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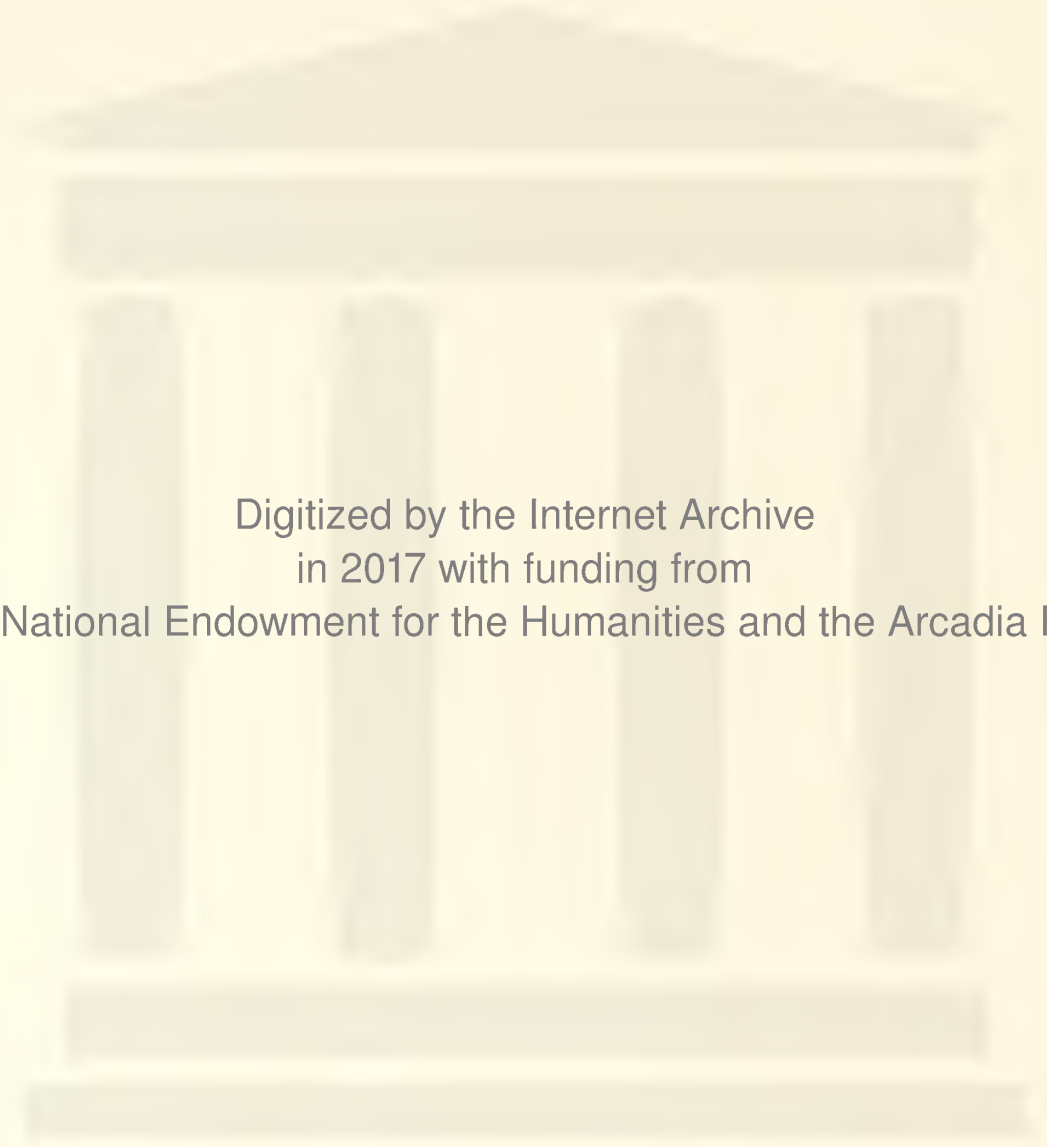

THE EFFECTS OF ARTIFICIALLY STRETCHING SMALL SEGMENTS OF THE PULMONARY ARTERY

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S. J. L.

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INTRODUCTION

There is both favorable as well as contradictory experimental evidence that the mechanism of death by pulmonary embolism partially or totally involves a neural reflex with sensory receptors in the pulmonary arteries and transmission of impulses over the vagus nerve. Clinically, it is a well known entity to have a patient suddenly die who at autopsy shows a minor embolus lodged in a segment of the pulmonary artery. It is apparent that such an embolus could not alter pulmonary blood flow to any significant degree and that the cause of death must be explained on other than a purely mechanical basis. The underlying disease, which many of these people have, may be an important factor in the cause of their death. In other cases, even where a significant amount of pulmonary circulation is affected, death has been too rapid to be accounted for without postulating some other factor than the impedance of blood flow. The possibility, that as an embolus suddenly lodges in a segment of the pulmonary artery, thereby stretching the walls of the segment and setting up a neural reflex, seems worthy of investigation. It is for this reason that the present study was undertaken.

REVIEW OF THE LITERATURE

In 1856 Virchow (1) reported a case in which embolism of the pulmonary artery was postulated as the cause of a sudden death. He attributed death to a decrease in coronary artery blood flow and resultant heart failure. Experiments designed to investigate the mechanism of death involved different conditions. Of importance are the state of anesthesia, operative conditions, and whether or not the experiments were performed immediately after operation.

The experiments of Dunn (2), in 1920, were among the earliest to simulate pulmonary embolism in order to study its pathological physiology. He injected starch particles into the veins of goats and noted that death followed in five minutes to eight hours depending upon the amount of starch used. At autopsy starch was found only in the pulmonary arterioles and not in the brain or other organs, thus indicating that his results truly were due to pulmonary embolization. Of interest in this work was that the tachypnea, induced by moderate doses of starch, was prevented by bilateral cervical vagotomy. Binger, Brow, and Branch (3), in 1924 repeated these experiments in dogs by freezing the vagi. They showed that the tachypnea of pulmonary embolism was not due to anoxemia but rather to reflexes due to congestion and edema of the lungs. Megibow et al (4,5) using starch embolization reached the conclusion that the cause of death in pulmonary embolism was a direct result of the mechanical determent of the flow of blood

through the lungs. They showed that with massive embolization a pulmonary hypertension was reached which caused right heart failure and hence distention of the great veins, particularly the mouth of the superior vena cava. They believed this elicited a reflex tachypnea and dyspnea which was prevented by bilateral cervical vagotomy.

Churchill (6) postulated three mechanisms for death in massive pulmonary embolism; first, complete obstruction of the main artery with immediate death; second, partial obstruction with delayed death due to reduced effective blood volume; third, partial obstruction with delayed death and right heart failure. However, none of these mechanisms explain adequately the fatalities in which only parts of the pulmonary vasculature are blocked. It cannot be denied that mechanical factors play a role when a large artery is blocked, but that this is the only factor can largely be refuted by many experimental and clinical reports. De Takats et al (7) subjected dogs to massive pulmonary embolism and found that 100% died immediately after embolism if nothing were done. 68% of the dogs survived from ten minutes to twenty-four hours when an intravenous atropine preparation was given, and 60% survived when papaverine was used. Scherf and Schönbrunner (8) showed electrocardiographic changes indicative of decreased coronary blood flow in two out of ten dogs subjected to pulmonary emboli. They cite two clinical cases of angina relieved by nitrite following pulmonary embolism. De Takats and his group felt that pulmonary hypertension proximal to an obstructing embolus stimulates sensitive vasoreceptors,

both vagal and sympathetic, which reflexly caused a fall in systemic blood pressure, coronary constriction, vasoconstriction of the pulmonary arteries, bronchial spasm, and vagal inhibition of the heart. In this way they explain why death ensues when only a minor amount of pulmonary tissue is devitalized.

Other experiments have not supported these ideas. Mann (9), in 1917, using blood clots and paraffin in both anesthetized and unanesthetized dogs found that in order to produce death "almost complete" obstruction of the pulmonary circuit was necessary either by one large embolus or by multiple small emboli. Of extreme interest are those of Hall and Ettinger (10). These investigators, using dogs, attempted to demonstrate neural receptors in the area of the main pulmonary artery bifurcation. They used several experimental techniques to do this, such as clamping off the main pulmonary artery or one of its branches, releasing blood clots into a vein with and without vagotomy, stimulating the external surface and intima of the pulmonary artery with a faradic current, and distending the main pulmonary artery and its branches with a rubber cot and at other times with a spring dilator. Their findings indicated that there was no evidence of cardio-systemic reflexes in the dog with distention of a main branch of the pulmonary artery with or without occlusion, or with faradic stimulation of the pulmonary artery bifurcation. They conclude: "The theory that death from pulmonary embolism is due

to reflex effect is not supported by experiments on the dog." However, it must be considered that these experiments were all acute, with open chests, and under deep ether anesthesia.

A short report by Haynes et al (11) described a method of studying circulatory changes in experimental pulmonary embolism by use of a venous catheter fitted with a balloon on its end. This was passed into a lobar pulmonary artery and dilated by a pressure higher than that in the pulmonary artery so as to obstruct blood flow to that lobe. They report "no consistent change" in respiratory rate, femoral artery pressure, pulse, and pulmonary artery pressure in both anesthetized and unanesthetized dogs. Unfortunately, this report does not state the pressure produced upon the walls of the artery nor any of the other data. In contrast, these investigators regularly produced, by slow infusion of 1% lycopodium spores into a lobar pulmonary artery, a rise in respiratory rate, pulmonary artery and right ventricular pressures, electrocardiographic changes, and a decrease in femoral artery pressure in anesthetized dogs. These changes were not altered by vagotomy or pithing the spinal cord.

Carlens, Hanson, and Nordenström (12), using a Cournand cardiac catheter fitted with a thin latex rubber cuff, temporarily occluded one of the main pulmonary arteries of anesthetized dogs by slowly filling the cuff with radiopaque material. They performed ten experiments on eight dogs and report no complications although no actual

pressure and pulse rate data are given. In one dog "very rapid and hard" occlusion was attained with no electrocardiographic or other changes. In a few dogs "slight" increase in pulmonary artery pressure was noted in immediate association with occlusion of one of the main pulmonary artery branches. In 1954, Nordenström (13) performed a series of experiments on a much larger number dogs with no complications when segments of the pulmonary artery were occluded. His method was to inflate the balloon of specially designed venous catheters with radiopaque material under fluoroscopic control, so that the position, shape, size, and movements of the balloon were observed. Sufficient contrast medium was injected into the balloon to cause it to be flattened somewhat by its pressure against the vascular wall. The animals were all under nembutal anesthesia.

In a recent review article, Lilienthal and Riley (14) concluded from the work of others (15, 16, 17) that "There is ample support for the view that pressure changes in the pulmonary bed are monitored locally and that information is transmitted centrally with compensatory reflex adjustments occurring in the pulmonary and systemic circulations." In connection with this Schwiegk (15) demonstrated that alterations in static pressures within the pulmonary bed produced bradycardia and systemic arterial hypotension depending upon the integrity of the vagi. Pearce and Whitteridge (16) recorded from single vagal fibers afferent impulses which were discharged in synchrony with the pulse wave of the pulmonary artery and out of phase

with the aortic wave, thus producing more direct evidence that pressor receptors were operating on the arterial side of the pulmonary circuit. Aviado et al (17) showed that the receptive zone was restricted to the first part of the pulmonary artery.

PLAN

The experimental procedures planned in this study were designed to test whether when segments of the pulmonary artery are put on the stretch, there are cardio-systemic reflexes. Occlusion of blood flow as an initiator of cardio-systemic reflexes was not being tested although in some experiments it simultaneously occurred with the stretching of the artery. Thus, these experiments do not attempt to simulate what actually happens in clinical pulmonary embolism, but rather to delineate a particular physiological function of the pulmonary artery which may be instrumental in death due to pulmonary emboli. In studies such as these it is important to reduce to a minimum the unphysiological conditions of experimentation. For this reason experiments were planned immediately following and six to seven days after operation, closed-chest procedures used rather than open-chest, and waking as well as anesthetized preparations used.

