
原 著

A MODIFIED CARDIOPNEUMONOPEXY UTILIZING CONGESTIVE LUNG AND ASBESTOS POWDRAGE IN MYOCARDIAL REVASCULARIZATION

by

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INTRODUCTION

As is well-known, during the past quarter century a number of operative techniques¹⁻¹⁷⁾ have been designed and practiced in the surgical treatment of coronary insufficiency.

The authors have been of the opinion that the intervention of the operation for coronary insufficiency should be as small as possible because of the nature of the disease, and also that blood should be positively introduced into the ischemic myocardium. Based on this idea, a new improved cardiopneumonopexy—a modified technique utilizing the congestive lung and asbestos poudrage—was designed in May, 1956¹⁸⁾.

Results, studied from various view-points, of the application of this modified cardiopneumonopexy to a number of dogs were satisfactory on the whole.

The present article reports the results of these experiments.

OPERATIVE PROCEDURES

Mongrel dogs 10-15 kg in weight were anesthetized by intravenous thiopental sodium. Under endotracheal artificial respiration, left thoracotomy was performed in the fourth intercostal space (Fig. 1). The pericardium was resected widely in order to expose the left ventricle. The middle lobe branches of the left pulmonary veins, corresponding to the lingular vein in human beings, were ligated or partially occluded at the hilum to create congestion in the lobe. Then the surface of the myocardium and the medial surface of the middle lobe were powdered with a small amount of asbestos powder. Finally, the middle lobe was inflated by endotracheal pressure and introduced into the pericardial sac, and sutures were made at several points between the opened pericardial edges and the middle lobe so as to keep the

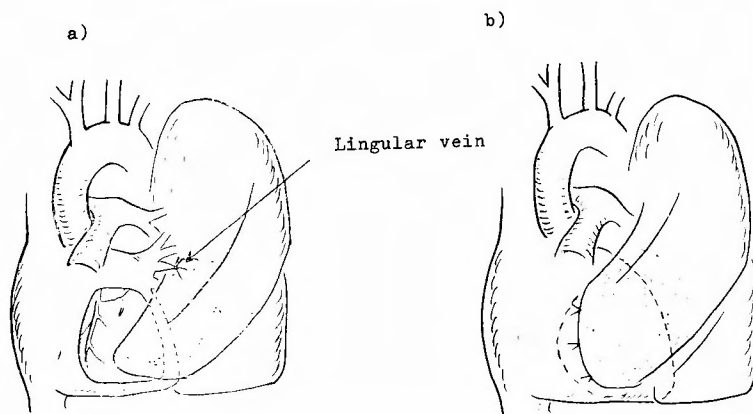


Fig. 1 Operative procedure of modified cardiopneumonopexy utilizing congestive lung and asbestos poudrage

tip and the medial surface of the lobe in close contact with the myocardial surface. The operation was concluded by closure of the thorax.

This operative technique is very simple, and the whole procedure may be completed within 20~30 minutes.

EXPERIMENTAL METHODS AND RESULTS

A. First, the following three experiments were conducted for evaluating the effects of modified cardiopneumonopexy.

Experiment I Studies on the Ligation of the Anterior Descending Branch of the Left Coronary Artery

For the purpose of studying to what extent this modified operative technique is capable of preventing the disturbances provoked by the ligation of the anterior descending branch of the left coronary artery, it was carried out in dogs, in which ligation was done about one month later. The ligation was always made 0.5 cm distal to the origin of the anterior descending branch. Then changes in the ECG pattern and the mortality rate were studied. The dogs that survived the ligation were sacrificed and examined as to whether myocardial infarction was present or not more than one month after the ligation.

Control dogs were subjected to the anterior descending branch ligation but not to the modified cardiopneumonopexy (unprotected dogs).

a) ECG Findings (Lead II, aVf).

In the ECG pattern, marked changes in ST segments or T-waves, or premature contractions were found in all 25 cases of unprotected dogs at the time of the anterior descending branch ligation. But in 15 protected dogs, the ST segment was depressed in one case, T-wave became taller in two cases and flattened in two cases, that is, in only five cases were abnormalities found. Besides, the degree of these

changes was slight—within only about 0.1 milivolt.

b) Mortality Rate.

Of 48 unprotected dogs, 13 died of the anterior descending branch ligation, the mortality rate being 27%. In 13 protected dogs the results were excellent with not a single dog dying.

c) Investigation of the Infarction Caused by Ligation.

In unprotected dogs, clear myocardial infarction was found in all the 7 cases that survived the ligation. Widespread scar tissue had formed over the left anterior ventricular wall, which proved to be transmural on cut sections. The thickness of the ventricular wall decreased even to 0.2~0.3 cm.

