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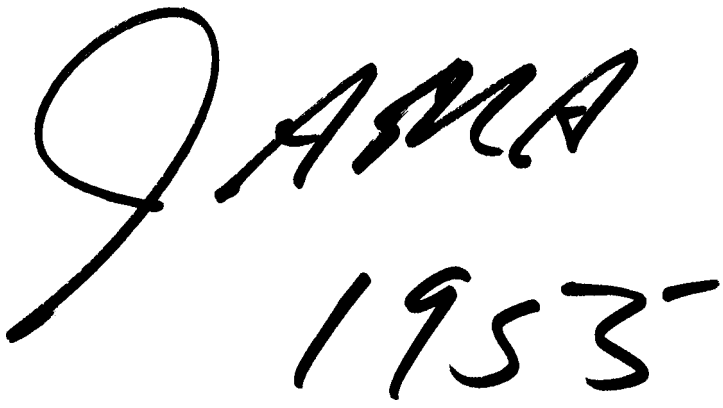
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COMMENT

Postgraduate medical education has many unique problems that dictate a need for unusual methods, techniques, and teachers. The small group-discussion or seminar, though employed only occasionally in postgraduate medical education, was ranked highest by physicians as a postgraduate learning method. Individual supervised clinical casework, lectures, and panels, and demonstrations were considered next most effective. The present disproportionate prevalence of didactic methods in postgraduate education points to the need for a reversal of present policy to increase the use of participative methods. Nevertheless, didactic methods have a larger place in postgraduate education than in undergraduate medical education, since the physician-student has foundations upon which to anchor the knowledge he receives. If didactic methods are to continue to play such an important part in postgraduate medical education, a more thorough investigation of indirect methods using the mass communication mediums is warranted, since these could result in more economical use of faculty as well as student time. Of these mediums, television shows the greatest promise.

It is apparent that no one method or plan is likely to be the sole answer to postgraduate medical education. Pedagogic ideals often come into conflict with practical considerations. The solution lies in a realistic adjustment of the educational objectives to the limitations of the situation, but with full recognition of the fact that the compromises required may result in less than optimal learning potentials. Postgraduate education can also serve as a proving ground for new medical educational methods and techniques if careful evaluation procedures are employed.

The teachers in postgraduate medical education are largely drawn from the ranks of undergraduate, graduate, and postgraduate medical schools. In order to do effective postgraduate teaching they must spend considerable time in preparation for each session and even more in travel. One of the major needs of postgraduate medical education is to enlarge the teaching force, drawing on such sources as the staffs of large hospitals, research centers, physicians in smaller towns, and residents. It is equally important that definite proportions of medical-school faculty time be assigned to postgraduate teaching, with the full recognition that this is one of the instructors' primary duties, not a secondary chore. Faculty time could be much more efficiently used by the development of a well-organized and coordinated system of all postgraduate activities within each region.

Intrathoracic Surgery.—In recent years intrathoracic surgery has become so safe that excision of a pulmonary lesion is usually the indicated treatment when surgical therapy is contemplated. Resection has reached this preferential position as a result of improved technical methods, the wide spectrum of protection afforded by antibiotics, the improvement in anesthesia that permits the pleural cavity to be open for long periods without hazard, the development of procedures to determine ventilatory function and finally the better understanding of pre- and postoperative management. These have provided the foundation on which thoracic surgery rapidly grew to maturity, one of the most spectacular records in the annals of surgical history.—Cranston W. Holman, M.D., Principles of Pulmonary Resection, *The American Journal of Surgery*, January, 1955.

CHEMICAL LABORATORY

This is the fourth report on cigarettes, cigarette smoke, and filters by the Chemical Laboratory of the American Medical Association. The first report, concerning filter-tip cigarettes, appeared in THE JOURNAL, *July 4, 1953, page 917. The second report, concerning cigarettes claiming to contain tobacco of low nicotine content, appeared in* THE JOURNAL, *July 11, 1953, page 1035. The third report, on cigarette holders, appeared in* THE JOURNAL, *Feb. 20, 1954, page 678. The laboratory work reported in this series was done by Mr. Robert R. Stark of the Chemical Laboratory.*

WALTER WOLMAN, Ph.D., *Director.*

A STUDY OF CIGARETTES, CIGARETTE SMOKE, AND FILTERS

4. Regular Cigarettes, King-Size Cigarettes, and Additional Filter-Tip Cigarettes

The Chemical Laboratory of the American Medical Association has examined a number of the largest selling brands among the regular and king-size cigarettes as well as a number of brands of filter-tip cigarettes that have appeared on the market since the Laboratory's original report [1] on filter-tip cigarettes. Reports on the effects of cigarette smoke on the health of habitual smokers have prompted the introduction of many new brands of filter-tip cigarettes during the past several months.

The methods of analysis and experimental conditions for smoking have been described in a previous report.[1] Briefly, 47 mm. of both the "standard" and "king-size" cigarette were smoked (67% of a standard 70 mm. cigarette and about 55% of a king-size cigarette) using 35 ml. puffs of two seconds' duration taken once a minute. In addition, king-size cigarettes were smoked 62 mm. to a 23 mm. butt (the same length butt as a 70 mm. cigarette smoked 47 mm.).

The results of the experiments are given in tables 1 and 2. Table 1 lists the type of cigarettes tested, the type of filter used, if any, the physical characteristics of the cigarettes and filters, and the percentage of moisture and nicotine found in the tobacco. Letters assigned to brands reported in previous papers have been retained as the first letter for the same brands in this report. The addition of the letters k and f to the letter symbolizing the brand name designates king-size and filter-tip respectively. Table 2 gives the results obtained from the smoking of the cigarettes.