The actual stretching of the pulmonary artery segments was done by balloons made of polyethylene in order to reduce tissue reaction to a minimum. These were placed in the pulmonary artery by an open thoracotomy and left in situ for six to seven days for the second experiment, the first experiment being performed immediately after operation. The following measurements were taken in order to reflect any neural reaction to the stretching of the segments of the pulmonary

artery:

1. Pulmonary artery pressure (proximal to balloon)
2. Systemic arterial pressure
3. Pulse rate
4. Respiratory rate
5. Intrapleural pressure

The pressure in the balloon was also simultaneously measured. Inasmuch as the polyethylene is ineleastic and the balloon diameter much larger than that of the artery, the pressure in the balloon is an actual measure of the pressure exerted on the interior of the segment of pulmonary artery being stimulated if the balloon is not maximally distended.

Although the details of the individual experiments differed, the general plan for all dogs was as follows:

First Phase

An open thoractomy is performed in which the balloon is inserted in the left pulmonary artery, the tube leading from the balloon brought out between two ribs and sutured subcutaneously. A polyethylene cannula for measuring blood pressure is sutured over the main pulmonary artery and also brought out between two ribs to be sutured subcutaneously. Immediately following operation the artery was stimulated with the chest closed and the above measurements recorded on the Hathaway machine.

Second Phase

Six to seven days following the operation the animals were

subjected to a second stimulation and recording. Waking preparations were planned for this phase in most cases.

Inasmuch as a neural reflex was being sought, stimulation times of thirty seconds to two minutes were considered to be adequate to elicit results. At least two recordings were planned for each experiment.

One acute experiment using a very distensible rubber balloon (on a #10 Foley hard rubber catheter) was planned to get maximal dilation of the pulmonary artery segment. However, this was not generally used because this elastic structure obviated the measurement of the actual pressure on the inner wall of the artery. Also, it would have caused too much tissue reaction so that a chronic experiment under more physiological conditions could not be carried out.

MATERIALS AND METHODS

Animals

Mongrel dogs of both sexes weighing 12.5 - 18.0 kgm. were used as experimental subjects. They were kept in large cages and received a diet of ground dog food. Food was removed from their cages twenty-four hours before any operative procedure was performed on them. Operative procedures were carried out under aseptic conditions unless it was planned to sacrifice the animal on the same day. Following operation the dogs received 150,000 units of penicillin and 0.25 gm. of streptomycin intramuscularly daily for six to eight days. When an animal was to be sacrificed, he received an overdose of nembutal intravenously. Autopsy was performed within a half hour of death.

Balloons

The balloons used were made in our laboratory from polyethylene tubing of .085 inch i.d. and .128 inch o.d. The end of the tubing was sealed off and then a segment of approximately 1.5 cm. gently heated over a small microburner. This softened the polyethylene sufficiently so that gentle blowing into the open end of the tubing produced a balloon of the desired shape and size. In general they had a diameter of 1.0 - 1.6 cm. and a volume capacity of 1.0 - 1.5 c.c. were flexible and withstood internal pressures of 200 mm. of mercury or more. The tail of the balloon varied in length from 12 to 20 cm. The end of the tail was heated gently and

Fig. 1. A polyethylene balloon with an attached #15 needle.

then pulled out so as to form a constriction which snuggly held a #15 needle. These and other polyethylene equipment were sterilized by soaking in zephiran overnight.

For a few experiments the 5 c.c. rubber balloons on the ends of #10 hard rubber Foley catheters were used. A great deal of pressure was needed (over 300 mm. of mercury) to distend these.

Pulmonary Artery Pressure

In order to measure the pulmonary artery pressure in a closed chest, polyethylene cannulas as described by Harrison and Liebow (18) were made. Briefly, these are made from polyethylene tubing of .208 inch i.d. and .260 o.d. by heating a short segment and then blowing it into a flattened spheroid which is then trimmed so that a curved flange of approximately 2 mm. projects beyong the tube. A membranous piece of polyethylene seals the flanged end of the cannula and perforations are made about the circumference of this end so that it may be sutured to the pulmonary artery. An obturator of smaller diameter is introduced into the cannula and this is now used to guide a #18 spinal needle to the pulmonary artery from the intact chest wall. In this way pulmonary artery pressure was measured directly.

Aortic Pressure and Pulse Rate

Aortic pressures were measured by dissecting out the femoral artery and passing a polyethylene catheter up into the abdominal aorta. A three-way stopcock on the end of the catheter allowed for

the attachment of a pressure gauge from the Hathaway maching and the introduction of a 1/20 heparin solution. The latter was made by diluting heparin with sterile saline. Pulse rate was obtained from the recordings of blood pressure.

Intrapleural Pressure and Respiratory Rate

Intrapleural pressure and respiratory rate were measured by introducing a #15 needle into the intrapleural space and threading small polyethylene tubing through the needle. The needle was then removed leaving the tubing in the intrapleural space. The tubing was then filled with saline and connected to a Hathaway pressure gauge.

Pressure in the Balloon

The tail of the balloon was connected to a T tube so that simultaneous pressures on the Hathaway could be recorded as the pressure was raised in the balloon. This was accomplished by raising the pressure in a mercury manometer with a syringe to the desired level and then by means of a three-way stopcock the mercury in the manometer simultaneously raised the pressure in the balloon and the Hathaway gauge. This system contained saline or water since a fluid system is less compressible than an air system.

Recording Apparatus

All pressures were measured by a five channel Hathaway Type SYBP-1 Blood Pressure Recording System. The gauge of the Hathaway consists of a plunger which is the pickup element and which fits

into a special hypodermic syringe. The plunger is used to fill the gauge with only a small amount of fluid thus diminishing the damping effect of a long column of fluid. The electrical output of the gauge is directly proportional to the pressure applied through the fluid in the syringe. This output is amplified by amplifier elements in the Hathaway MBC-2 Control Unit, and then fed to the cathode ray tube (which monitors one channel at a time) and the galvanometers in the Type S14-C Oscillograph. The gauges are linear and hence can be calibrated by any static pressure within its range. The pressures measured by the gauges are recorded by the S14-C Oscillograph on a moving photosensitive chart contained in a removable magazine. Time lines and record speeds used in these experiments were 0.1 seconds apart and 1 inch per second respectively. After a record was taken the photosensitive paper was developed with x-ray developer and fixer in the dark room and the record rolled into a convenient scroll. Mean pressures from these records were calculated by the use of a planimeter.

Procedure for First Experiment

The animals were not fed the night preceding the operation. They were anesthetized with intravenous sodium nembutal (60 mgm./c.c.), the dosage level being approximately 35 mgm./kgm. An endotracheal tube was passed so that intermittent positive pressure oxygen could be administered after the chest was opened. The thorax and left femoral area were shaved and prepared with soap, saline, and zephiran.

A fourth left intercostal space incision was made. The upper lobe of the left lung was carefully retracted so that the pulmonary vessels could be isolated with a minimum of dissection. In one dog the main left pulmonary artery was ligated permanently; in all others it was ligated temporarily in order to control bleeding during the insertion of the balloon. The point of entrance of the balloon into the pulmonary vascular tree and its position varied in each experiment and will be mentioned in the individual protocols. However, in general, a minor branch of the pulmonary artery was sacrificed and the balloon passed to any desired position and then the tail secured by a purse string suture at the point of entry. The pericardium was then incised and the polyethylene guide cannula used in measuring pulmonary artery pressure was sutured on the main pulmonary artery at about the level of its bifurcation with atraumatic sutures. The pericardium was closed and both the end of the cannula and the tail of the balloon brought out through the third or fifth intercostal space to be buried subcutaneously. The chest was closed in layers with silk and stainless steel wire. The left femoral area was then dissected and the femoral artery isolated and cannulated. A #18 spinal needle was passed through the skin and, guided by the polyethylene cannula, entered the pulmonary artery directly for the measurement of the pulmonary artery pressure. Small polyethylene tubing was passed into the right intrapleural space for the measurement of respirations as described above. The tail of the balloon was connected to the

T tube arrangement mentioned previously. The pressure gauges were all connected and the record started. After a short control run, pressure was increased to the desired level in the balloon and hence on the inner walls of the segment of pulmonary artery wherein the balloon lay. Several stimulations were recorded. The animal's wounds were then closed and the animal brought back to his cage.

Procedure for Second Experiment

Following the first experiment the dogs were kept on 150,000 units of penicillin and 0.25 gm. of streptomycin for six to seven days at which time they were brought back to the laboratory for the final experiment. Aseptic procedure was not followed in this stage. The anesthesia usually was 2½% sodium pentothal and an intravenous drip of 5% glucose was started to keep a vein open in the event more anesthesia was needed. This was used so that a short acting anesthetic would allow the animal to be prepared and then a waking preparation obtained when it wore off. No intubation was used in these experiments. The skin was incised over the old chest wound so that the tail of the balloon could be obtained. The right femoral area was dissected and the right femoral artery isolated and catheterized. The other connections were the same as in the acute experiments. Stimulations and recordings were performed in both the anesthetized and waking states. The animals were sacrificed by an overdosage of nembutal intravenously and autopsied.

RESULTS

Since procedures varied from dog to dog, individual protocols will be presented.

#359

This was a 17.7 kgm. black female mongrel. On September 3, 1954 a thoracotomy was performed through a 4th left intercostal space incision. The polyethylene balloon was inserted through the left upper lobe pulmonary artery distally toward the left lower lobe. Bleeding from the main pulmonary artery was controlled by a temporary elastic ligature proximal to the left upper lobe. The polyethylene guide cannula was sutured onto the main pulmonary artery as described in the Materials and Methods section. Both the cannula and the balloon stem were sutured subcutaneously in the third left interspace. No acute experiment was performed.

The animal did well for nine days and was maintained on 150,000 units of penicillin and 0.25gm. streptomycin per day. On the eighth postoperative day half the wound sutures were removed. On the ninth postoperative day (September 12, 1954) the animal was being prepared for the chronic experiment with 10 c.c. of nembutal anesthesia. This was given too rapidly and the dog immediately died. No autopsy was performed.

#364

This was a 13.2 kgm. white and brown female mongrel. On September 14, 1954 a thoracotomy and acute experiment were performed under aseptic conditions and sodium nembutal anesthesia. The usual 4th left intercostal space incision was made and the polyethylene balloon introduced through the left upper lobe pulmonary artery distally toward the left lower lobe. The main left pulmonary artery proximal to the left upper lobe was at first ligated temporarily by an elastic band, then permanently by a silk suture. The polyethylene guide cannula was sutured to the main pulmonary artery in the usual manner and the chest closed. Both the cannula and balloon tail came out through the 3rd left intercostal space. The left femoral artery was dissected out and a polyethylene cannula passed into the abdominal aorta. Immediately following operation an acute experiment was performed. Calibration of this experiment was inaccurate due to shifting of the base line in the Hathaway machine, so that the absolute pressure measurements from the pulmonary artery, aorta, and intrapleural space could not be calculated. However, a careful examination of the record showed no obvious changes in these pressures at any time during or after the stimulation. Pulse and respiratory rates could be calculated:

Balloon pressure increased from 0 mm. Hg to over 200 mm. Hg stepwise.
Total stimulation time was 2 min. 30 sec.

	Pulse Rate	Respiratory Rate
At beginning of stimulation	180/min.	24/min.
After 1 min. 15 sec. of stimulation	174/min.	30/min.
30 sec. after stimulation stopped	180/min.	30/min.

The dog withstood the procedure with no apparent effects. An excellent recovery was made while receiving 300,000 units of penicillin and 0.25 gm. of streptomycin for seven days.

The chronic experiment was carried out on September 21, 1954. Sodium pentothal was the initial anesthetic but the dog kept coming out of anesthesia making it impossible to work so that nembutal had to be administered. The right femoral artery was cannulated up to the abdominal aorta. Other measurements were taken as described in Materials and Methods. The calibration in this experiment was inaccurate because of the same defect in the Hathaway as in the first experiment. The respiratory gauge was also defective at this recording. A careful inspection of the record shows no changes in the pulmonary artery or aortic pressures.