On the contrary, no infarction was found at all in all the 6 cases of protected dogs that survived, the myocardial thickness was normal, and histopathological changes of degeneration were not found.

The experimental results described above may be interpreted to mean that this modified cardiopneumonopexy is very successful in protecting dogs from the disturbances caused by anterior descending branch ligation.

*Experiment 2 Comparative Studies of the Effects of
Various Other Operative Techniques and Modified
Cardiopneumonopexy on Coronary Artery Ligation*

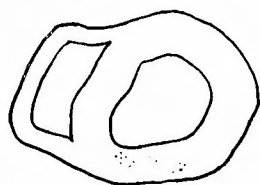
The well-known operative techniques for coronary insufficiency in use to date are; cardiopericardiopexy⁹⁾, Beck I operation¹⁵⁾, cardioomentopexy¹⁷⁾, BIMAL¹⁶⁾, Vineberg's operation¹²⁾ and cardiopneumonopexy (Lezius's simple pexy with sutures²⁾, Carter's operation with asbestos poudrage³⁾ or Harken's operation with phenol-de-epicardialization⁴⁾. For the purpose of comparing the effect of the present modified cardiopneumonopexy with those of the techniques mentioned above, the same procedure as in c) in the preceding experiment was repeated. That is, thoracotomy was performed to ligate the anterior descending branch in dogs that had been subjected one month earlier to the various operative techniques mentioned above. The dogs that survived this ligation were sacrificed several months later to see whether infarction was present or not and to make histopathological comparisons of the severity of damage.

As controls, dogs subjected to simple pericardiotomy were used, as well as unprotected ones subjected to anterior descending branch ligation only.

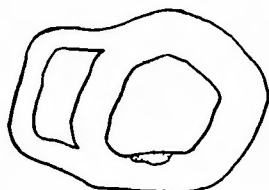
In order to demonstrate the myocardial infarction quantitatively and clearly for each operative technique, Goldman's infarct ratio¹⁴⁾ was used and the cases were also graded 1~5 as to degree of severity depending on the extension of cicatrization on the cut surface of the left ventricular wall (Fig. 2). The expression of the degree of myocardial infarction was made using these two standards.

The results of this experimental evaluation of 41 dogs are tabulated as follows (Table I, II).

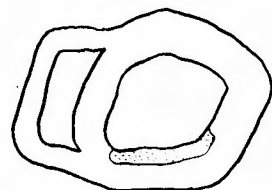
These data indicate that this modified cardiopneumonopexy appears to be the best way of protecting dogs from infarction provoked by ligation of the anterior descending branch.



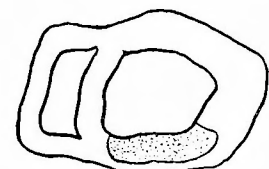
1st degree: Patchy fibrosis in the ventricular wall.



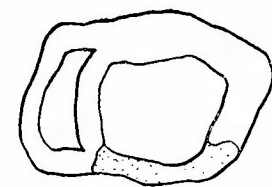
2nd degree: Small circumscribed scar tissue formation in the subendocardium.



3rd degree: Scar tissue formation in the subendocardial myocardium.



4th degree: Scar tissue is almost transmural, except for a thin layer of normal subepicardial myocardium.



5th degree: Scar tissue occupies entire layer of ventricular wall.

Fig. 2 Author's classification of the degree of myocardial infarction of the transverse cut surface of the anterior ventricular wall.

Table. I Goldman's Infarct ratio following several procedures.

	0	10	20	30	40	50	60	70
Control { Unprotected dog					●●	●●●●●●		
Control { Simple pericardiotomy				●	●●			
Cardiopericardiopexy	●	●		●				
Beck I operation	●	●		●				
Cardioomentopexy			●	●●				●
BIMAL			●	●●				
Vinebdrg's operation			●	●	●			
Lezius's operation				●	●	●		
Cardio-pneumono- pexy { Harken's operation					●●●●			
Cardio-pneumono- pexy { Carter's operation				●●	●			
Asada's operation		●●●●		●				

Table. II Author's classification of myocardial infarction in the cut surface after several procedures.

	No infarct	1	2	3	4	5
Control { Unprotected dog						●●●●●●●●
Control { Simple pericardiotomy						●●●●
Cardiopericardiopexy	●		●			●
Beck I operation	●		●	●		
Cardioomentopexy				●	●●	●
BIMAL					●	●●
Vineberg's operation				●		●●
Lezius's operation					●	●●
Cardio-pneumono- pexy { Harken's operation				●	●	●
Cardio-pneumono- pexy { Carter's operation				●	●	●
Asada's operation	●●●●●●		●			

*Experiment 3 Studies on the Effect of Modified Cardiopneumonopexy
on Dogs with Their Coronary Arteries Gradually Occluded
(GO Dog)*

Gradual occlusion of the coronary artery was done in dogs by placing a sponge containing dicetyl phosphate at the origin of the anterior descending branch of the left coronary artery and by surrounding both sponge and artery with a frame made of an aluminum plate and steel wires (Fig. 3)¹⁹.