In table 2, column 2, the figures are obtained by multiplying the average number of puffs required to consume the designated length of cigarette smoked by the volume of each puff (35 ml.) and represent the average volume of smoke drawn into the absorption train. This mainstream smoke represents the smoke that would reach the smoker's mouth. Column 4 of table 2 shows the weight of nicotine in the smoke from intact cigarettes and column 3 gives the weight of nicotine in the smoke obtained from the cigarettes in which the filter-tip was removed. The percentage reduction in nicotine in the mainstream smoke effected by the filter is listed in column 5 and is based on the difference between columns 3 and 4. In column 9 of table 2, the weights of the tars appearing in the mainstream smoke per cigarette are given for the intact cigarettes and column 8 gives the weights of tars in the smoke obtained from the cigarettes in which the filter-tip was removed. Column 10 lists the percentage reduction in tars effected by the filter, based on the difference between columns 8 and 9.

The figures for nicotine and tars in the mainstream smoke listed in columns 3 and 8 were obtained from the short cigarettes resulting from the removal of the filters, and are higher than would be obtained from intact all-tobacco cigarettes of regular or king-size length, since tobacco itself is a rather good filter. If the filters of the filter-tip cigarettes were to be replaced by an equal length of tobacco, this tobacco would filter out a certain amount of the nicotine and tars passing through it. This filtering

1. A Study of Cigarettes, Cigarette Smoke, and Filters: 1. Filter-Tip Cigarettes, a report of the Chemical Laboratory, J A M A 152: 917-920 (July 4) 1953

effect of tobacco is illustrated in table 2 by the king-size cigarettes from which 15 mm. of tobacco was cut and the resulting 70 mm. cigarettes were smoked 47 mm. The amount of nicotine and tars appearing in the smoke was considerably greater than the amount obtained from the intact 85 mm. king-size cigarettes smoked 47 mm.

If a king-size cigarette is smoked 62 mm. instead of 47 mm. (to the same 23 mm. butt length as a regular 70 mm. cigarette smoked 47 mm.), 31.9% more tobacco is consumed; however, the nicotine and tars found in the mainstream smoke are higher to the mainstream smoke without the filters and with the intact cigarette respectively. Under comparable conditions, the proportion of nicotine transferred from the tobacco of the smoked portion of the cigarette to the mainstream smoke is rather constant.

A factor contributing to differences in the smoking of the filter-tip cigarettes was the variation in the filters of the individual cigarettes. There were differences in porosity of the filters, but the greatest variation was in the length of the separate filters. The filters of brand M cigarettes ranged from 10.4 to

TABLE 1.—*Moisture, Nicotine Content, and Physical Characteristics of Cigarettes*

Columns	1	2	3	4	5	6	7	8	9
Brand	Type of Filter	Date Sample Obtained	Average Weight of Cigarette, Gm.	Average Weight of Filter-Tip, Gm.	Total Length of Cigarette, Mm.	Average Length of Filter-Tip, Mm.	Average Circumference of Cigarette, Mm.	Moisture in Tobacco, %	Nicotine in Tobacco (Moisture-Free Basis), %
H	.....	Feb., 1954	1.038	.....	70.0	....	26.4	11.95	2.51
D	.....	Aug., 1953	1.096	.....	69.9	....	26.5	11.52	2.08
I	.....	Feb., 1954	1.088	.....	70.0	..	26.1	11.22	1.93
J	.....	Aug., 1954	1.053	.....	70.0	....	26.2	10.63	2.00
K	.....	May, 1954	1.072	.....	69.8	....	26.2	10.54	2.11
Lk	.....	June, 1954	1.233	.....	84.8	....	25.7	11.89	2.29
Dk	.....	Sept., 1954	1.297	.....	84.8	....	26.0	11.57	1.86
Mf	Cellulose acetate fibers	April, 1954	1.102	0.178	69.9	13.1	26.1	11.10	1.78
Afk	Cellulose acetate fibers	Jan., 1954	1.288	0.181	85.0	13.0	25.3	10.89	2.00
Nfk	Cellulose acetate fibers	July, 1954	1.265	0.150	85.0	15.0	25.8	11.78	2.12
Bfk	Asbestos laminated with paper	Oct., 1954	1.192	0.130	85.0	11.5	25.8	10.41	2.53
Ofk	Activated charcoal with paper	Nov., 1954	1.274	0.141	85.0	13.2	25.9	11.03	2.30