Balloon pressure increased from 0 mm. Hg to 200 mm. Hg repeatedly for 5 minutes.

	Pulse Rate
At beginning of stimulation	90/min.
After 2 min. 30 sec. of stimulation	85/min.
At end of stimulation	87/min.

The animal tolerated the procedure well and was then sacrificed by an excess of nembutal.

At autopsy the left lung was loosely adherent to the left chest wall, but peeled away easily. The left upper lobe was infarcted as was a small part of the left lower lobe. The balloon was seen to be intact with very little tissue reaction about it. It lay in the left lower lobe pulmonary artery proximal to its branches. Increasing the pressure in the balloon demonstrated what was considered to be adequate stretching of the pulmonary artery wall.

#366

This was a 12.5 kgm. black female mongrel. On September 21, 1954 operation was performed through the usual 4th left intercostal space incision under nembutal anesthesia. The main left pulmonary artery was occluded temporarily by a clamp with rubber shoes. When this was removed the artery was left permanently patent. The polyethylene balloon was introduced through the sacrificed left upper lobe branch of the pulmonary artery and passed distally toward the left lower lobe. The polyethylene guide cannula was sutured onto the main pulmonary artery in the usual manner and the chest closed. A left femoral dissection was carried out and the left femoral artery cannulated to the abdominal aorta. An acute experiment was carried out with the following results:

First Stimulation

Balloon pressure increased from 0 mm. Hg to 220 mm. Hg stepwise.

Total stimulating time was 65 sec.

	Mean Pul. Art. Pres.	Mean Aortic Pres.	Pulse	Resp.	Mean Intrapleural Pres.
At beginning of stimulation	16 mm. Hg	106 mm. Hg	222/min.	48/min.	-8 mm. Hg
After 30 sec. of stimulation	16 mm. Hg	115 mm. Hg	216/min.	42/min.	-8 mm. Hg
30 sec. after stimulation stopped	16 mm. Hg	112 mm. Hg	198/min.	40/min.	-8 mm. Hg

Second Stimulation (4 min. after 1st stimulation)

Balloon pressure increased from 0 mm. Hg to 220 mm. Hg rapidly.

Total stimulation time was 45 sec.

	Mean Pul. Art. Pres.	Mean Aortic Pres.	Pulse	Resp.	Mean Intra-pleural Pres.
At beginning of stimulation	15 mm. Hg	122 mm. Hg	228/min.	48/min.	-9 mm. Hg
After 24 sec. of stimulation	18 mm. Hg	112 mm. Hg	222/min.	52/min.	-12 mm. Hg
24 sec. after stimulation stopped	18 mm. Hg	120 mm. Hg	216/min.	54/min.	-10 mm. Hg

The dog withstood this procedure well and was returned to its cage where it was maintained on 300,000 units of penicillin and 0.25 gm. of streptomycin for six days. An uneventful recovery was made.

On the sixth postoperative day (September 27, 1954) the second experiment was carried out. 2½% sodium pentothal was used

as the anesthetic, an intravenous infusion of 5% glucose being used to keep a vein open for rapid administration of the anesthetic when needed. Stimulations and recordings were performed while the dog was deeply anesthetized, under light anesthesia, and awake.

First Stimulation (deep anesthesia)

Balloon pressure increased from 0 mm. Hg to 240 mm. Hg rapidly.
Total stimulation time was 60 sec.

	Mean Pul. Art. Pres.	Mean Aortic Pres.	Pulse	Resp.	Mean Intrapleural Pres.
At beginning of stimulation	26 mm. Hg	88 mm. Hg	192/min.	24/min.	-12 mm. Hg
After 30 sec. of stimulation	22 mm. Hg	96 mm. Hg	198/min.	27/min.	-10 mm. Hg
25 sec. after stimulation stopped	32 mm. Hg	84 mm. Hg	204/min.	30/min.	-11 mm. Hg

Second Stimulation (20 min. after first stimulation; very light anesthesia)

Balloon pressure increased from 0 mm. Hg to 250 mm. Hg rapidly.
Total stimulation time was 60 sec.

	Mean Pul. Art. Pres.	Mean Aortic Pres.	Pulse	Resp.	Mean Intrapleural Pres.
At beginning of stimulation	32 mm. Hg	62 mm. Hg	200/min.	22/min.	-8 mm. Hg
After 40 sec. of stimulation	38 mm. Hg	60 mm. Hg	180/min.	30/min.	-6 mm. Hg
30 sec. after stimulation stopped	30 mm. Hg	60 mm. Hg	180/min.	35/min.	-11 mm. Hg

Third Stimulation (12 min. after second stimulation; waking state)
Balloon pressure increased from 0 mm. Hg to 250 mm. Hg rapidly.
Total stimulation time was 60 sec.

	Mean Pul. Art. Pres.	Mean Aortic Pres.	Pulse	Resp.	Mean Intrapleural Pres.
At beginning of stimulation	24 mm. Hg	66 mm. Hg	210/min.	35/min.	-12 mm. Hg
After 30 sec. of stimulation	24 mm. Hg	52 mm. Hg	200/min.	38/min.	-10 mm. Hg
15 sec. after stimulation stopped	19 mm. Hg	40 mm. Hg	190/min.	38/min.	-15 mm. Hg

The dog suffered no apparent effects from these stimulations and was sacrificed in the usual manner with nembutal. At autopsy the chest cavity was clear. There were some very slight adhesions of the left lung to the body wall. Part of the left upper lobe was infarcted. The left lower lobe was free of infarction. Dissection of the pulmonary arteries showed that the main left pulmonary artery was completely patent and free of thromboses. It was apparent that blood flowed freely by the balloon into the left lower lobe. The balloon was intact and stretched the left lower lobe pulmonary artery when the pressure was increased. It lay in the left lower lobe artery just proximal to its branches. No explanation of the significantly higher pulmonary artery pressures and lower systemic pressures in the second experiment could be found.

Fig. 2 Autopsy specimen of Dog #366. The balloon is seen in the dissected left lower lobe artery.

#365

This was an 18.0 kgm. white male mongrel. An operation and the first experiment were performed on September 23, 1954 under sodium nembutal anesthesia. The usual 4th left intercostal space incision was made and the left pulmonary artery identified. The polyethylene balloon was introduced through the left upper lobe pulmonary artery into the main pulmonary artery proximal to the left upper lobe branch. The polyethylene guide cannula was sutured onto the main pulmonary artery in the usual manner and the chest closed. The left femoral artery was cannulated and an acute experiment was carried out.

The record showed very aberrant pressure changes which were explained at autopsy. The dog showed no apparent changes during or immediately following the experiment and was returned to his cage. Approximately one and a half hours later he was found dead. At autopsy there were no hemorrhages in the chest or femoral area. The right lung was discolored and there was a questionable right pneumothorax. No infarction of either lung was noticed. The right heart was dilated. As the right ventricle and pulmonary artery were dissected, the balloon was found in the main pulmonary artery where it apparently acted as a ball valve intermittantly blocking the outflow tract. It completely blocked the right pulmonary artery.

#380

This was a 15.9 kgm. brown and white male mongrel. On December

22, 1954 an operation and the first experiment were performed under nembutal anesthesia. A 4th left intercostal space incision was made and the pulmonary artery to the left lower lobe identified. The branch to the lateral and anterior basalar segments was sacrificed to be used as the point of entry for the balloon. This was passed proximally to the beginning of the left main pulmonary artery which was left patent. The guide cannula was sutured onto the main pulmonary artery and brought out through the left 3rd intercostal space along with the tail of the polyethylene balloon. The chest was closed and the left femoral area dissected. The abdominal aorta was cannulated via the left femoral artery in the usual way.

In the first experiment which followed, the respiratory guage was not working and so respiratory rate was counted by an assistant. All other measurements were made as described in Materials and Methods.

First Stimulation

Balloon pressure increased from 0 mm. Hg to 140 mm. Hg rapidly. Total stimulation time was 80 sec.

	Mean Pul. Art. Pres.	Mean Aortic Pres.	Pulse	Resp.
At beginning of stimulation	14 mm. Hg	128 mm. Hg	180/min.	38/min.
After 40 sec. of stimulation	11 mm. Hg	125 mm. Hg	174/min.	40/min.
25 sec. after stimulation stopped	10 mm. Hg	122 mm. Hg	174/min.	40/min.

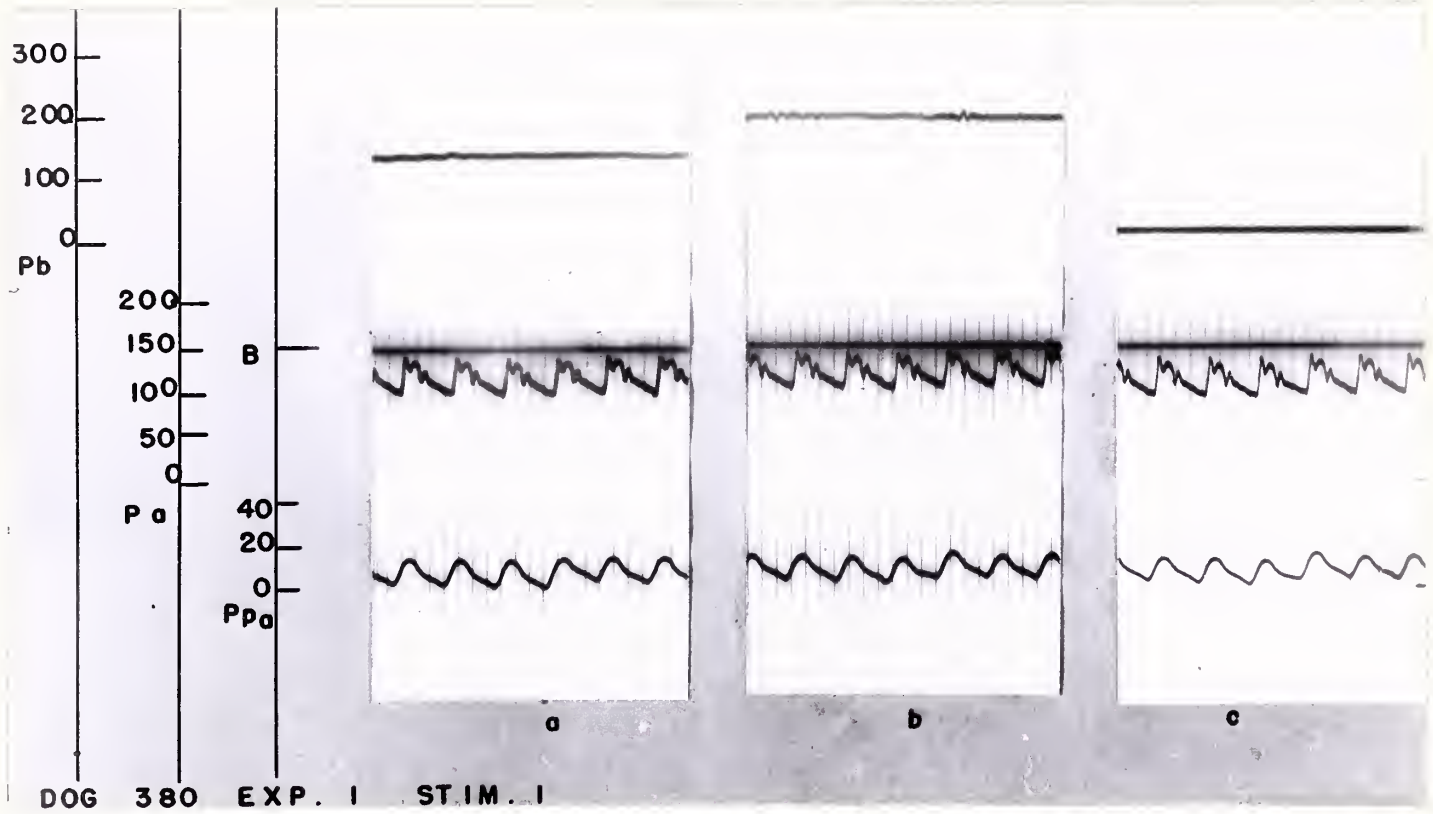

Fig. 3 All pressures in mm. of Hg. Pb=pressure in balloon. Pa= aortic pressure. Ppa=pulmonary artery pressure. B=calibration base line. a=at beginning of stimulation. b=after 40 sec. of stimulation. c=25 sec. after stimulation stopped. Time lines 0.1 sec. apart.