In these dogs, the coronary arteries were compressed and thus occluded gradually by granuloma which developed increasingly around the dicetyl phosphate crystals during the 1~2 months after the operation.

Among 45 dogs thus treated, 10, or 22 %, were found to have moderate

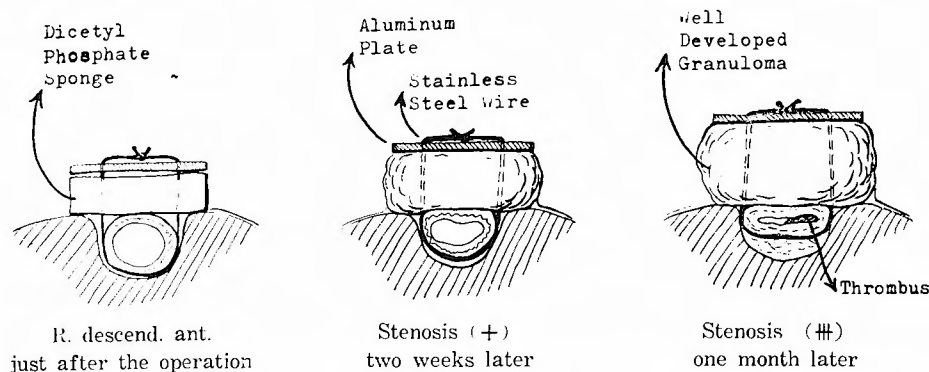


Fig. 3 Production of gradual occlusion of R. descend. ant.

coronary narrowing, and 25, or 56%, were markedly narrowed. Histologically, there were invasion of connective tissue into the media marked intimal proliferation and thrombus formation in the wall of the narrowed coronary artery (Fig. 4). Also the area of myocardium supplied by this narrowed artery was found to be infarcted in eight cases and had patchy fibrosis in nine out of 45 cases. In addition, most cases showed signs of myocardial anoxia such as vacuolization, pyknosis etc. In short, these dogs showed symptoms quite similar to the coronary sclerosis of human beings. The authors refer to such dogs as GO dogs.



Fig. 4 Photomicrograph of narrowed artery (GO dogs).
($\times 50$, hematoxylin and eosin stain).

For the purpose of studying to what extent this modified cardiopneumonopexy is capable of protecting the myocardium from this type of gradual occlusion of the coronary artery, dogs were subjected to gradual occlusion and to this modified operative technique simultaneously and were sacrificed 1~2 months later.

Among the eight dogs employed in this experiment marked coronary narrowing was present in six cases and moderate narrowing in two, the area of myocardium supplied by the coronary artery showed quite normal histopathological findings

except that a small area of patchy fibrosis was found in two cases among the former.

These results indicate that this modified cardiopneumonopexy is also capable of protecting the myocardium from disturbances provoked by progressive gradual coronary occlusion.

B. The next experiments were performed to elucidate the mechanism of the pronounced protective effect shown by this modified cardiopneumonopexy.

Experiment 4 Studies on the Collateral Vessels in the Adhesions Between the Lung and the Heart

As this modified cardiopneumonopexy was initially intended to promote collateral vessel formation between the lung and the myocardium by creating congestion in the former, the first morphological studies on the cardiopulmonary adhesions were carried out with great concern.

a) Observations on Protected Dogs.

Six cases of protected dogs that had been subjected to the modified cardiopneumonopexy and had survived the ligation of the anterior descending branch performed one month later, were sacrificed after 1~6 months and examined after injection of india ink into the left pulmonary artery.

Macroscopically, india ink was distinctly observed to have reached the myocardium flowing through the collateral vessels between the lung and the heart, and to have reached the papillary muscles in large quantities. Comparison of these results with those in the control dogs which were subjected to the cardiopneumonopexies of Lezius, Carter or Harken revealed that the degree of india ink infiltration from the lung to the myocardium was far greater in the case of this modified procedure than in the other three.



Fig. 5 Adhesion between the lung and the myocardium with plenty of newly formed vessels, including many particles of india ink which had been injected into the pulmonary artery. ($\times 50$, hematoxylin and eosin stain).