TABLE 2.—*Analysis of Smoke from Cigarettes*

Columns		1	2	3	4	5	6	7	8	9	10
				Weight of Nicotine Found in Mainstream Smoke per Cigarette, Mg.			Nicotine in Tobacco Actually Smoked That Is Transferred to Mainstream Smoke, %		Weight of Tars Found in Mainstream Smoke per Cigarette, Mg.		
Brand		Weight of Tobacco Actually Smoked (Dry Weight), Gm.	Average Volume of Mainstream Smoke per Cigarette, Ml.	With Filter-Tip Removed	Intact	Reduction of Nicotine in Mainstream Smoke, %	With Filter-Tip Removed	Intact	With Filter-Tip Removed	Intact	Reduction of Tars in Mainstream Smoke, %
H	47 mm. smoked	0.588	350	....	3.31	..	..	22	....	18.0	..
D	47 mm. smoked	0.631	378	....	2.85	..	..	20	....	18.2	..
I	47 mm. smoked	0.622	368	....	2.54	..	..	20	....	16.6	..
J	47 mm. smoked	0.605	371	....	3.13	..	..	20	....	16.0	..
K	47 mm. smoked	0.621	346	....	2.77	..	.	21	.	17.2	..
Lk	47 mm. smoked	0.577	336	....	2.55	..	.	19	.	14.4	..
	62 mm. smoked	0.762	452	....	3.54	..	.	20	.	21.0	..
	Cigarette cut to 70 mm. 47 mm. smoked	0.577	338	....	2.91	.	..	22	....	15.6	..
Dk	47 mm. smoked	0.669	357	....	3.08	..	..	17	....	13.6	..
	62 mm. smoked	0.804	457	....	2.90	..	..	19	....	18.4	..
	Cigarette cut to 70 mm. 47 mm. smoked	0.609	350	....	2.39	..	..	21	....	15.4	..
Mf	47 mm. smoked	0.633	356	2.13	3.60	34	22	14	16.9	21.3	22
Afk	47 mm. smoked	0.654	372	2.44	3.87	23	19	14	14.1	21.3	20
	62 mm. smoked	0.863	481	....	2.85	..	..	17	....	15.4	..
Nfk	47 mm. smoked	0.814	460	2.70	3.32	14	21	15	14.9	19.1	19
	62 mm. smoked	0.810	521	....	3.20	..	..	19	....	17.1	..
	Cigarette cut to 70 mm. 47 mm. smoked	0.611	394	....	2.67	..	..	20	....	12.7	..
Bfk	47 mm. smoked	0.565	345	3.11	1.86	40	22	13	15.3	9.0	41
	62 mm. smoked	0.745	441	.	2.96	..	..	18	..	13.4	
	Cigarette cut to 70 mm. 47 mm. smoked	0.565	348	....	2.12	..	..	15	..	10.8	..
Ofk	47 mm. smoked	0.611	371	2.55	1.70	31	18	12	14.7	10.1	31
	62 mm. smoked	0.807	484	....	2.61	.	..	14	....	14.0	..
	Cigarette cut to 70 mm. 47 mm. smoked	0.611	375		2.02	..	..	14	....	12.1	..

than can be accounted for by the extra weight of tobacco smoked. As the cigarette is puffed and the smoke travels through the cigarette, the tobacco filters out a portion of the nicotine and tars. At each succeeding puff, therefore, the remaining tobacco becomes richer in nicotine and tarry material. As this enriched tobacco is burned during subsequent puffs a portion of the deposited nicotine and tars is transferred to the mainstream smoke. It is plain that one cannot have the added protection of the extra length of tobacco and at the same time have a 21% longer smoke as some ads for king-size cigarettes have claimed.

Columns 6 and 7, table 2, show the percentage of the total

17.1 mm. long, with an average of 13.1 mm.; brand A filters ranged from 10.7 to 16.0 mm. long, with an average of 13.0 mm.; brand N filters ranged from 12.3 to 17.8 mm. long, with an average of 15.0 mm.; brand B filters ranged from 8.8 to 14.5 mm. long, with an average of 11.5 mm.; and brand O filters ranged from 9.5 to 17.0 mm., with an average of 13.2 mm. These differences are of little significance when the efficiency of the filter is about the same as the tobacco it replaces, but as the efficiency of the filter increases beyond this point, the variations become increasingly evident. Chemical examination showed that the brand M filter was not α-cellulose as claimed by the carton insert. Additional tests indicated that it was cellulose

At the present state of filter-tip development, filtering efficiencies in the range of those found in brands A, B, M, and O, seem to be the optimum for a commercially successful product, striking a sort of balance between effectiveness and a smoke too thinned to please many habitual smokers. The early history of the brand B filter seems to indicate this. These early brand B filters removed about 60% of the nicotine and tars from the mainstream smoke, but smokers apparently found it too difficult to draw through the tight filters and the smoke too thin to be satisfying. Consequently, the brand B filters were modified to their present state of effectiveness.

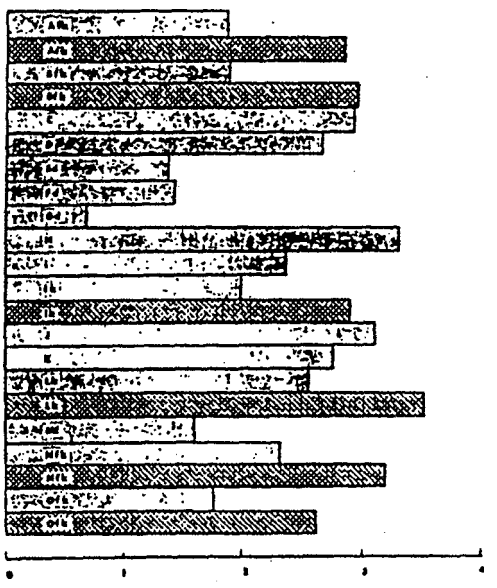
From the series entitled "A Study of Cigarettes, Cigarette Smoke, and Filters," data of greatest pertinence to the physician have been gathered together in the following résumé and are presented in graph form for ease of reference.

NICOTINE AND TARS IN MAINSTREAM SMOKE

The recent rise in the popularity of king-size and filter-tip cigarettes may be caused partly by the feeling that these types of cigarettes are giving a measure of health protection to the smoker. This feeling has been encouraged by advertisers who have dwelt on the real or fancied importance of such features as the efficiency of the filter, the type of filter material, and the length of the cigarette. Seldom has the advertiser given the information that is of prime importance to the smoker, namely, the amounts of smoke constituents that reach the smoker's mouth. The importance of this information lies in the fact that the amounts of these constituents that reach a smoker's mouth are proportional to the amounts assimilated by the smoker. The determinations of the amounts assimilated cannot easily be made because of the biological variations among individuals and the differences in their smoking habits.

