial revascularization

procedures, pericardiotomy, cardiopericardiopexy (THOMPSON's Method), cardiopneumonopexy without talc powder, cardiopneumonopexy with talc powder (HARKEN's Method), and BECK I Operation was carried out.

Generally, ligation of the anterior descending branch of the left coronary artery has been used as a method for the analysis of possible benefits derived from surgical procedures. However, perusal of the literature on ligation of this artery at its origin in the unprotected dog yielded a surprising variation in the reported mortality from this procedure, i. e., CHARDACK 10%,[11] CARTER 48%,[10] THOMPSON and UCHIYAMA 50%,[31][33] SIDERYS 53%,[30] BECK 70%,[6] and VINEBERG 90%.[36] In attempting it, inclusion of the septal branch which arises from the deep surface of the left common coronary artery or from the under-surface of the origin of the anterior descending branch, has considerable bearing on the mortality as known already. Accordingly, only dogs, in which, after autopsy, the septal branch has not been occluded, should be counted.

In the present study, the anterior descending artery was completely ligated at its origin after dissecting out the vascular area, where the left common coronary artery ramifies into its two main branches, so that no branch of this artery was missed, under anesthesia with sodium pentobarbital and ventilation with 100 per cent oxgen. The mortality from this ligation, both immediate and later, in the control series was only 27 per cent. It is considerably lower than generally thought to be. As CHARDACK reported, it was desired for statistical evaluation that a more easily standardized and a more constantly lethal type of ligation should be used.

Ligation of the circumflex branch of the left coronary artery in the dog having undergone no surgery carried a higher mortality, 75 per cent, roughly approaching the reported mortality (BECK 90%[6] and FAUTEUX 80%[15]).

Consequently, the comparative study was carried out, using this ligation. The ligation was performed three months after in all dogs, prepared in advance by the above surgical procedures, because HARKEN demonstrated that significant benefits derived from his method were noted in animals studied three or more months after operation as contrasted with the poor results in those surviving less than three months.

The infarcts resulting from the ligation were measured in those dogs that lived long enough to develop an infarct by making transverse sections of the heart at various levels. It was decided whether the infarct is transmural or not. The electrocardiogram was used as confirmatory evidence of the other examinations. According to LITVAK et al.[24] the canine electrocardiogram can reveal manifestations of extreme deviation compared with its human counterpart, mainly due to positional changes. Therefore, its changes following the circumflex-ligation were carefully evaluated in relation to the preoperative record. They showed the typical responses to coronary ligation with the development of currents of injury, displacement of ST segments up or down, the development of T wave changes, and arrhythmias.

SIDERYS et al.[30] and UCHIYAMA[33] had already confirmed that simple pericardio-

tomy per se protects the heart considerably, after a major coronary artery is occluded, mainly due to its improving of intercoronary communications. However, it was an unexpected observation that animals having undergone pericardiotomy did almost as well following the circumflex-ligation as did those having undergone the other procedures such as cardiopericardiopexy (THOMPSON's Method) and cardiopneumonopexy (HARKEN's Method). According to BECK,[6] any operation on the heart has the potential of being beneficial, because the trauma incidental to operation produces inflammation which, in turn, produces intercoronary communications. This trauma consists of exposure of the heart to air, possible drying of the surface of the heart, possible friction against gloves and gauze sponges.

The study on acrylic resin casts of the coronary arteries revealed that pericardiotomy produces remarkable new-growing and over-development of intercoronary anastomoses. In addition, most animals having undergone pericardiotomy had easily broken adhesions between the peri- and epicardium. Consequently, it is concluded that most of this protection is provided by intercoronary arterial channels. This fact should be considered seriously in performing surgical treatment for coronary insufficiency. Cardiopneumonopexy without application of talc powder also protected the heart considerably from the circumflex-ligation, though this procedure had hardly produced adhesions between heart and lung and those between peri- and epicardium. Therefore, it is suggested that blood being added to the heart from outside is less important.

The gradual constriction of the coronary arteries devised by us to create a more realistic type of coronary insufficiency is at first produced mechanically by expansion of Laminaria and then biologically by reactive hyperplasia of the vascular wall. In the preliminary study with this test, the electrocardiographic study correlated favorably with pathohistological findings showing myocardial degeneration and necrosis.

After all, it is concluded from the results obtained from the comparative studies with both ligation and constriction tests, that BECK I Operation is the most beneficial and there are no significant differences between the other procedures. This fact is self-evident, considering that BECK I Operation improves the intercoronary channels in two ways, inflammation to the heart and partial sinus ligation.