Histologically, the endothelial cells of the pulmonary pleura and of the epicardium disappeared or were disarranged, so that the parenchyma of the lung and the myocardium had become closely and directly adherent to each other with newly formed granulation tissues between them (Fig. 5). Within this newly formed granulation tissue were also found crystals of asbestos surrounded by macrophages. Among them were found winding many newly formed vessels with diameters as great as $70\ \mu$, within which india ink particles were closely packed.

These particles of india ink were found further to have infiltrated into the coronary arterial branches on the cardiac surface, and into both arteries and veins within the myocardium.

b) Results Obtained from Protected GO Dogs.

Eight dogs were sacrificed 1~2 months after the procedure and gradual occlusion. After being injected with Schlesinger's masses²⁰⁾ (translucent to X-ray, larger than $40\ \mu$ in diameter) in the left pulmonary arteries, these dogs were examined radiographically and histopathologically.

In the X-ray pictures of the vessels, Schlesinger's masses were distinctly observed infiltrating from the lung into the myocardium. This infiltration only minimally observed in the dogs described in a) above whose normal hearts were subjected to the modified cardiopneumonopexy.

The cardiopulmonary adhesions in these dogs were formed more clearly and closely than those in the dogs used in a). They were quite resistant to attempts to tear them apart with the fingers, and when torn apart forcibly, heavy bleeding resulted.

Histological findings were similar to those obtained in a), but more vessels were newly developed and many of them were found to be greater in diameter,

The above findings seem to indicate that the cardiopulmonary adhesion is formed more distinctly in GO dogs than in normal ones by the modified cardiopneumonopexy, namely that the collateral vessels are formed more distinctly when the myocardium is ischemic.

Yet here rises a question : does the blood actually flow from the pulmonary circulatory system with its lower pressure to the coronary circulatory system with its higher pressure, even when the presence of cardiopulmonary collateral vessels is proved histologically ? In order to answer this question, the following experiments were conducted.

Experiment 5 Investigations on Whether Blood Flow Takes Place from the Lung to the Myocardium in Dogs Subjected to this Modified Cardiopneumonopexy

Instant injection of Evan's blue solution was made into the pulmonary arteries of dogs subjected to the modified cardiopneumonopexy. Blood was collected from the coronary sinus at intervals, and the time between the injection and the first

appearance of Evan's blue in the coronary sinus was determined. In other words, studies were made as to whether a direct short circuit existed between the lung and the myocardium along the blood passage from the left pulmonary artery to the coronary sinus—via the left pulmonary vein—left atrium—left ventricle—aorta—coronary artery—myocardium—and coronary vein.

In five cases of non-treated control dogs, the time required for this circulation was 11~13 seconds, average 11.8 seconds.

In two cases of unprotected dogs, subjected to this modified operative procedure but not to the anterior descending branch ligation, i. e. with the cardiopulmonary adhesions on a normal heart, the time required was 11 and 12 seconds, average 11.5 seconds—the same time as in the non-treated dogs described above.

However, in three cases of protected dogs with this modified operative procedure and anterior descending branch ligation, the time required was 7.8 and 8 seconds, that is, the circulation time was decreased by about 1/3.

The results above may be interpreted to indicate that the short circuit from the lung to the myocardium will not be formed as long as the myocardium is normal, even though the modified cardiopneumonoexy has created new collateral vessels between the lung and the myocardium, and that once the myocardium becomes ischemic the blood flows from the lung to the myocardium.

Experiment 6 Perfusions from the Lung to the Heart

For the purpose of investigating whether the blood flow from the lung to the myocardium takes place even when GO dogs are subjected to the modified cardiopneumonoexy, this experiment of perfusion from the lung to the heart was conducted (Fig. 6).

a) The modified cardiopneumonoexy was applied to dogs at the same time the gradual occlusion was started. Thoracotomy was repeated 1~2 months later. Leaving the cardiopulmonary adhesion as it was, every other connection between the left lung and the surrounding tissues, such as pericardium, mediastinum, chest wall etc, was divided so as to leave the left lung in contact with the body's circulatory system through the cardiopulmonary adhesion alone. Subsequently, congo red solution was injected into the left pulmonary artery at 30 mm Hg, close to the normal pressure of the pulmonary artery. Most of the injected solution flowed out of the cut ends of the pulmonary vein and the bronchial vein or the cut surface of the lung after perfusing through the left lung. Investigations were made to find whether or not part of the perfusing solution actually infiltrated into the general circulatory system through the cardiopulmonary adhesion to the myocardium by observing the degree of congo red increase in the general circulation. Then, upon termination of this perfusion, the quantity of blood plasma in the general circulation was determined using Evan's blue solution. With these figures, the quantity of perfused solution that moved into the myocardium was calculated.