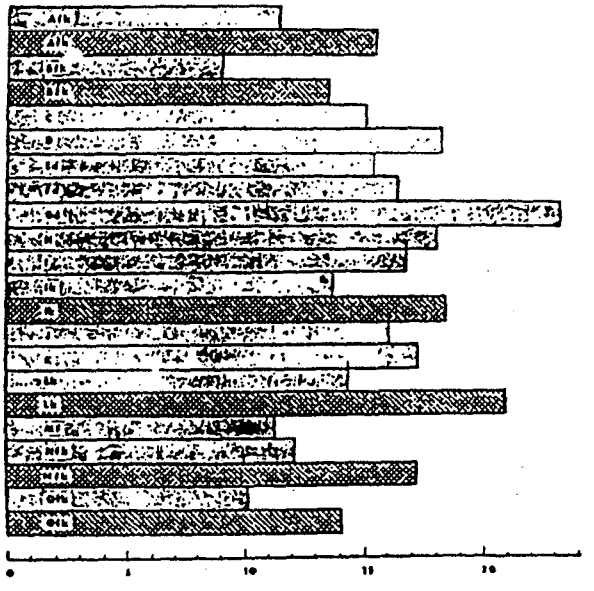
The amounts of nicotine and tars that reach a smoker's mouth can be approximated in the laboratory by the use of a smoking machine that simulates human smoking under carefully controlled conditions. The nicotine and tars in the mainstream smoke (the smoke that reaches the smoker's mouth) have been determined by this laboratory [1] for the best-selling cigarettes and brands for which special claims have been made. For ease of comparison and reference these data accumulated in the previous studies are brought together in figures 1, 2, 3, and 4.

Figures 1 and 2 show the amounts of nicotine and tars, respectively, that were found in the mainstream smoke of the cigarettes tested. Using standard cigarettes, brand D, figures 3 and 4 show the average nicotine and tar contents in the mainstream smoke based on the first five cigarettes smoked through various cigarette holders. The capital letters used to identify the brand names of the cigarettes correspond to the letters used in the earlier papers.



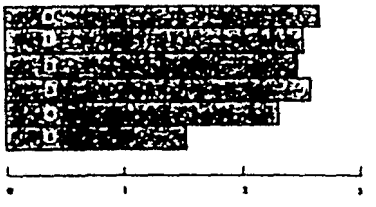
Nicotine, Mg.

Fig. 1.—Nicotine in mainstream smoke of cigarettes. Gray bars represent cigarettes smoked 47 mm. Cross hatched bars represent king-size cigarettes smoked 62 mm.



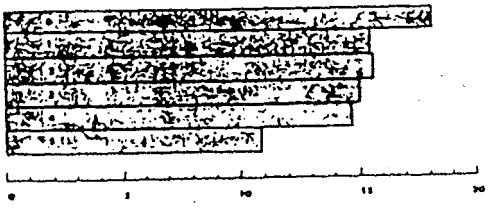
Tars, Mg.

Fig. 2.—Tars in mainstream smoke of cigarettes. Gray bars represent cigarettes smoked 47 mm. Cross hatched bars represent king-size cigarettes smoked 62 mm.



Nicotine, Mg.

Fig. 3.—Nicotine in smoke drawn through cigarette holders.



Tars, Mg.

Fig. 4.—Tars in smoke drawn through cigarette holders.

1. A Study of Cigarettes, Cigarette Smoke, and Filters: 1. Filter-Tip Cigarettes, a report of the Chemical Laboratory, J. A. M. A. 152: 917-920 (July 4) 1953. 2. Special Low-Nicotine Cigarettes, ibid. 152: 1035-1036 (July 11) 1953. 3. Cigarette Holders, ibid. 154: 678 (Feb. 20) 1954. 4. Regular Cigarettes, King-Size Cigarettes, and Additional Filter-Tip Cigarettes, ibid. 157: 1109 (April 9) 1955.

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SCIENTIFIC BASIS FOR THE SURGICAL TREATMENT OF CORONARY ARTERY DISEASE

Claude S. Beck, M.D.
and
David S. Leighninger, M.D., Cleveland

To understand the scientific basis for the surgical treatment of coronary artery disease it is necessary to analyze information obtained by experiments on dogs. One of us (C. S. B.) and his associates have done about 5,000 operations on the coronary blood vessels in the last 23 years, and these are the basis for this presentation. There are several variables inherent in this work, and it is appropriate here to state that these must be properly taken care of, otherwise erroneous conclusions will be made. A report on much of this experimental work has been published in THE JOURNAL.[1] In these experiments the reduction in coronary artery inflow was produced by placing ligatures around the coronary arteries. In the human, arteriosclerosis produces reduction in coronary artery inflow. The net result is reduction in arterial inflow. This is not a study of arteriosclerosis. Even if this disease could be produced experimentally in adequate numbers of dogs the occlusion probably could not be localized nor could the degree of occlusion be controlled with the precision demanded by the experiment, and as a method of investigation it would be inferior to the ligature.