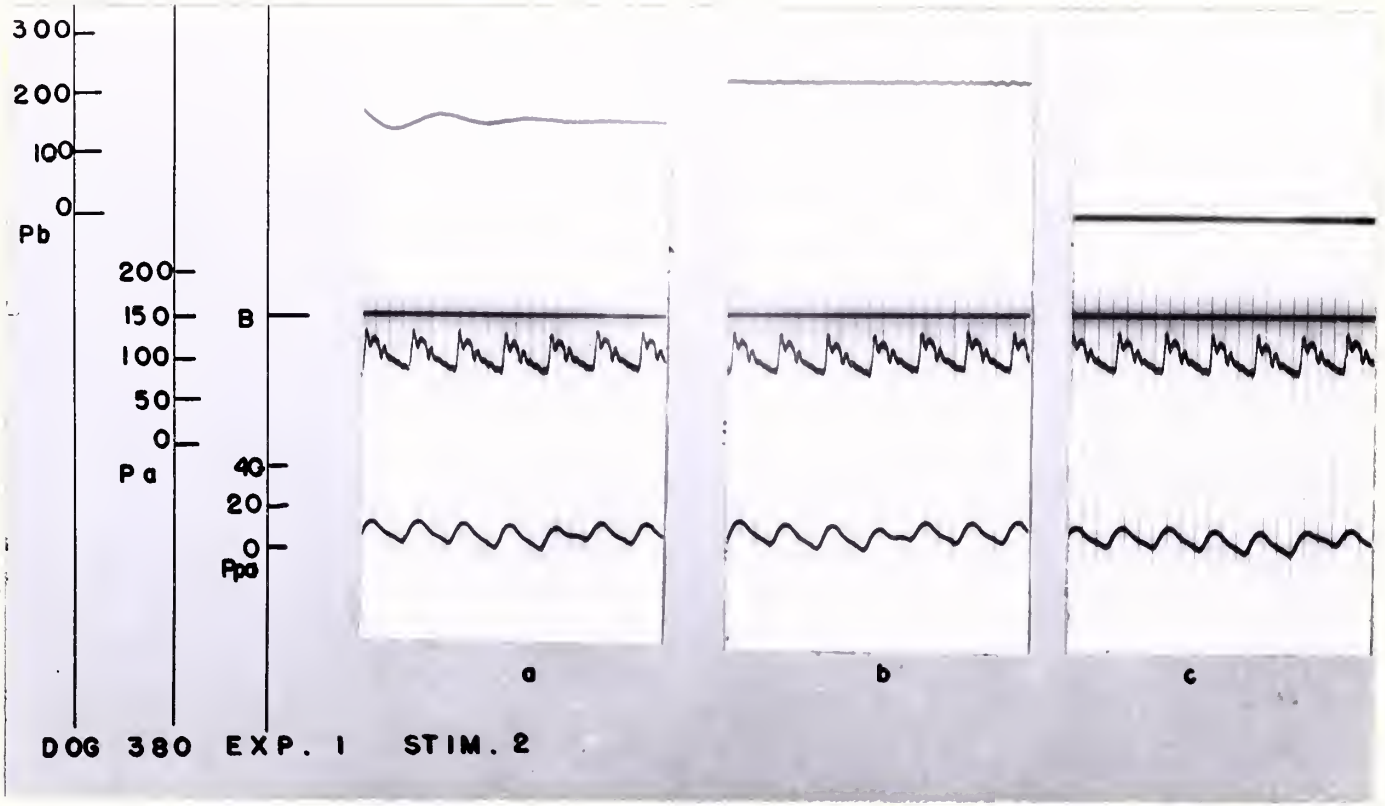

Fig. 4 All pressures in mm. of Hg. Pb-pressure in balloon. Pa=aortic pressure. Ppa-pulmonary artery pressure. B=calibration base line. a-at beginning of stimulation. b=after 24 sec. of stimulation. c-24 sec. after stimulation stopped. Time lines 0.1 sec. apart.

Second Stimulation (7 minutes after first stimulation)
Balloon pressure increased from 0 mm. Hg to 250 mm. Hg stepwise.
Total stimulation time was 48 sec.

	Mean Pul. Art. Pres.	Mean Aortic Pres.	Pulse	Resp.
At beginning of stimulation	11 mm. Hg	112 mm. Hg	162/min.	24/min.
After 24 sec. of stimulation	14 mm. Hg	110 mm. Hg	174/min.	24/min.
24 sec. after stimulation stopped	8 mm. Hg	114 mm. Hg	180/min.	24/min.

No untoward effects were noted from the experiment and the dog was returned to his cage. He had an uneventful recovery and was maintained on 150,000 units of penicillin and 0.25 gm. of streptomycin per day for seven days.

On December 29, 1954, (7 days postoperative) the second experiment was performed under pentothal anesthesia, very light anesthesia, and in the waking state. A 5% glucose intravenous drip was started to keep an open vein for the rapid administration of anesthesia when needed. The intrapleural pressure calibration was inaccurate so that this measurement could not be taken, although respiratory rate could be.

First Stimulation (7 days postoperative; deep anesthesia)
Balloon pressure increased from 0 mm. Hg to 250 mm. Hg stepwise.
Total stimulation time was 40 sec.

	Mean Pul. Art. Pres.	Mean Aortic Pres.	Pulse	Resp.
At beginning of stimulation	36 mm. Hg	200 mm. Hg	150/min.	10/min.
20 sec. after stimulation stopped	28 mm. Hg	215 mm. Hg	144/min.	15/min.

Second Stimulation (1 minute after first stimulation; deep anesthesia)
Balloon pressure increased from 0 mm. Hg to 250 mm. Hg rapidly.
Total stimulation time was 40 sec.

	Mean Pul. Art. Pres.	Mean Aortic Pres.	Pulse	Resp.
At beginning of stimulation	36 mm. Hg	206 mm. Hg	150/min.	10/min.
20 sec. after stimulation stopped	38 mm. Hg	215 mm. Hg	150/min.	10/min.

Third Stimulation (15 minutes after first stimulation; very light anesthesia)
Balloon pressure increased from 0 mm. Hg to 250 mm. Hg rapidly.
Total stimulation time was 66 sec.

	Mean Pul. Art. Pres.	Mean Aortic Pres.	Pulse	Resp.
At beginning of stimulation	74 mm. Hg	250 mm. Hg	138/min.	16/min.
After 33 sec. of stimulation	66 mm. Hg	250 mm. Hg	132/min.	15/min.
20 sec. after stimulation stopped	54 mm. Hg	258 mm. Hg	126/min.	12/min.

Fourth Stimulation (45 seconds after third stimulation; very light anesthesia)

Balloon pressure increased from 0 mm. Hg to 250 mm. Hg rapidly.

Total stimulation time was 3 min. and 20 sec.

	Mean Pul. Art. Pres.	Mean Aortic Pres.	Pulse	Resp.
At beginning of stimulation	60 mm. Hg	260 mm. Hg	126/min.	13/min.
After 2 min. and 40 sec. of stimulation	54 mm. Hg	250 mm. Hg	120/min.	12/min.
20 sec. after stimulation stopped	50 mm. Hg	250 mm. Hg	132/min.	12/min.

Fifth Stimulation (15 minutes after fourth stimulation; waking state)

Balloon pressure increased from 0 mm. Hg to 215 rapidly.

Total stimulation time was 45 sec.

	Mean Pul. Art. Pres.	Mean Aortic Pres.	Pulse	Resp.
At beginning of stimulation	74 mm. Hg	244 mm. Hg	138/min.	20/min.
After 36 sec. of stimulation	70 mm. Hg	250 mm. Hg	138/min.	21/min.

No record taken after stimulation stopped.

The dog withstood the procedure well and then was sacrificed by an excess of intravenous nembutal.

At autopsy there was no evidence of infarction in either lung. The left upper lobe and lingula were slightly adherent to the pericardium, but stripped away with ease. The balloon lay just at the beginning of the left pulmonary artery proximal to the left upper

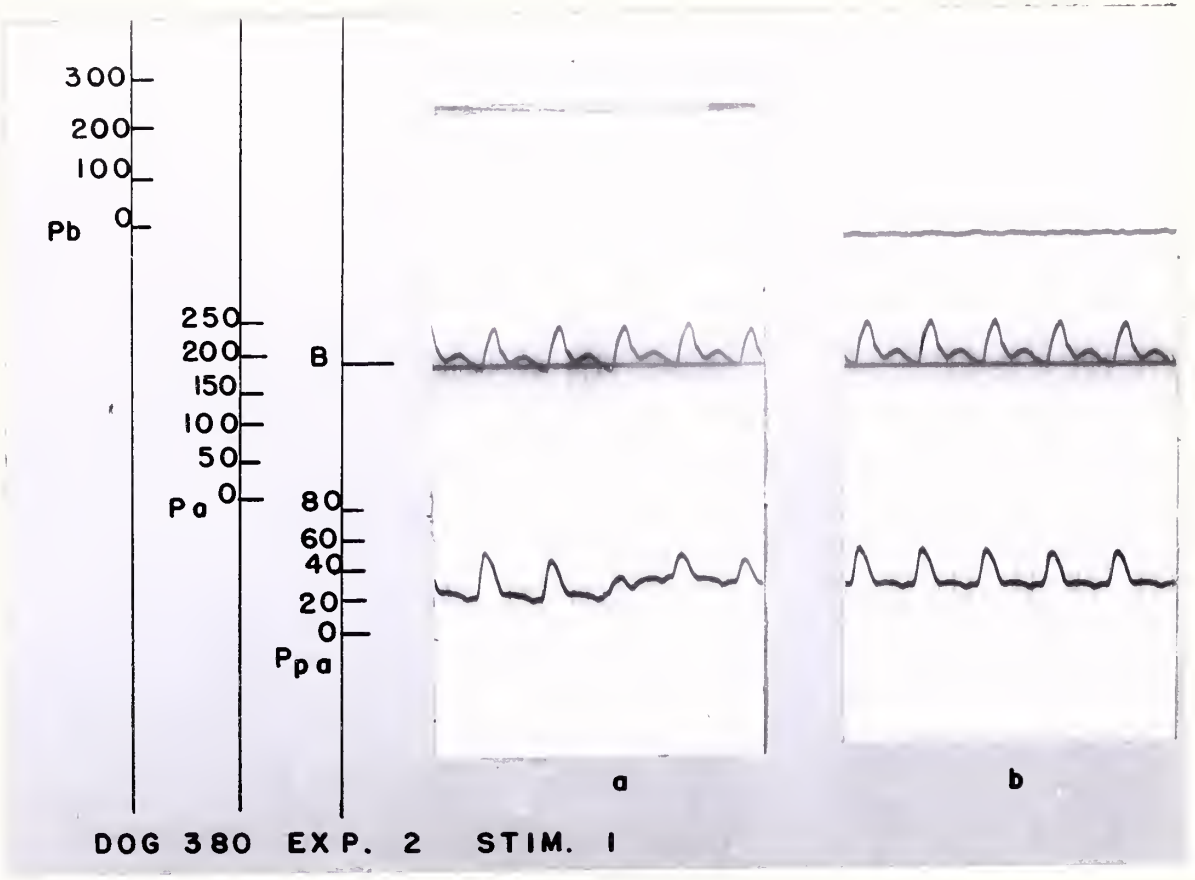

Fig. 5 All pressures in mm. of Hg. Pb=pressure in balloon. Pa=aortic pressure. Ppa=pulmonary artery pressure. B=calibration base line. a=at beginning of stimulation. b=20 sec. after stimulation stopped.
Time lines 0.1 sec. apart.