In three cases of control dogs (normal dogs subjected to the modified cardiopneumonoexy), 4.2~5.8 cc, average 5 cc of congo red solution per 100 gm (of

with Carter's, Harken's and Lezius's operations in that order.

Histological examination of the degree of cardiopulmonary adhesions resulting from these four operations revealed the formation of the most distinct adhesions in the group treated by the modified cardiopneumonoexy, followed by the rest in the order given above.

These results demonstrate that among the various techniques of forming cardiopulmonary adhesions, those that form more distinct cardiopulmonary adhesions provoke more abundant blood flow from the lung to the heart. Here again the modified cardiopneumonoexy proved to be excellent.

*Experiment 7 Participation of the Bronchial Arterial
System in the Functional Mechanism of Modified
Cardiopneumonoexy*

That blood supply occurs from the lung to the heart through the cardiopulmonary adhesion when this modified cardiopneumonoexy is applied was proved in the above experiment. However, the pulmonary arterial system is originally of lower blood pressure, and there is the bronchial arterial system with higher pressures in the lung. It is natural, then, that the latter should in some way be related to the blood supply. The present experiment was designed to determine which of these two arterial systems plays the leading role in this blood supply.

After gradual occlusion, dogs were subjected to modified cardiopneumonoexy, and thoracotomy was performed 1~2 months later.

i) First, radio isotope I_{131} ($150 \mu c$) was injected into the left pulmonary artery. Blood was collected at the coronary sinus, and the change in the amount of I_{131} appearing here was recorded against the function of time.

ii) With the same dogs, I_{131} was subsequently injected into the thoracic aorta (the bronchial artery). Blood was collected as in the above experiment at the coronary sinus for recording. The same procedure was also done with non-treated normal dogs as controls.

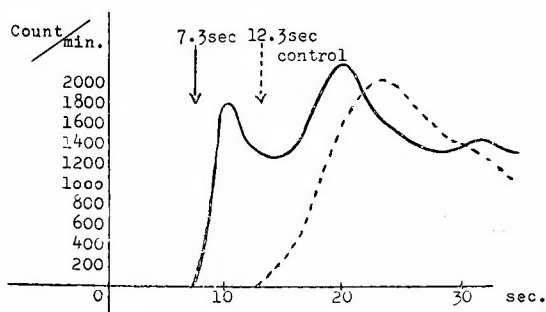


Fig. 7 Results of Experiment i), showing amount of I_{131} in the blood collected from coronary sinus after the injection of I_{131} into the left pulmonary artery.

In the two dogs used in Experiment i), I_{131} was detected at the coronary sinus after 6.4 and 8.2 seconds; average 7.3 seconds. In the two control dogs the time required was 11.7 and 12.9 seconds, average 12.3 seconds. From these data was obtained the curve shown in Fig. 7.

Also in the two cases in Experiment ii), I_{131} was detected at the coronary sinus after 9.1 and 10.1 seconds, average 9.6 seconds, while in five control dogs, the time required

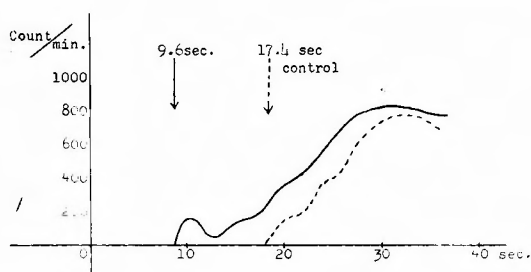


Fig. 8 Results of Experiment ii), showing amount of I_{131} in the blood collected from coronary sinus after the injection of I_{131} into the thoracic aorta.

was 14.5~20 seconds, average 17.4 seconds. Thus the curve shown in Fig. 8 was obtained.

These results indicate that part of both pulmonary arterial blood and bronchial arterial blood flowed from the lung to the myocardium directly through the collateral communications newly developed in the cardiopulmonary adhesions. In short, both arterial systems are related to this blood supply.

Experiment 8 Morphological Studies on the Intercoronary Collateral Communications

Now, it is established that among the coronary arterial branches there are intercoronary anastomoses that are not functional under ordinary conditions, but, once a circulatory disorder takes place in some arterial branch, they are distinctly developed and activated to protect the peripheral myocardium from the occurrence of disorders. Beck et al.¹⁵⁾ claim that the effect of operation for coronary insufficiency is exclusively attributed to the development of these intercoronary collaterals. With this in mind, the present experiment was designed to examine these intercoronary collaterals.