The surgical treatment of coronary artery disease is based upon four considerations. 1. Operation adds 4.7 cc. of blood per minute (282 cc. per hour) to an area of myocardium made ischemic by complete ligation of the artery that normally feeds this muscle. This quantity of blood is of little or no significance if it is delivered to myocardium that is fed by a normally patent artery or if the artery is occluded by three-fourths of its diameter. But if the artery is totally occluded then this quantity of blood is protective. When the circumflex artery is ligated in a normal dog the average amount of blood available to the muscle beyond the ligature is 3.8 cc. per minute. Operation adds 4.7 cc. to this quantity, making an average total of about 8.5 cc. per minute. 2. This quantity of blood accomplishes three favorable results: It reduces mortality following test coronary artery occlusion, it likewise reduces the size of the infarct in these dogs that live following the arterial occlusion, and it provides time for additional blood to run into this low pressure area of occlusion from adjacent high pressure areas of myocardium. In a few days this ischemic but viable myocardium begins to contract. In 24 dogs the average amount of blood available to the myocardium beyond the ligature was 62 cc. per minute. 3. Of all the people who die of coronary artery disease about 90% die because the heart becomes electrically unstable. The hearts in these people are capable of continued function under slightly altered circulatory conditions, and these are the patients who can be helped by surgical operation. The remaining 10% of the patients who die from coronary artery disease have extensive myocardial degeneration, and these patients die in circulatory failure. Little or nothing can be accomplished by surgical operation in these patients (fig. 1). 4. The transfer of this information from the laboratory to the human patient is being made without conflict in the science.

From the Western Reserve University School of Medicine and the University Hospitals.

Read before the Section on Surgery, General and Abdominal, at the 104th Annual Meeting of the American Medical Association, Atlantic City, June 8, 1955.

This work was supported by grants from the United States Public Health Service and the Cleveland Area Heart Society.

The burs used in the number 1 operation are made by Kapp Surgical Works, 2004 St. Clair Ave., Cleveland.

1. Beck, C. S., and Leighninger, D. S.: Operations for Coronary Artery Disease, J. A. M. A. **156**: 1226 (Nov. 27) 1954.

ELECTRICALLY STABLE AND UNSTABLE HEARTS

An electrically stable heart is a uniformly well oxygenated heart. Emphasis is placed upon the uniformity of oxygen tension throughout the myocardium (fig. 2*A*)

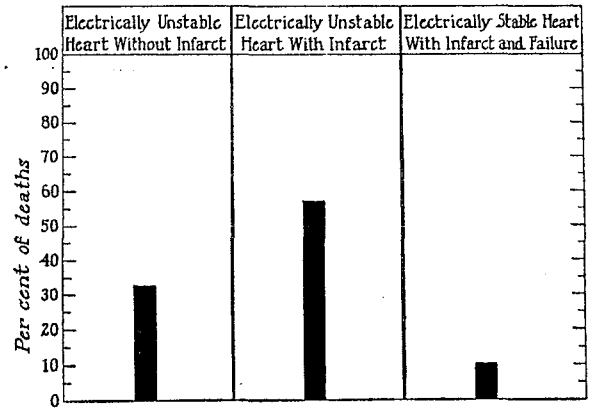

Fig. 1.—One-third of all victims of coronary artery disease have no infarct, either old or recent, according to Yater.[4] In this group, column 1, the hearts became electrically unstable. Approximately 10% of all victims die of circulatory failure. In this group, column 3, the currents incidental to progressive occlusions were never strong enough to fibrillate the heart and stability was maintained from one occlusion to another until failure supervened. Of the remaining 57%, column 2, both muscle damage and instability were present, and, in many of these specimens, the destruction of muscle was not so great but that continued function would have been possible were it not for the electrical potentials that destroyed the coordinated mechanism. In the first group of patients there was no muscle damage, and continued function was possible in this group, provided the heart remained electrically stable.

Stability persists when the oxygen tension is reduced provided the reduction is uniform throughout the myocardium. A uniformly cyanosed heart is also a stable heart, as indicated by observations made in our laboratory on about 60 dogs in which the intratracheal tube was clamped off for periods of six to nine minutes. The heart in these experiments became increasingly cyanosed; it dilated; the beat became weak, and then it stopped in standstill. In none of these experiments did the heart fibrillate. When oxygen was again delivered into the lungs and the heart massaged a few times a strong vigorous beat was restored. Thus the mechanism