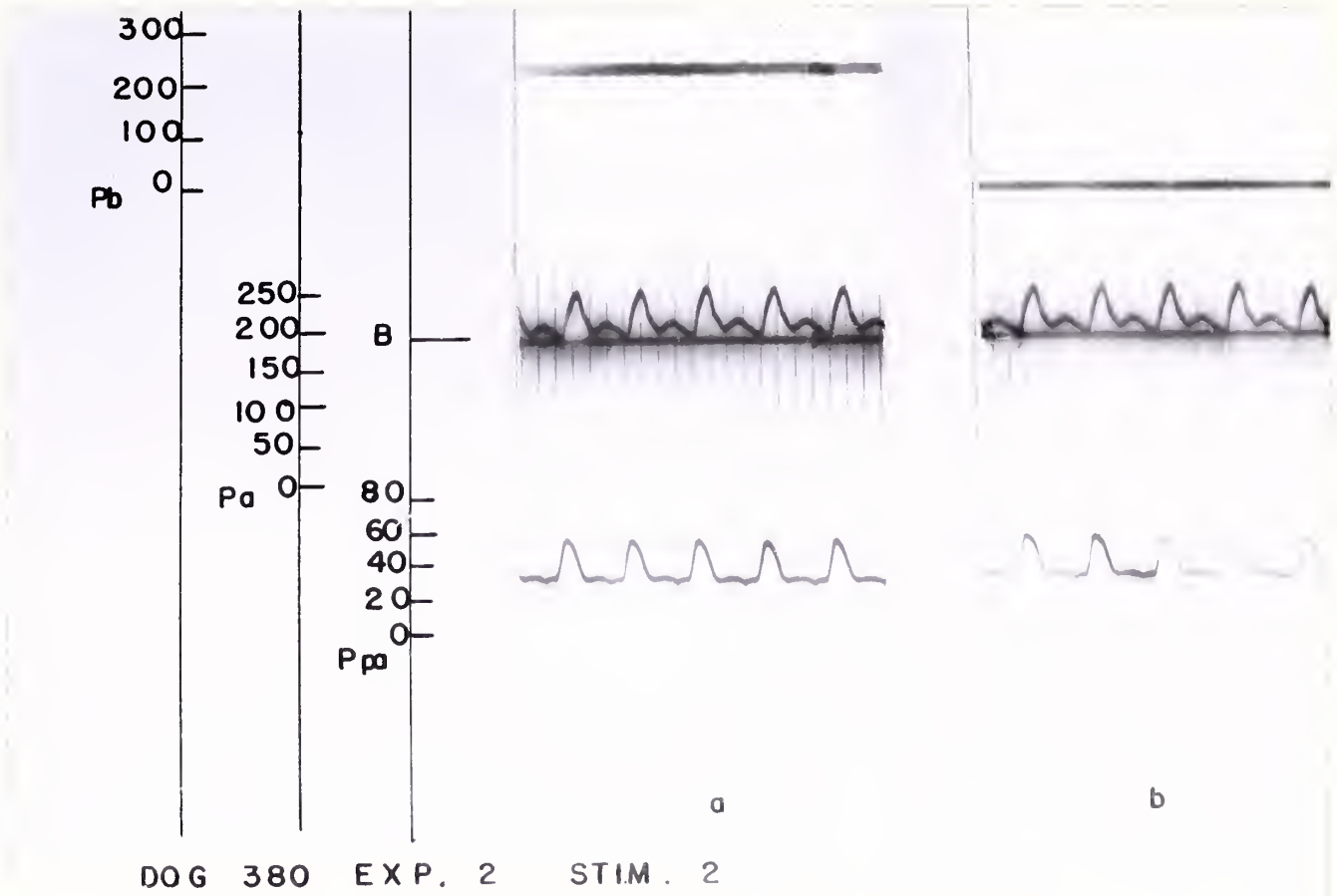

Fig. 6 All pressures in mm. of Hg. Pb=pressure in balloon. Pa=aortic pressure. Ppa-pulmonary artery pressure. B=calibration base line. a=at beginning of stimulation. b=20 sec. after stimulation stopped.
Time lines 0.1 sec. apart.

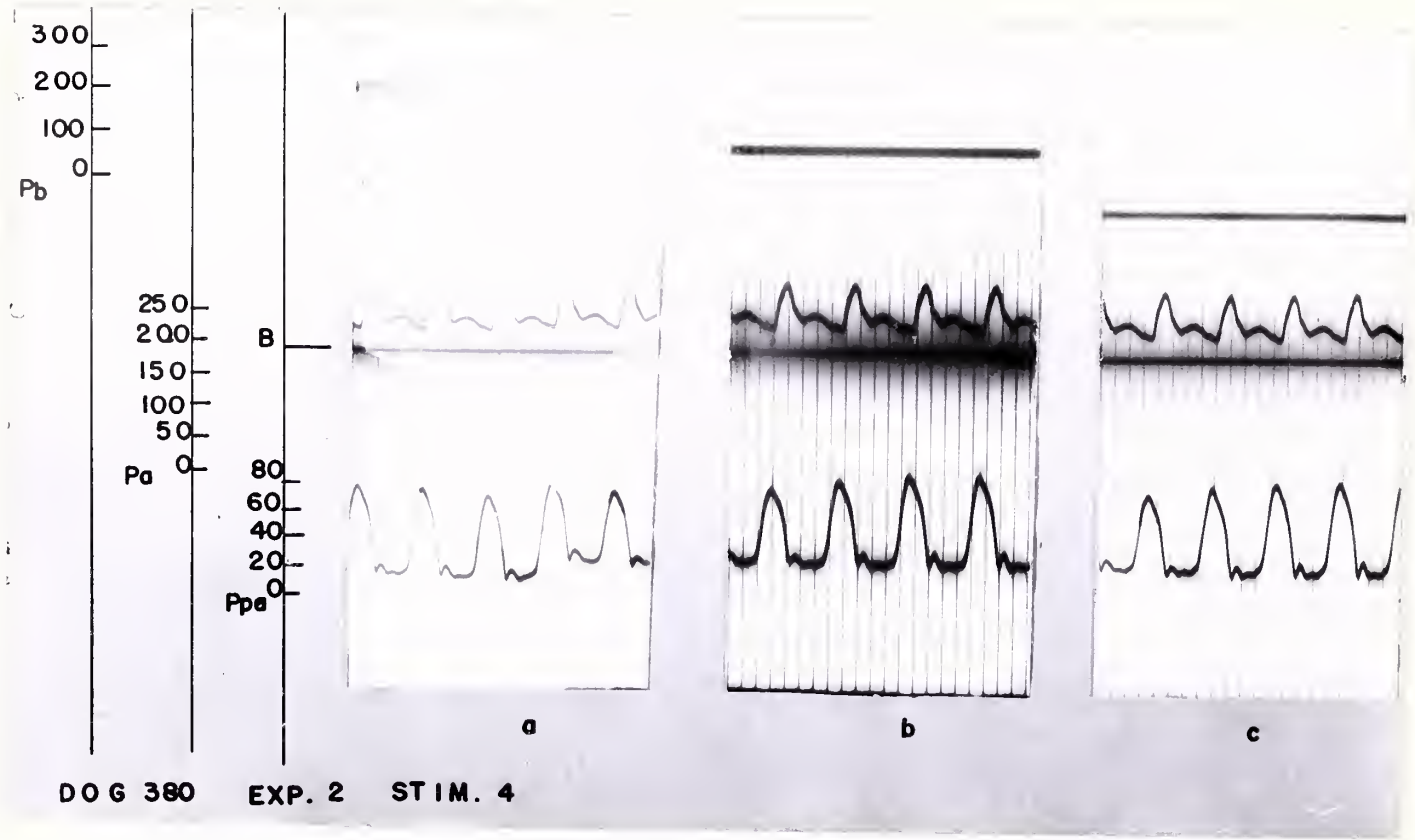

Fig. 7 All pressures in mm. of Hg. Pb=pressure in balloon. Pa=aortic pressure. Ppa-pulmonary artery pressure. B=calibration base line. a=at beginning of stimulation. b=after 2 min. and 40 sec. of stimulation. c=20 sec. after stimulation stopped.
Time lines 0.1 sec. apart.

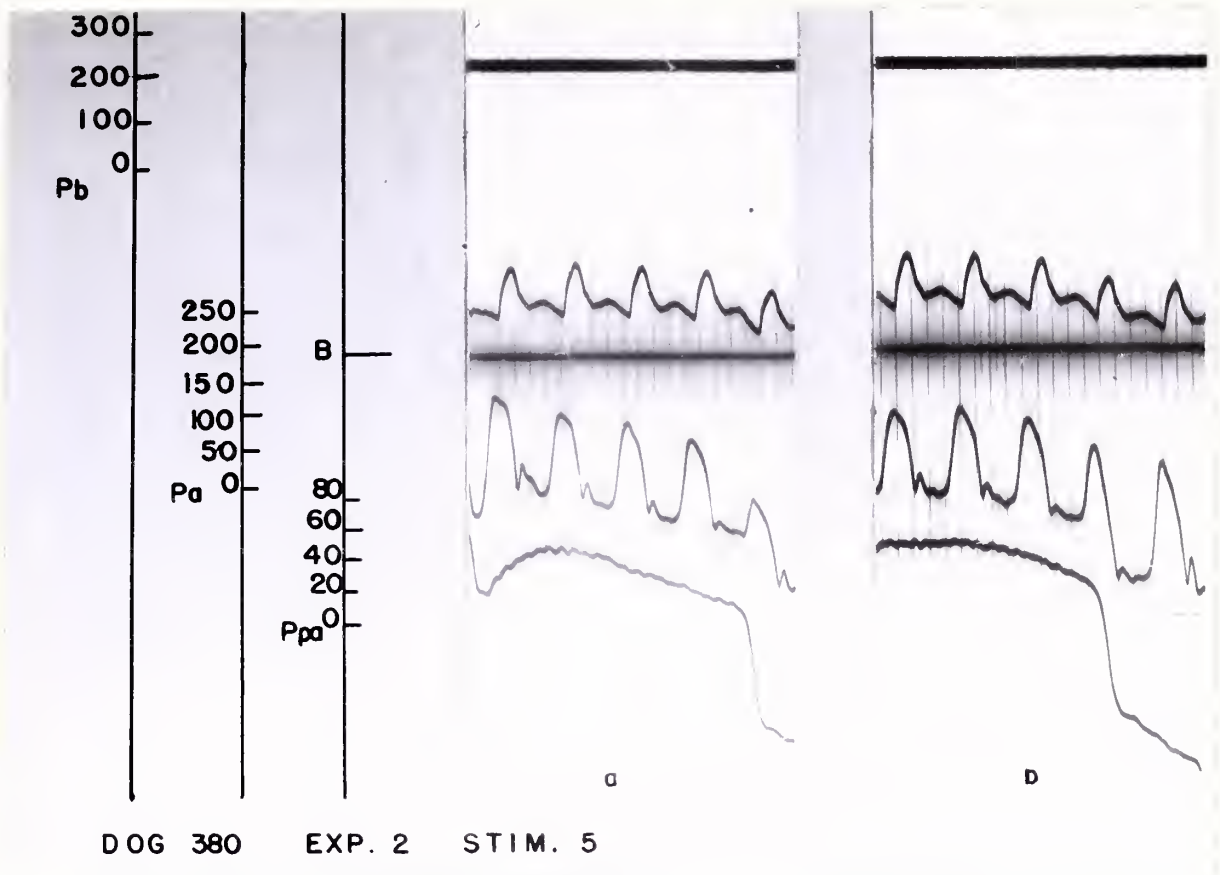

Fig. 8 All pressures in mm. of Hg. Pb=pressure in balloon. Pa=aortic pressure. Ppa=pulmonary artery pressure. B=calibration base line. a=at beginning of stimulation. b=after 36 sec. of stimulation.
Time lines 0.1 sec. apart.

Fig. 9 Autopsy specimen of Dog #380. The balloon is seen in the dissected left upper lobe artery.

Fig. 10 Closer view of balloon in fig. 9.

lobe branch. A small antemortem clot had formed at the tip of the balloon but this did not obstruct blood flow or interfere with the function of the balloon. The artery was patent distal to the balloon. There was no evidence of tissue reaction about the segment of artery which was observed to stretch as the balloon was inflated. There was no apparent reason for the large differences in pulmonary artery pressures and systemic pressures between the first and second experiments. The rise which occurred between stimulations during the second experiment was considered to be due to the animal coming out of anesthesia.