Plastic resin casts of the coronary vessels were produced in (i) normal dogs, (ii) anterior descending branch ligated dogs, (iii) GO dogs, (iv) dogs subjected to the modified cardiopneumonopexy and one month later to the anterior descending branch ligation and (v) GO dogs subjected to the modified cardiopneumonopexy, to compare the development of intercoronary collaterals.

(i) Intercoronary collaterals were very rare in normal dogs.

(ii) In the ligated dogs, transmural infarction had been formed and the myocardium in this section cicatrized about one month after the ligation. The anterior descending branch was found to be filled retrogradely via the thick peripheral intercoronary collaterals on the surface of these cicatrices. These intercoronary collaterals were distinct thick ones that had been produced principally at the cardiac apices between the arteries and the circumflex branches (Fig. 9).

(iii) In GO dogs, the anterior descending branches were found bending and narrowing corresponding to the occluded sections in the arteries. In their peripheries fine networks of intercoronary collaterals were found to have been formed between the arteries and the circumflex branches mainly in the anterior wall of the left ventricle (Fig. 10).

(iv) In dogs subjected to the modified cardiopneumonopexy and one month later to the anterior descending branch ligation and (v) in those subjected to con-

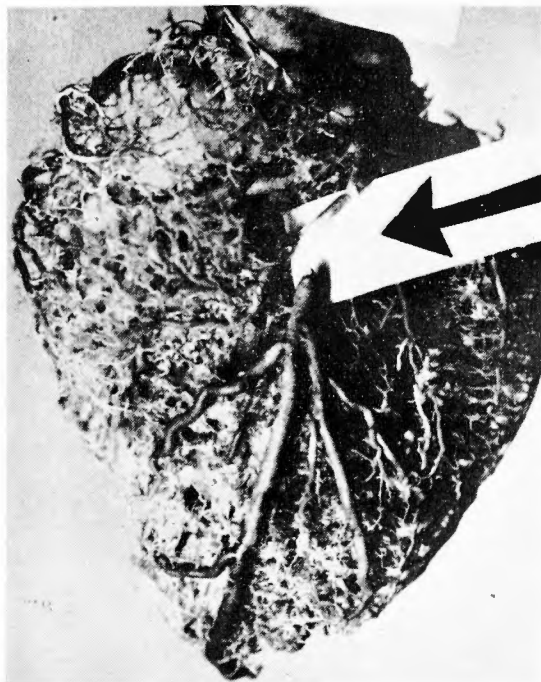


Fig. 9 Photograph of plastic resin cast of the coronary vessels in an anterior descending branch ligated dog, showing distinct thick peripheral intercoronary collaterals.

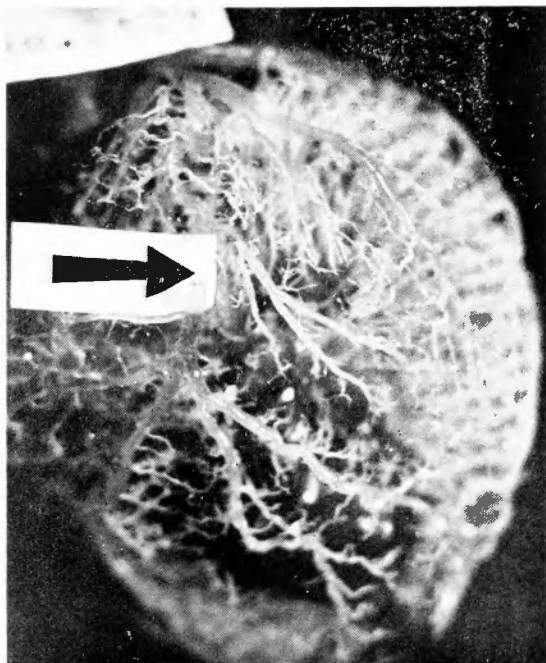


Fig. 11 Less development of intercoronary collaterals in a dog subjected to the modified cardiopneumonopexy and followed by anterior descending branch ligation one month later.

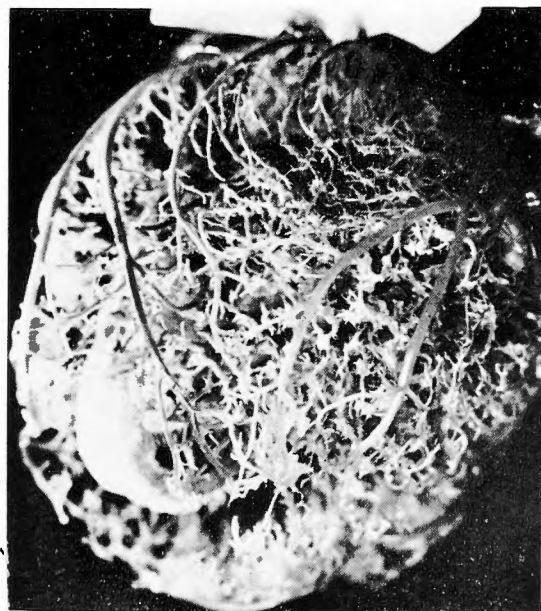


Fig. 10 Fine networks of intercoronary collaterals which developed in a GO dog.