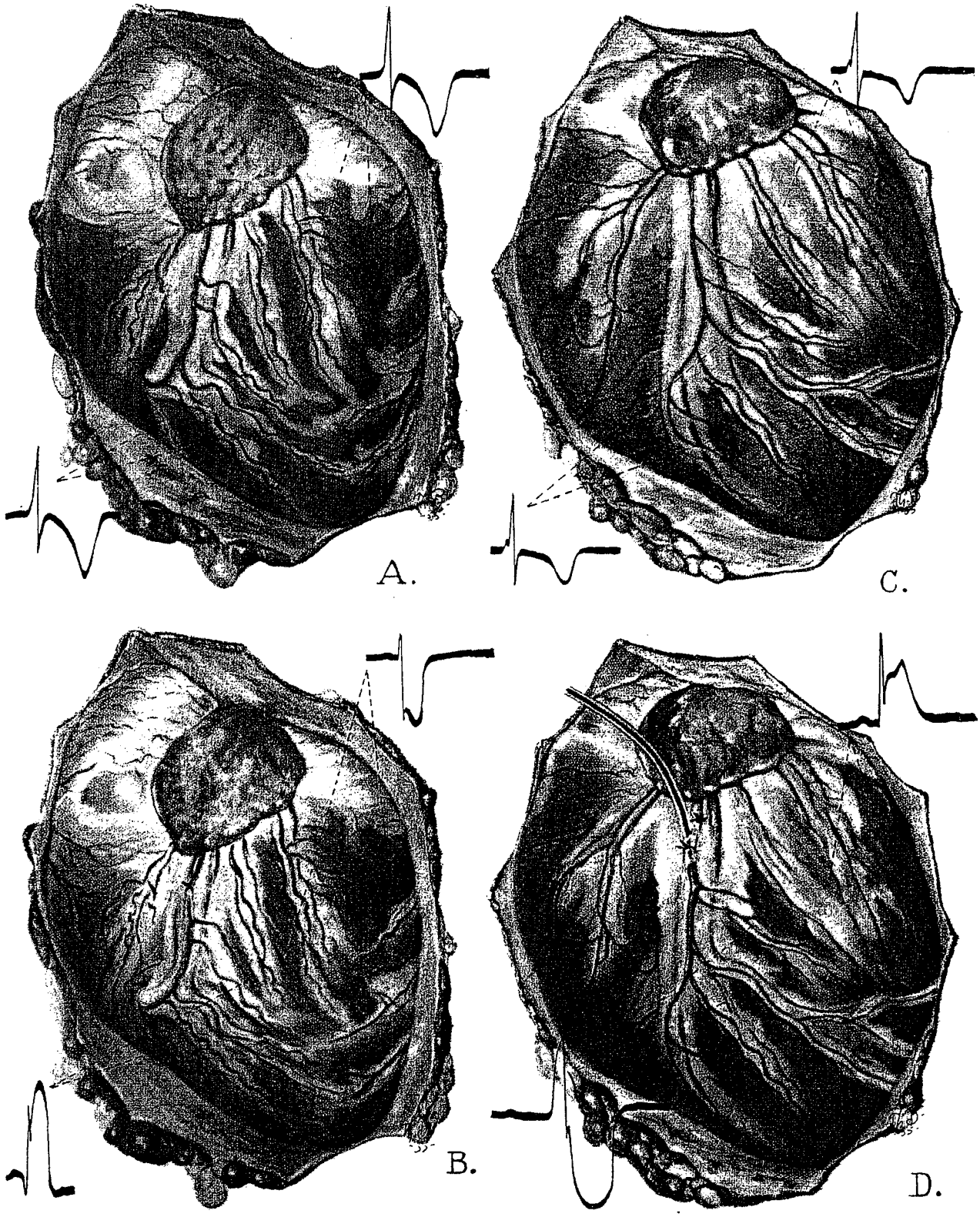

Fig. 2.—Dog hearts illustrating four conditions of myocardial oxygenation, with direct epicardial electrocardiograms demonstrating measurement of electrical potentials. *A* and *C* are the same heart; the one is uniformly well oxygenated, and the other is uniformly and severely cyanosed. These hearts are electrically stable as shown by the isoelectric S-T segment in each condition. *B* and *D* are electrically unstable because the oxygen tension in each heart is not uniform throughout. The S-T segment is depressed over the pink or well-oxygenated myocardium and elevated over the blue or cyanosed myocardium. These differences in potentials are often strong enough to fibrillate the heart. The term "current of oxygen-differentials" is introduced to replace "current of injury," which is obviously incorrect. A uniformly cyanosed heart is not an injured heart.

remained coordinated as the heart changed in color from pink to blue and back again to pink. Direct epicardial electrocardiograms taken from the surface of the uniformly pink and the uniformly cyanosed heart are shown in figure 2*A* and *C*. The heart becomes electrically unstable and may fibrillate when the oxygen tension is not uniform throughout the myocardium. Thus a cyanosed area surrounded by well-oxygenated myocardium or a well-oxygenated area surrounded by cyanosed myocardium are conditions that produce electrical instability. These conditions are produced experimentally by ligation of one or more coronary arteries in a well-oxygenated heart and by delivery of pink (arterial) blood through a catheter in a coronary artery in a deeply cyanosed heart. The appearance of these two types of trigger and the electrical potentials from the surface of these hearts are shown in figure 2*B* and *D*. These differences in electrical potential from pink and blue areas measure 5 to 20 mv.[2] They are produced at the precise plane of contact between blue and pink and pink and blue muscle. They are produced by differences in oxygen tension, and we use the term oxygen differential to refer to this phenomenon. The term "current of injury" has been commonly used to refer to currents produced by ligation of a coronary artery, but this term is probably not correct. The terms stable and unstable heart are also of recent origin and seem to have a place in cardiac nomenclature.

No doubt the amount of current and the voltage produced under experimental conditions vary in different dogs. The same current may fibrillate the heart in one dog and fail to do so in another. In different dogs and under different conditions there appears to be a difference in what might be referred to as the threshold for fibrillation. The threshold for fibrillation is lowered by hypothermia in the absence of coronary artery occlusion, and in a series of experiments in which the descending ramus of the left coronary artery was ligated the heart fibrillated in every experiment, whereas under normal temperatures the incidence of fibrillation was 50%.[3]