#383

This was a 15.4 kgm. black female mongrel. On December 28, 1954 a thorocotomy through the fourth left intercostal space and an acute experiment were performed under nembutal anesthesia. The balloon was introduced through the lateral and anterior basalar branch of the left lower lobe pulmonary artery proximal to the beginning of the main left pulmonary artery. The polyethylene guide cannula was sutured onto the main pulmonary artery and the chest closed. A left femoral dissection was carried out and the abdominal aorta cannulated in the usual way. In this acute experiment the intrapleural pressure recording was inadequate (probably due to clogging) during the first stimulation.

First Stimulation

Balloon pressure increased from 0 mm. Hg to 218 mm. Hg stepwise.
Total stimulation time was 62 sec.

	Mean Pul. Art. Pres.	Mean Aortic Pres.	Pulse	Resp.
At beginning of stimulation	12 mm. Hg	100 mm. Hg	180/min.	36/min.
After 31 sec. of stimulation	19 mm. Hg	104 mm. Hg	186/min.	36/min.
26 sec. after stimulation stopped	8 mm. Hg	112 mm. Hg	186/min.	36/min.

Second Stimulation (3 minutes after first stimulation)

Balloon pressure increased from 0 mm. Hg to 230 mm. Hg stepwise.
Total stimulation time was 85 sec.

	Mean Pul. Art. Pres.	Mean Aortic Pres.	Pulse	Resp.	Mean Intrapleural Pres.
At beginning of stimulation	21 mm. Hg	140 mm. Hg	162/min.	54/min.	-14 mm. Hg
After 42 sec. of stimulation	22 mm. Hg	142 mm. Hg	168/min.	66/min.	-20 mm. Hg
20 sec. after stimulation stopped	15 mm. Hg	126 mm. Hg	168/min.	72/min.	-12 mm. Hg

Third Stimulation (5 minutes after second stimulation)

Balloon pressure increased from 0 mm. Hg to 240 mm. Hg rapidly.
Total stimulation time was 90 sec.

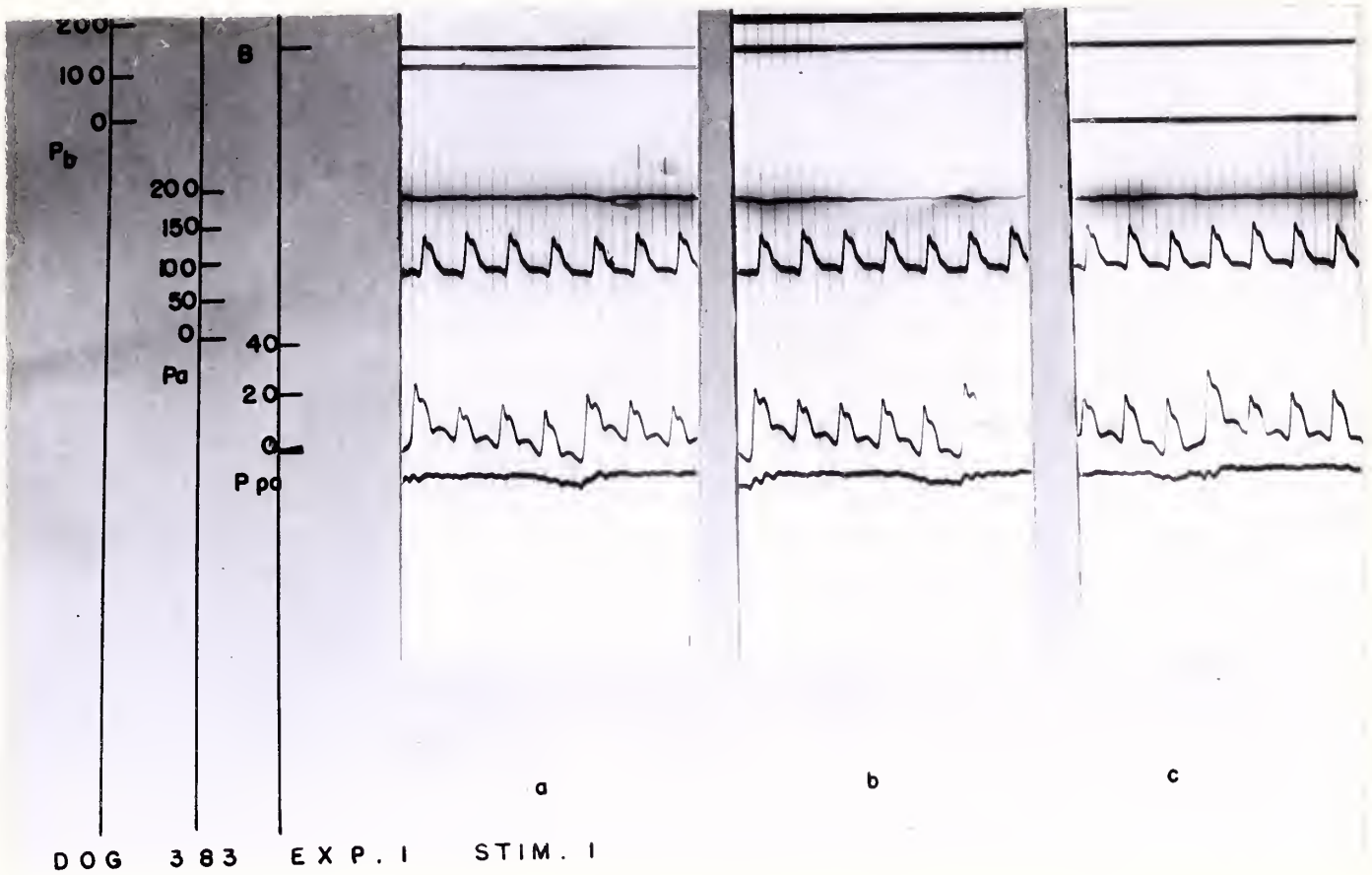

Fig. 11 All pressure in mm. of Hg. Pb=pressure in balloon. Pa=aortic pressure. Ppa-pulmonary artery pressure. B=calibration base line. a-beginning of stimulation. b=after 31 sec. of stimulation. c=26 sec. after stimulation stopped. Time lines 0.1 sec. apart.

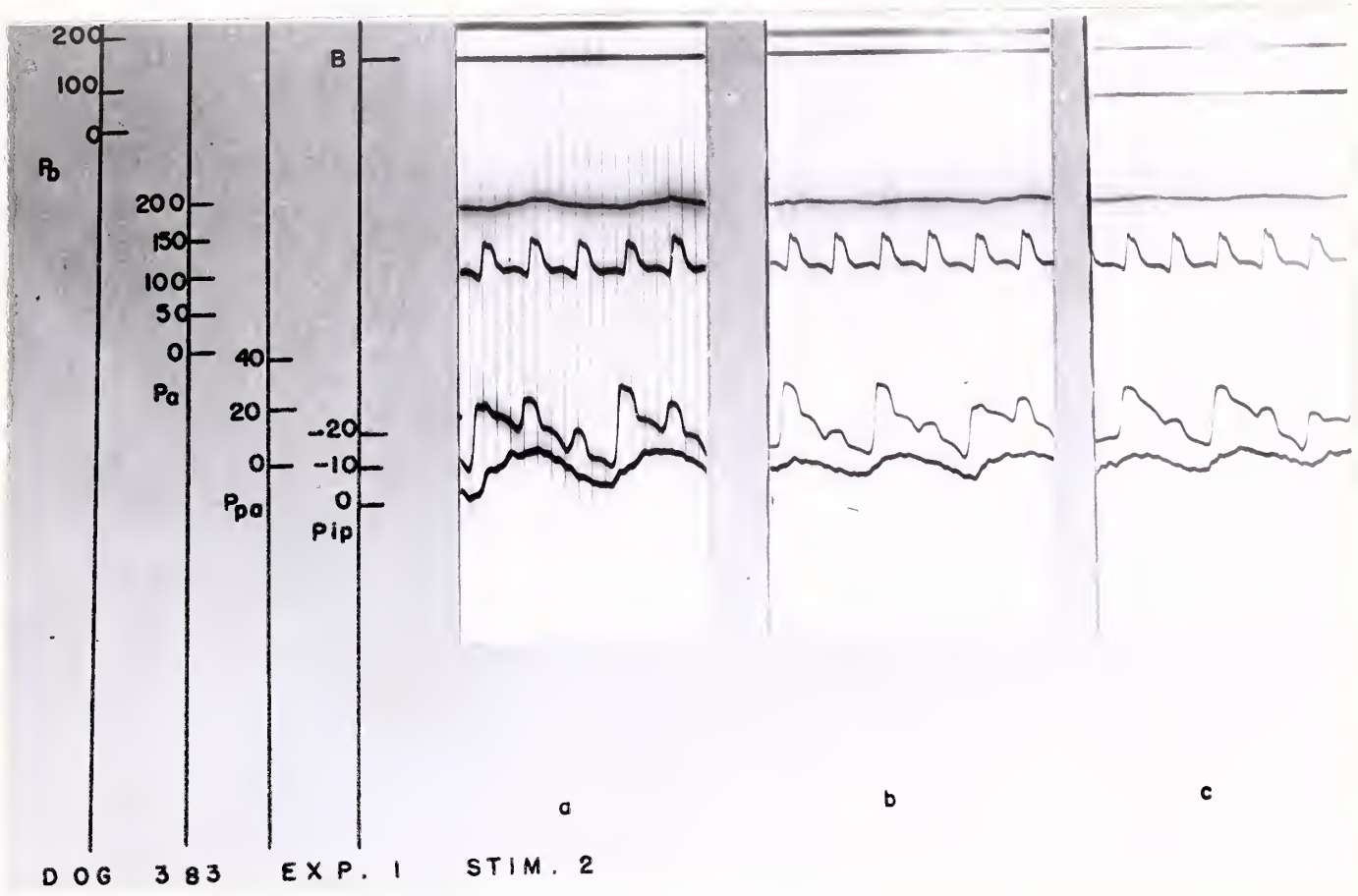

Fig. 12 All pressure in mm. of Hg. Pb=pressure in balloon. Pa=aortic pressure. Ppa=pulmonary artery pressure. Pip=intrapleural pressure. B=calibration base line. a=beginning of stimulation. b=after 42 sec. of stimulation. c=20 sec. after stimulation stopped.
Time lines 0.1 sec. apart.

	Mean Pul. Art. Pres.	Mean Aortic Pres.	Pulse	Resp.	Mean Intrapleural Pres.
At beginning of stimulation	18 mm. Hg	130 mm. Hg	162/min.	48/min.	-20 mm. Hg
After 45 sec. of stimulation	25 mm. Hg	134 mm. Hg	162/min.	48/min.	-15 mm. Hg

No record taken after stimulation stopped.

The dog suffered no apparent untoward effects from the experiment. He received 150,000 units of penicillin and 0.25 gm. of streptomycin for the next six days.

On January 3, 1955 (six days postoperative) the second experiment under sodium pentothal anesthesia and in the waking state was performed. The right femoral artery was cannulated to the abdominal aorta in the usual manner.

First Stimulation (6 days postoperative; pentothal anesthesia)
Balloon pressure increased from 0 mm. Hg to 240 mm. Hg rapidly.
Total stimulation time was 80 sec.

	Mean Pul. Art. Pres.	Mean Aortic Pres.	Pulse	Resp.	Mean Intrapleural Pres.
At beginning of stimulation	20 mm. Hg	168 mm. Hg	180/min.	19/min.	-5 mm. Hg
After 40 sec. of stimulation	14 mm. Hg	175 mm. Hg	186/min.	18/min.	-6 mm. Hg
30 sec. after stimulation stopped	20 mm. Hg	175 mm. Hg	180/min.	18/min.	-4 mm. Hg

Second Stimulation (18 minutes after first stimulation; waking state)
Balloon pressure increased from 0 mm. Hg to 240 mm. Hg rapidly.
Total stimulation time was 120 sec.