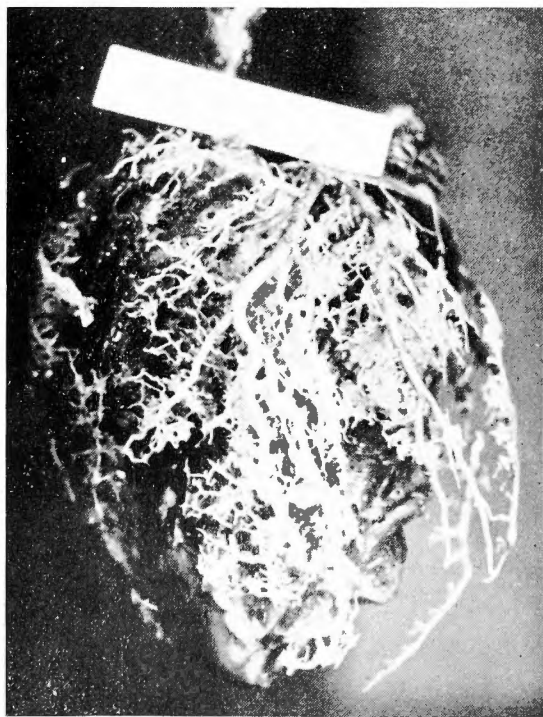


Fig. 12 Poor development of intercoronary collaterals in a dog subjected to concomitant GO formation and modified cardiopneumonopexy.

comitant GO formation and modified cardiopneumonopexy, the development of intercoronary collaterals was poor as compared with that in the ligated dogs and GO dogs used as controls, and only minute anastomoses were found at the apices in (iv) and in the anterior wall of the left ventricles in (v) (Fig. 11, 12).

These results demonstrate that the dogs subjected to the modified cardiopneumonopexy do not develop intercoronary collaterals such as those found in the control groups even after anterior descending branch ligation or gradual occlusion, and yet the subordinate myocardium was protected from the disorders provoked by the ligation or occlusion. Accordingly, the effect of this modified cardiopneumonopexy may be attributed mainly to the development of extracoronary collateral anastomoses within the cardiopulmonary adhesion.

DISCUSSION

1. This new operative technique of ours was designed intending to technically introduce as much exterior blood as possible into the myocardium. The source of this idea was as follows.

i) The viscera, closest to the heart and containing most blood is the lung.

ii) The clinical fact that a distinct collateral communication is formed between the portal system and the caval system in patients with portal hypertension, indicated the possibility of producing collateral communications between the lung and the heart. That is, it was considered that congestion should be created in the lung by means of ligation or occluding the pulmonary veins in order to endow potential ability of collateral anastomosis formation to the pulmonary lobe or area to be adhered to the heart.

iii) In the preliminary experiments, dogs with the left middle lobe vein ligated were examined at intervals. Most of these dogs failed to show any symptoms, but a very few cases had cough and sputum for a few days. Anatomically, the middle lobe formed distinct adhesions with the mediastinum, chest wall and other pulmonary lobes. There a number of collateral vessels developed with the progress of time, with a resultant decrease and disappearance in about one month of congestion in the middle lobe. It was further revealed that the pulmonary parenchyma contained enough air and its tissue appeared almost the same as normal lungs, except that the pulmonary pleura remained thickened. Also examinations of pulmonary function in dogs having the pulmonary vein of one side entirely ligated proved that both ventilation rate and O_2 up-take return to 90% of the preligation state.

iv) For the purpose of enhancing the cardiopulmonary adhesion formation, the authors investigated poudrage with aseptic stimulants (talc and asbestos). Also for the purpose of removing epicardium, a barrier on the myocardial surface, the method of spreading corrosive agent (95% phenol, 5% trypallavin) onto the portion was studied. The latter resulted rather in cicatrization or in regressive degeneration of the outer myocardial layer. In the former asbestos was found superior. It was further confirmed that better results can be expected when a small amount (0.02 gm for dogs and 0.2 gm for human beings) of relatively fine asbestos powder is

spread on the surface of the heart as evenly as possible, and that no sign of cicatrization was detected even during an observation period of two years.

The present modified cardiopneumonopexy was designed on the basis described in the above.