Electrical instability leads to fibrillation and death in a large number of people. The classic example of this occurs in the man who goes out and shovels snow and in a few moments is dead. The exercise improves oxygenation of myocardium everywhere except in an area supplied by a coronary artery that is not normally patent although it may not be completely occluded. In some instances the arterial disease is slight. Under these conditions an oxygen differential is produced that in turn produces sufficient current to fibrillate the heart. Had this man remained indoors without this vigorous exercise the circulation of red blood into the myocardium would have been less brisk; the heart under conditions of rest would have been less pink; and the oxygen differential probably would not have produced sufficient current to have fibrillated the heart. To society the loss produced by these currents is incalculable. These currents occur in people who could live productively provided small alterations were present in the coronary artery circulation. One-third of all victims of coronary artery disease have no damage in the myocardium, either old or recent,[4] and many of the remaining two-thirds have heart muscle that probably could continue to function for years were it not for these currents. In about 10% of the victims of coronary artery disease these currents were never severe enough to fibrillate the heart; the patient continued to live, and the occlusive disease advanced to the point where extensive damage and failure occurred. It appears then that oxygen differentials of a fatal nature can be produced in the absence or in the presence of myocardial destruction. It also appears that myocardial destruction can proceed to the stage of failure without producing currents strong enough to fibrillate the heart. The production of currents and the destruction of muscle are both related to oxygen, but they are different biological processes. The purposes of surgical operation are to reduce these currents and to preserve viability of muscle although the occlusive process may proceed later on even to the point of cardiac failure.

SURGICAL OPERATIONS

The principles for aiding a crippled coronary circulation were previously presented in THE JOURNAL.[1] According to our experience the most important aid is provided by the presence of intercoronary arterial communications, so that a red blood cell entering the descending ramus or one of its branches can get over to the circumflex ramus or one of its branches, where it fulfills a more important function. The addition of blood from outside sources is less effective than the distribution of blood that is already in the coronary system. We tried to add blood to the heart in many different ways, one of which was to enter it through the coronary sinus system of veins in a retrograde direction. This method provides the greatest amount of protection of all methods that we tested, but retrograde flow tapers off in the dog after six to eight weeks and is replaced by a protective set of intercoronary channels. Whether retrograde flow tapers off in the presence of coronary artery-inflow disease in the human patient cannot be stated at this time. Other sources of flow from the outside, such as from parietal pericardium, mediastinal fat, lung, internal mammary arteries, chest wall, omentum, spleen, and intestine grafted upon the heart, are yet to be measured.

Considerable work on this subject has been done, and anatomic channels large enough to carry blood have been demonstrated between graft and coronary arteries, but so far measurements of flow have not been done. No doubt these measurements will be made, because methods for measurement are available and some of these surgical procedures may be found to be effective. For the present we have laid aside the operation that diverts arterial blood into the coronary sinus system of veins because the long-term condition of the circulation in the human heart will not be known until a number of specimens are examined. This operation is technically difficult. It requires two stages. It has a definite mortality

2. Brofman, B. L.; Leighninger, D. S., and Beck, C. S.: Electrical Instability of the Heart: A New Concept in Coronary Artery Disease, to be published.

3. Selman, M. W., and Brofman, B. L.: The Effect of Hypothermia on Survival Rates Following Coronary Occlusion in Dogs, Surgery **37**: 707 (May) 1955.

4. Andrus, E. C., and others: Coronary Artery Disease, M. Ann. District of Columbia **20**: 313 (June) 1951. Yater, W. M., Beck, C. S., Leighninger, D. S., and Brofman, B. L.: Symposium on Coronary Arterial Disease, Am. Rev. Tuberc. **71**: 904 (June) 1955.

and also some side-effects from the arteriovenous fistula produced by the operation. However, as stated above, it produces the greatest amount of benefit, and we might apply it in those patients who still have pain after the number 1 operation has been used.

The Number 1 Operation.—The number 1 operation consists of the following steps. 1. The lining of the parietal pericardium and the surface of the heart are

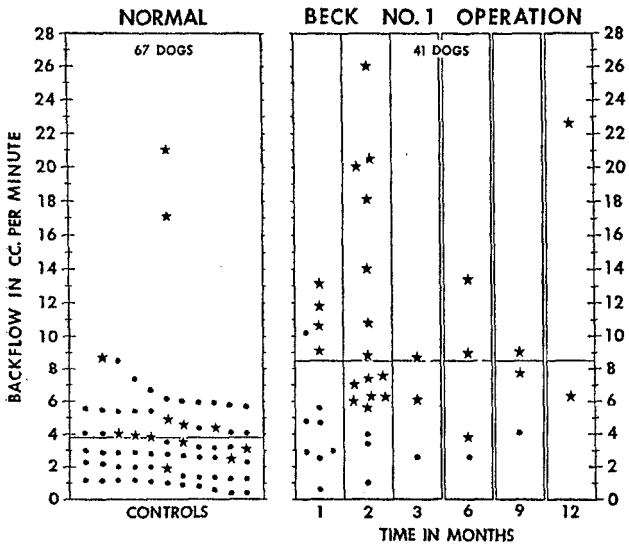

Fig. 3.—Mautz-Gregg backflow measurements in normal control dogs and in dogs upon which number 1 operation was done. Average in 67 normal dogs was 3.8 cc. per minute and in 41 dogs in which the number 1 operation was done was 8.5 cc. per minute. This increased backflow was present one year after operation. Star indicates that electrocardiographic evidence of protection was present, and solid circle indicates it was absent.

abraded or roughened by special burs. This produces mechanical trauma, which in turn produces inflammation and intercoronary arterial channels. We experimented with necrotizing chemicals for the removal of epicardium, but no satisfactory chemical agent has been found, and strong chemicals such as carbolic acid should not be used. 2. Application of 0.2 gm. of coarsely ground asbestos is made to the entire surface of the heart. This produces mild inflammation, which persists for a period of months and which in turn produces intercoronary arterial channels. We experimented with many different inflammatory agents, and asbestos is the most effective agent. 3. The coronary sinus is occluded to a diameter of 3 mm. Ligation of this vein is not beneficial when the arterial circulation in the heart is normal because it reduces arterial inflow, but when a major coronary artery such as the circumflex is occluded then ligation of the sinus affords protection against loss of coordinated mechanism, and it also provides for greater absorption of oxygen from the blood in the occluded vascular bed.[5] Ligation also aids in the development of intercoronary arterial channels. 4. Parietal pericardium and mediastinal fat is applied to the surface of the heart. This grafted tissue stimulates the development of intercoronary arterial channels and in some instances probably becomes the source of additional blood to the heart.