Intrapleural pressure recording was inadequate.

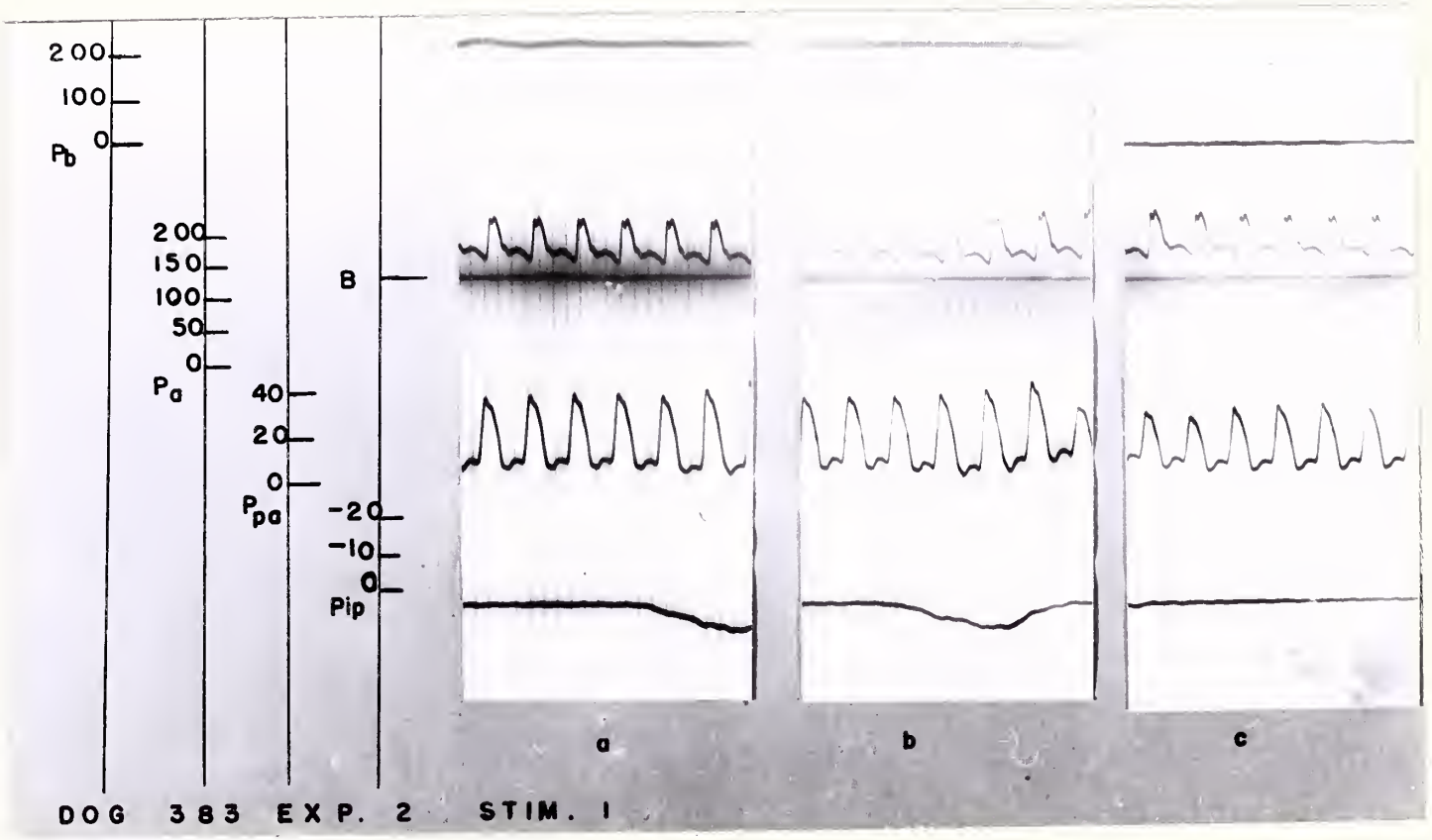

Fig. 13 All pressure in mm. of Hg. Pb=pressure in balloon. Pa=aortic pressure. Ppa=pulmonary artery pressure. Pip=intrapleural pressure. B=calibration base line. a-beginning of stimulation. b=after 40 sec. of stimulation. c-36 sec. after stimulation stopped.
Time lines 0.1 sec. apart.

	Mean Pul. Art. Pres.	Mean Aortic Pres.	Pulse	Resp.
At beginning of stimulation	20 mm. Hg	200 mm. Hg	168/min.	23/min.
After 75 sec. of stimulation	23 mm. Hg	210 mm. Hg	168/min.	24/min.

No record taken after stimulation stopped.

The dog withstood the procedure well. She was then taken down to the xray room and angiograms both with the balloon deflated and inflated were taken to determine the effect of the balloon on blood flow. The animal was sacrificed by excess nembutal intravenously.

At autopsy the left lung was slightly adherent to the body wall, but peeled away easily. No evidence of infarction was found. The balloon lay in the left main pulmonary artery at its beginning just proximal to the left upper lobe branch. A small antemortem clot was adherent to its tip but this did not interfere with its function. The wall of the artery was noted to stretch when the balloon was inflated. The pulmonary artery was sclerosed about the point where the tail of the balloon was tied in. This was due to the silk suture being too close to the left lower lobe branch. It is important to realize that this would only interfere with blood flow to the left lower lobe and not to the left upper lobe or with the purpose of the experiment which was taking place at the proximal end of the left pulmonary artery. This was confirmed by the angiograms which as interpreted by the radiologist, showed that dye entered the left upper lobe only with the balloon collapsed. When the balloon was

expanded angiograms were again taken but the position of the animal was shifted so that it was not possible to determine whether any dye got passed it. The conclusions reached from the angiograms, therefore, were that in the collapsed state some blood (amount not determined) flowed by the balloon.

* * * * *

The capacity of the polyethylene balloons did not allow for maximal stretching of the pulmonary artery, therefore an attempt was made to test this factor. The next series of dogs were to determine whether stretching with larger capacity (5 c.c.) rubber balloons would be more effective than the smaller capacity polyethylene balloons. A #10 hard rubber Foley catheter was utilized for this purpose. This obviated the measurement of the pressure on the arterial walls and also necessitated only acute experiments.

#389

This was a 15.9 kgm. brown female mongrel. On January 17, 1955 an operation was performed under nembutal anesthesia and an acute experiment was attempted. A third left intercostal space incision was made and the pulmonary artery to the left lower lobe was used as the point of entry for a #10 Foley catheter which was passed proximally to about the level of the left upper lobe pulmonary artery. A polyethylene guide cannula was sutured on the main pulmonary artery in the usual manner. The chest was closed.

At this point the animal was becomming very light. 1.5 c.c. of nembutal was given intravenously, apparently too fast. Shortly thereafter the animal was noticed to have stopped breathing and had no pulse. Attempts of cardiac massage and defibrillation were unsuccessful in resuscitating the dog. No autopsy was performed.

#390

This was a 14.5 kgm. brown and black male mongrel. On January 21, 1955 an acute experiment was performed following operation under nembutal anesthesia through a 4th left intercostal space incision. The #10 Foley catheter was introduced through the left lower lobe pulmonary artery proximally to the beginning of the left pulmonary artery. The guide cannula was put on in the usual manner and the chest closed. The left femoral artery was cannulated.

The balloon of the catheter was inflated and within a short time the dog died. At autopsy the right heart was markedly dilated. The balloon was found to lie just at the entrance of the right pulmonary artery, apparently having been inserted too far during the operation. When it was inflated, it retracted into the main pulmonary artery and completely occluded the outflow tract. This obviously defeated the purpose of the experiment and caused the death of the dog.

#392

This was a 25.0 kgm. black and white female collie who underwent an operation and an acute experiment on January 28, 1955 under nembutal anesthesia. A 4th left intercostal incision was made and the left lower lobe pulmonary artery used to introduce the #10 Foley catheter proximally to the beginning of the left main pulmonary artery. The guide cannula was sutured in place, the chest closed, and the left femoral artery cannulated in the usual manner. The balloon was inflated several times and the pulmonary artery pressure watched on the monitoring cathode ray tube of the Hathaway machine. Very dramatic rise in pulmonary artery pressure and drop in aortic pressure was noted with each inflation of the balloon. This was later explained at autopsy after sacrificing the dog with nembutal. The right heart was tremendously dilated and the balloon lay at the beginning of the left pulmonary artery. However, as the balloon was inflated it would slip into the main pulmonary artery by pulling the left pulmonary artery with it causing an intussusception of the latter. With the balloon in the main pulmonary artery the outflow tract was completely obstructed thus defeating the purpose of the experiment.

#393

This was a 13.6 kgm. black female dachshund. On January 31, 1955 an operation and acute experiment were performed under nembutal anesthesia. A 4th left intercostal space incision was made and the #10 Foley catheter introduced through the left upper lobe pulmonary artery going distally toward the left lower lobe. The guide cannula was sutured in place and the chest closed. The usual left femoral artery cannulation was carried out. The following results from inflation of the balloon were obtained:

First Stimulation
Total stimulation time was 85 sec.

	Mean Pul. Art. Pres.	Mean Aortic Pres.	Pulse	Resp.	Mean Intrapleural Pres.
At beginning of stimulation	18 mm. Hg	153 mm. Hg	186/min.	66/min.	-8 mm. Hg
After 45 sec. of stimulation	22 mm. Hg	160 mm. Hg	186/min.	72/min.	-11 mm. Hg

No record taken after stimulation stopped.

Second Stimulation (2 minutes after first stimulation)
Total stimulation time was 45 sec.

	Mean Pul. Art. Pres.	Mean Aortic Pres.	Pulse	Resp.	Mean Intrapleural Pres.
At beginning of stimulation	22 mm. Hg	160 mm. Hg	192/min.	70/min.	-11 mm. Hg
After 25 sec. of stimulation	20 mm. Hg	153 mm. Hg	192/min.	66/min.	-8 mm. Hg
30 sec. after stimulation stopped	25 mm. Hg	150 mm. Hg	192/min.	60/min.	-10 mm. Hg

The dog withstood the procedure well. The chest was then re-opened through the same incision and the balloon redirected so that it went proximally and now lay in the beginning of the left main pulmonary artery. A suture bound the artery so that the balloon would not pull it and thus cause an obstruction of the main pulmonary artery. By maintaining tension on the exteriorized tail of the balloon this was insured. The chest was closed and another stimulation carried out:

Third Stimulation (balloon going proximally)
Total stimulation time was 26 sec.

	Mean Pul. Art. Pres.	Mean Aortic Pres.	Pulse	Resp.	Mean Intrapleural Pres.
At beginning of stimulation	16 mm. Hg	100 mm. Hg	144/min.	66/min.	-8 mm. Hg
After 23 sec. of stimulation	16 mm. Hg	95 mm. Hg	136/min.	60/min.	-11 mm. Hg
24 sec. after stimulation stopped	12 mm. Hg	102 mm. Hg	140/min.	60/min.	-12 mm. Hg

The animal was sacrificed with nembutal after having suffered no untoward effects from the stimulation. At autopsy the lungs and heart were normal. The balloon lay in the most proximal part of the left main pulmonary artery, and if tension was maintained on the tail (as in the above experiment) the balloon would stretch this segment without slipping into the main pulmonary artery.

SUMMARY AND EVALUATION OF RESULTS

The experiments were successfully carried out in five dogs: #364, #366, #380, #383, and #393. Table 1 summarizes the conditions of these experiments. In order to evaluate the results (recorded in the individual protocols) of these experiments, control recordings were taken in dogs #380 and #383 before any stimulation was attempted. The values for these are presented in Table 2.

A neural reflex may be considered to have been elicited if the following criteria are fulfilled:

1. Time interval between stimulation and effect must be short; 15 seconds or less.
2. Any change must be greater than those of the control recordings and actually should be observable by inspection of the records.
3. A neural reflex should be reproducible.