2. Changes in electrocardiography were very small and the mortality rate was 0 at the time of the anterior descending branch ligation, and no infarction was seen in the myocardium supplied by the ligated branch in the dogs that had been subjected to this modified procedure. These results are quite excellent as compared with those obtained in control dogs.

In order to compare the modified cardiopneumonopexy with various typical operative techniques on coronary insufficiency that are generally accepted nowadays, we compared the severity of infarction provoked by ligation of the anterior descending branch, which is considered to be far more accurate than examination of the mortality rate. This also revealed that the modified cardiopneumonopexy was most excellent.

Dogs with gradual occlusion of the anterior descending branch of the left coronary artery were prepared in order to bring the experimental condition as close to clinical cases of human beings as possible. Examinations of the effect of the modified cardiopneumonopexy of these dogs not only proved the presence of distinct collateral communications between the lung and the heart angiographically and histologically, but also revealed the infarction to be far weaker in the myocardium supplied by the occluded artery.

The authors are of the opinion that the above experiments have proved experimentally and theoretically that the modified cardiopneumonopexy is quite a reasonable preventive operation for patients with clinically progressive coronary artery sclerosis or those with the possibility of coronary arterial occlusion in the future.

3. The cardiopulmonary adhesions produced by the modified technique are far more distinct than those produced by the cardiopneumonopexies of Lezius, Carter or Harken in which nothing is done to the adherent lung. Also many collateral communications were detected in the adhesions in this modified procedure, and india ink injected into the pulmonary artery was clearly observed macroscopically even in the inner myocardial layer. On the contrary, no such distinct collateral communications were macroscopically found in any of the other cardiopneumonopexies.

Besides, the formation of cardiopulmonary adhesions is even more evident in GO dogs. This seems to indicate that the degree of the cardiopulmonary adhesion formation becomes higher in the presence of ischemic myocardium, in other words, when the need for blood exists in the myocardium. In this respect, the GO dogs produced by the authors also offered significant and useful materials for experimental research on coronary insufficiency.

4. Determination of the time required for blood flow from the left pulmonary

artery to the coronary sinus and the perfusion test from the lung to the heart proved that, when the myocardium is ischemic (coronary artery ligated dogs or GO dogs), blood flow can take place from the lung to the myocardium through the collateral vessels formed in the cardiopulmonary adhesion.

Also, use of radio isotope I_{131} proved that both the low pressure pulmonary artery and the high pressure bronchial artery are involved in blood supply.

This is probably the first of its kind; such clear physiological demonstrations of the possibility of blood supply from the lung to the heart at the time of cardiopneumonopexy for coronary insufficiency.

Moreover, observations on the mold of the coronary arterial system revealed that the development of so-called intercoronary collateral anastomosis is poor in dogs in which this modified cardiopneumonopexy was effective. This may be considered side evidence for the existence of an extracoronary blood supply from the lung to the heart through the cardiopulmonary adhesions.

CONCLUSIONS

1. A modified cardiopneumonopexy for coronary insufficiency, in which the congested lung produced by ligating or occluding the lobe or segmental veins is made to adhere to the heart by means of asbestos poudrage, was designed.

2. This modified cardiopneumonopexy was proved excellent in its ability to protect the myocardium from disturbances caused by gradual narrowing or occlusion of the coronary artery.

3. An important role played by the blood supply from the lung to the myocardium in the functional mechanism of this modified cardiopneumonopexy was suggested by morphological and physiological experiments.

4. A theoretical basis for the applicability of modified techniques to patients with clinically progressive coronary artery sclerosis was presented based on the above results.

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和文抄録

心筋の血行改善を企図して考案された CARDIO-PNEUMONOPEXY の一変法 (鬱血肺と ASBESTOS POUDRAGE を用いる方法) について

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1. いわゆる Myocardial Revascularization の新しい術式として, 区域静脈を結紮し鬱血を生ぜしめた肺区域を, Asbestos Poudrage を用いて心臓に癒着せしめる心・鬱血肺癒着術を考案した.

2. この手術は, 冠動脈の急性閉塞乃至漸進的狭窄によつて生じる障害, 即ち, 心室細動, 心電図変化, 心筋梗塞の発生等を防禦する上で, 他の諸術式に比し, すぐれた能力を有することが判明した.

3. 本術式の作用機序としては, 心肺間癒着内の新生副血行路を経て肺から心筋へ供給される血液が重要な役割を有し, これには肺動脈系, 気管支動脈系の両者が関与していることが, 形態学的並びに機能的実験により明らかとなつた.

4. 以上の実験結果から, 本術式は冠不全の患者に対して実施さるべき理論的根拠を有するものと思われる.