As described in Experiment II, there was an occasion when the histological examination made on myocardial tissue stained with hematoxylin-eosin showed no detectable changes, although the electrocardiogram suggested its damage. If the electronmicroscopical examination had been carried out according to UEDA et al.,[34] remarkable pathological changes of the myocardium would have been found.

SUMMARY AND CONCLUSION

(1) Dogs were first subjected to the followings urgical procedures: (i) no surgery; (ii) pericardiotomy; (iii) cardiopericardiopexy (THOMPSON's Method); (iv) cardiopneumonopexy without application of talc powder; (v) cardiopneumonopexy with application of talc powder (HARKEN's Method), and (vi) BECK I Operation.

Three months after, the circumflex branch of the left coronary artery was ligated to discuss the comparative merits of these procedures.

In order to analyze possible benefits derived from each surgical procedure, electrocardiographic changes were followed up at suitable intervals for a fifteen minute period after the ligation. Mortality studies and measurements of infarct were also done.

(2) On the basis of the data it is concluded that BECK I Operation is the most beneficial and there are no significant differences between the other procedures.

(3) In order to create a more realistic type of coronary insufficiency, we devised a new method producing the gradual constriction of both main branches of the left coronary artery. The comparative study with this method also revealed the same results as described above.

(4) Experimental ligation of the anterior descending branch of the left coronary artery in a control series carries a mortality of 27 per cent. It is considerably lower than generally thought to be. Therefore, this ligation is an unsuitable method for statistical evaluation.

(5) Even such a simple procedure as pericardiotomy protects the heart almost as well after a major coronary artery is occluded as do the other procedures, such as cardiopericardiopexy (THOMPSON'S Method) and cardiopneumonopexy with (HARKEN'S Method) or without application of talc powder. This procedure produces no extensive adhesions between the peri-and epicardium. Usually there were easily broken adhesions along the line of the pericardial incision.

(6) The study on acrylic resin casts of the coronary arteries revealed that pericardiotomy produces the formation of new channels between the main coronaries as well as the dilatation and proliferation of already existing intercoronary anastomoses, due to its irritating effect upon the heart.

(7) Cardiopneumonopexy without application of talc powder also protects the heart from the circumflex-ligation, although this procedure produces hardly any adhesions between heart and lung and those between peri- and epicardium.

(8) Judging from (5), (6) and (7), it seems that most of the protection is provided by intercoronary arterial channels, and blood being added to the heart from outside is less important. This matter should be considered seriously in performing the treatment for coronary insufficiency.

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*Written in Japanese.

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冠不全の外科的治療に関する実験的研究

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(1) 犬を用い左冠動脈回旋枝結紮により下記術式の優劣を比較検討した.

(i) 無処置, (ii) 心膜切開, (iii) Cardiopericardiopexy) (Thompson氏法), (iv)Cardiopneumonopexy (Phenol de-epicarbializa-tion を行うが, タルク粉末を撒布せず), (V) Cardiopneumonopexy) (タルク粉末撒布, Harken 氏法), (vi)Beck 氏第1法.

各術式の効果は死亡率, 梗塞の大さ, 心電図により判定された.

(2) 実験結果によれば Beck 氏第1法が最も優れ, 他の手術式の間には大差が観られなかつた (但し無処置を除く).

(3) 吾々は冠動脈結紮によるよりも更に実際的な冠不全を作るために新しい方法を案出した. これは左冠動脈の回旋及び前下行枝の根部をプラスチック製の小管で被いこの中にラミナリアの小片を挿入し, 上記血管を徐々に狭窄する方法である.

本法によつて得られた実験結果も回旋枝結紮によるものと同様であつた.

(4) 無処置犬に於ける左冠動脈前下行枝結紮による死亡率は27%の低率であるので各術式の効果判定には不適当である.

(5) 心膜切開と云う簡単な術式でも Cardiopericardiopexy や Cardiopneumonopexy と殆ど同程度に冠動脈閉鎖に対して防禦作用を示す. この際の心膜と心臓の癒着は一般に心膜切開線に沿う軽度なものであつた.

(6) 冠動脈の合成樹脂鋳型標本によれば心膜切開は心臓に対する刺戟に因つて冠動脈相互の吻合を増強せしめる.

(7) タルク粉末を撒布しない Cardiopneumonopexy は殆ど心臓と肺及び心臓と心膜との癒着を生じないにもかゝわらず効果を示した.

(8), (5), (6), (7) から判断すると上記術式の効果は主として冠動脈間の吻合によつて生じたものであつて, 心臓外から心筋に添加される血液は大して意義のないものであると云うことが出来よう. この事は冠不全の外科的治療を行うにあたつて重視されねばならない.