Table 1 illustrates the variety of experimental conditions used in an attempt to elicit changes which would fulfill the above criteria. All were unsuccessful. If any change had taken place, it would have been noticed since the shortest stimulation time was 26 seconds. Without any stimulation (Table 2) mean pulmonary artery pressure varied as much as 6 mm. Hg, mean systemic blood pressure as much as 20 mm. Hg, pulse rate as much as 12 beats per minute, and respiratory rate as much as

16 per minute. These control values incorporate the errors in measurement and calculation with the planimeter, and those of the physiologic reaction to the traumatic procedures. No changes significantly greater than the control values were noted during stimulation or 15 seconds or more after stimulation stopped. It is to be emphasized that we are only interested in the changes during and shortly after stimulation and not absolute values. However, in one experiment the pulmonary and systemic hypertension which developed must be explained. This was the second experiment on dog #380. It will be noted that the high values developed when the balloon was collapsed and as the dog was coming out of anesthesia. Since no change occurred during stimulation, it must be concluded that the changes were independent of the intraballoon pressure and related solely to the animal coming out of anesthesia under traumatic conditions. No explanation could be found for the different ranges of pressures found between the first and second experiments on dogs #366 and #380.

Reproducibility of change was never noted. Those small changes which did occur were not consistent in direction even in the same experiments.

From the above it must be concluded that stretching of segments of the pulmonary artery does not elicit any significant changes which could be interpreted as the result of a neural reflex.

TABLE 1

Dog	Type of Exp.	Method of Stim.	Stim. Time	Anesthesia	Position of Balloon	Patency of Main P.A.
#364	First	stepwise to over 200 mm. Hg	2 min. 30 sec.	nembutal	distal to LUL	ligated
	Second	recurrent to 200 mm. Hg	5 min.	nembutal and pentothal	distal to LUL	ligated
#366	First	stepwise to 200 mm. Hg	65 sec.	nembutal	distal to LUL	patent
		rapidly to 200 mm. Hg	45 sec.	nembutal	distal to LUL	patent
	Second	rapidly to 240 mm. Hg	60 sec.	pentothal	distal to LUL	patent
		rapidly to 250 mm. Hg	60 sec.	light pentothal	distal to LUL	patent
		rapidly to 250 mm. Hg	60 sec.	waking state	distal to LUL	patent
#380	First	rapidly to 140 mm. Hg	80 sec.	nembutal	proximal to LUL	patent
		stepwise to 250 mm. Hg	48 sec.	nembutal	proximal to LUL	patent
	Second	stepwise to 250 mm. Hg	40 sec.	pentothal	proximal to LUL	patent

TABLE 1 (Cont.)

Dog	Type of Exp.	Method of Stim.	Stim. Time.	Anesthesia	Position of Balloon	Patency of Main P.A.
#380	Second (cont.)	rapidly to 250 mm. Hg	40 sec.	pentothal	proximal to LUL	patent
		rapidly to 250 mm. Hg	66 sec.	light pentothal	proximal to LUL	patent
		rapidly to 250 mm. Hg	3 min. 20 sec.	light pentothal	proximal to LUL	patent
		rapidly to 215 mm. Hg	45 sec.	waking state	proximal to LUL	patent
#383	First	stepwise to 218 mm. Hg	62 sec.	nembutal	proximal to LUL	patent
		stepwise to 230 mm. Hg	85 sec.	nembutal	proximal to LUL	patent
		rapidly to 240 mm. Hg	90 sec.	nembutal	proximal to LUL	patent
	Second	rapidly to 240 mm. Hg	80 sec.	pentothal	proximal to LUL	patent
		rapidly to 240 mm. Hg	120 sec.	waking state	proximal to LUL	patent
#393	acute (rubber balloon)	rapidly	85 sec.	nembutal	distal to LUL	patent
		rapidly	45 sec.	nembutal	distal to LUL	patent
		rapidly	26 sec.	nembutal	proximal to LUL	patent

TABLE 2

Dog #380

First experiment; nembutal anesthesia.

Time	Mean Pul. Art. Pres.	Mean Aortic Pres.	Pulse
0 sec.	11 mm. Hg	116 mm. Hg	186/min.
35 sec.	14 mm. Hg	136 mm. Hg	180/min.
70 sec.	14 mm. Hg	128 mm. Hg	180/min.

Second experiment; pentothal anesthesia.

Time	Mean Pul. Art. Pres.	Mean Aortic Pres.	Pulse	Resp.
0 sec.	30 mm. Hg	224 mm. Hg	150/min.	14/min.
25 sec.	36 mm. Hg	203 mm. Hg	150/min.	10/min.

Dog #383

First experiment; nembutal anesthesia.

Time	Mean Pul. Art. Pres.	Mean Aortic Pres.	Pulse	Resp.
0 sec.	9 mm. Hg	120 mm. Hg	168/min.	54/min.
24 sec.	6 mm. Hg	116 mm. Hg	174/min.	42/min.
45 sec.	12 mm. Hg	100 mm. Hg	180/min.	38/min.

Second experiment; pentothal anesthesia.

Time	Mean Pul. Art. Pres.	Mean Aortic Pres.	Pulse	Resp.	Mean Intrapleural Pres.
0 sec.	14 mm. Hg	174 mm. Hg	174/min.	18/min.	-4 mm. Hg
34 sec.	20 mm. Hg	168 mm. Hg	180/min.	19/min.	-5 mm. Hg

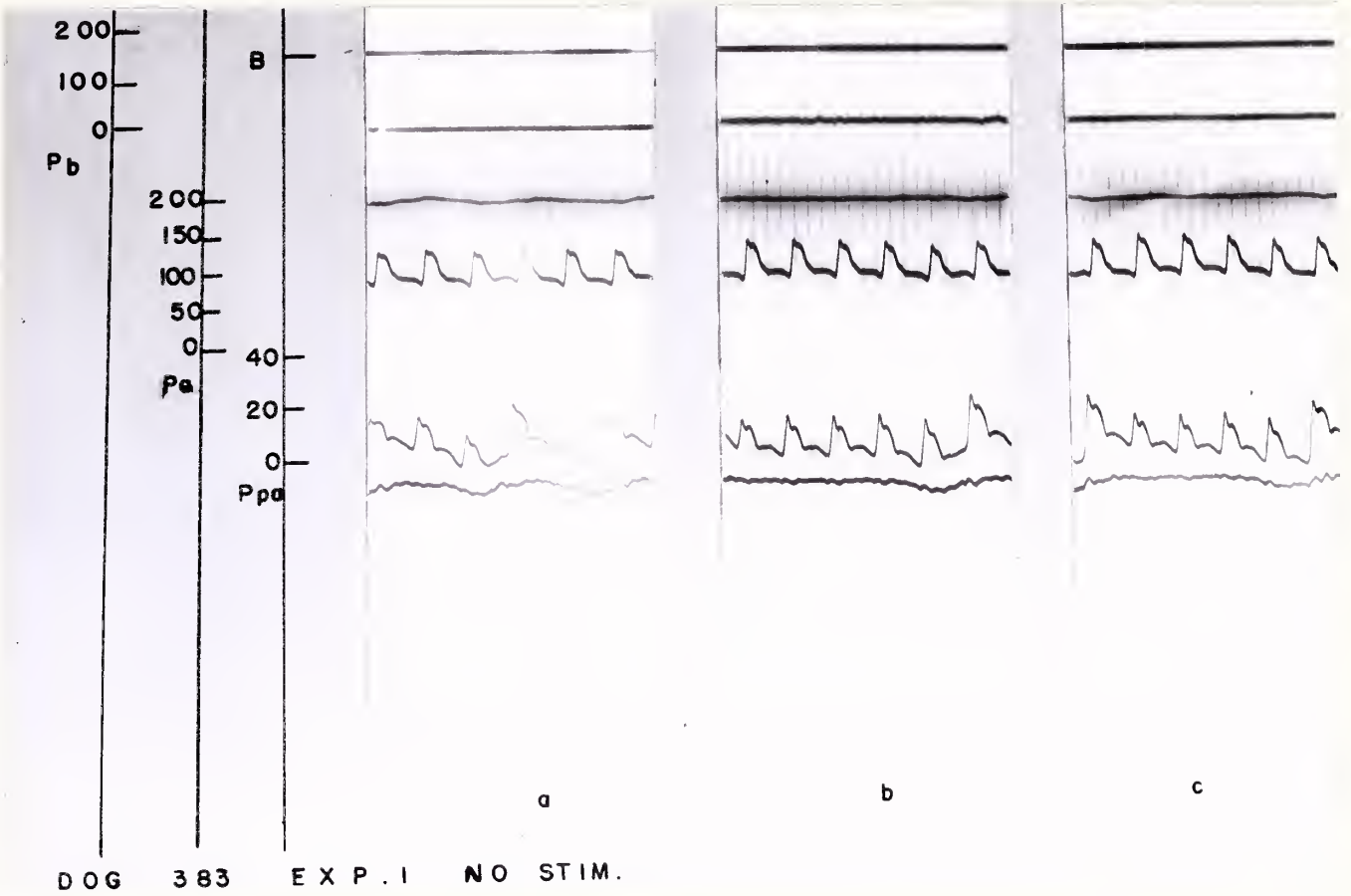

Fig. 14 All pressure in mm. of Hg. Pb=pressure in balloon. Pa=aortic pressure. Ppa=pulmonary artery pressure. B-calibration base line. a=0 sec. b=24 sec. c=45 sec.
Time lines 0.1 sec. apart.

DISCUSSION

The intention of this study was to determine whether there were cardio-systemic reflexes to stretching of small segments of the pulmonary artery. This was found not to hold in dogs under the particular experimental conditions used. Others (10, 11, 12, 13) have reached similar conclusions under different experimental conditions. This study attempted to control some of the more important variables which had not been done by other investigators. In contrast to the work of Hall and Ettinger (10), the chest was closed in all experiments, several waking preparations were used, and chronic experiments were performed to reduce the variables of traumatic operation. The actual pressures exerted and the values of cardio-systemic functions were accurately measured in contrast to the work of Haynes et al (11) and Carlens, Hanson, and Nordenström (12). The unphysiologic conditions of experimentation were not completely removed, however. Thus, anesthesia was necessary to prepare the dogs for the experiment even if a waking preparation was used. The polyethylene balloon is still a foreign substance in the body, no matter how unreactive it may be. The guide cannula sutured to the main pulmonary artery certainly may possibly interfere with a neurological function. These necessary experimental conditions may prove to be important in obviating a neurological function of the pulmonary artery. At present, they appear to be minimal factors.

The original stimulus for these experiments was to shed light on death due to pulmonary embolism. This study does not deny the possibility of a neural reflex having a role in death by pulmonary embolism, but does mitigate against the stretching of segments of the pulmonary artery as the initiator of such a reflex. The possibility still exists that other factors may elicit cardio-systemic reflexes. Wolff (19) has postulated that local anoxemia or inflammation of pulmonary vessels may act in this capacity. Sudden rerouting of blood flow may be a factor, but seems unlikely in view of the work of Nordenström (12, 13). Since the amount of blood flowing past the balloons was minimal (as shown by the angiograms taken), this last factor was not adequately tested in this study. As postulated by Hall and Ettinger (10) the last possibility is that in clinical embolism in man, stretching of the pulmonary artery does elicit a neural reflex, but not in experimental procedures in the dog.

CONCLUSIONS

1. In nine experiments on five dogs, stretching of segments of the pulmonary artery did not elicit cardio-systemic changes indicative of a neural reflex.

2. No conclusions can be reached as to the mechanism of death in pulmonary embolism from the results of these experiments.

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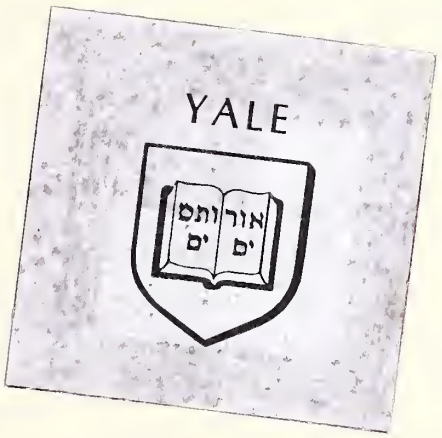
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