5. Gregg, D. E.: Coronary Circulation in Health and Disease, Philadelphia, Lea & Febiger, 1950.

6. Mautz, F. R., and Gregg, D. E.: The Dynamics of Collateral Circulation Following Chronic Occlusion of Coronary Arteries, Proc. Soc. Exper. Biol. & Med. 36: 797 (June) 1937.

This operation has been well tested in the experimental laboratory. The protection of the number 1 operation in terms of mortality and size of infarct has been reported.[1] In normal dogs the mortality following complete ligation of the descending ramus of the left coronary artery at its origin in one step was 70%. In 30 dogs in which the number 1 operation was done and sometime thereafter the same artery was ligated, the mortality was 26.6%. This is a reduction of 43.4% produced by the operation. The hearts in each group that survived test artery ligation were examined and the size of the infarct measured. In the hearts that were protected by operation the infarct was 60 to 70% smaller than in the control group. In some specimens there was no gross infarct, and this was never observed in a specimen of the control group.

Backflow.—The Mautz-Gregg method of backflow yields important information and was used in many experiments.[6] This method consists of ligation of either the circumflex ramus or the descending ramus of the left common coronary artery. One of these vessels is ligated proximally and cut distal to the ligature. The amount of blood from the cut artery is the backflow. A third measurement of protection, which has also been reported,[1] consists of the response made by the circulation after test artery ligation, provided the animal lived and the heart muscle was not destroyed by the ischemia. Backflow measurements made in an artery that was occluded one day were 10.8 cc. per minute; two days, 42.0 cc.; three days, 68.0 cc.; and six days, 20.0 cc.; the average up to four months in 24 dogs was 62.1 cc. per minute. The important consideration here is the fact

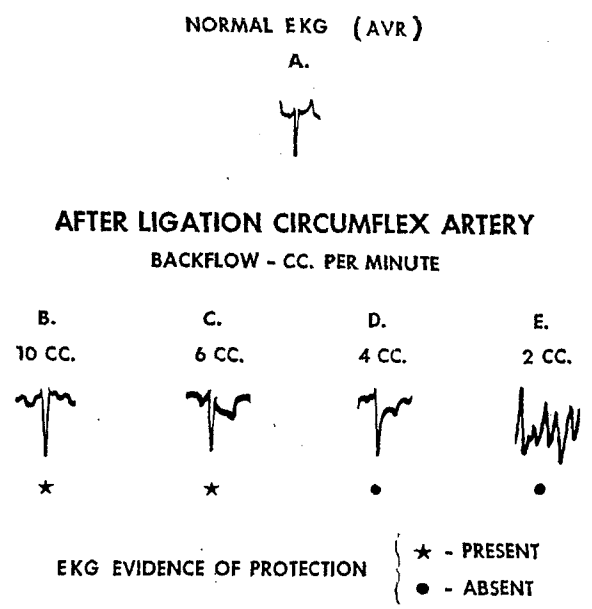

Fig. 4.—Relationship between electrocardiogram and Mautz-Gregg backflow.

that 4.7 cc. per minute of additional blood provided by operation carried the dog over the crisis of the arterial occlusion and also preserved the viability of myocardium. Under these conditions additional blood ran into the ischemic, low-pressure myocardium from adjacent myocardium where the pressure was higher, and later on this ischemic but viable myocardium had sufficient blood supply to restore contractility to this area of myocardium.

Recent measurements obtained by one of us (D. S. L.) are presented in figure 3. In 67 normal dogs the average backflow was 3.8 cc. per minute. After the number 1 operation was done the backflow in 41 dogs was 8.5 cc. per minute, or an increase of 4.7 cc. This increase in backflow was found one year after operation, so that the improvement is probably of a permanent nature. The relationship between backflow and electrocardiogram is shown in figure 4. Any quantity of blood added to that which is already present is protective. When the total quantity of backflow is 6 to 10 cc. per minute the electrocardiogram shows S-T segment depression less than 2 mm. and is indicated by a star. When the total backflow is 2 to 4 cc. per minute it shows greater S-T segment depression or the heart may fibrillate, and this is indicated by a solid circle. The various components of the number 1 operation were measured, and these are shown in figure 5. Each component contributes something to the backflow.

Thompson [7] advocated the introduction of 4 to 6 gm. of talc into the pericardial cavity for the treatment of coronary artery disease, and backflow in such experiments is given in figure 6. The average backflow in 20 dogs was 4.8 cc. per minute. This figure is 1.0 cc. greater than the average normal but is 3.7 cc. less than obtained in the number 1 operation. Vineberg [8] implanted the internal mammary artery into the myocardium of the left ventricle for the treatment of coronary artery disease. This artery is ligated and severed, but an intercostal branch is left open. The artery is placed in a tunnel in the myocardium with the expectation that branches will develop from it and these branches will connect with the smaller branches of the coronary arteries. Backflow measurements were made, and the results are shown in figure 6. The average backflow in 20 dogs was 3.9 cc. per minute. This operation did not increase backflow measurements over the normal, and the measurements were about the same with the mammary artery occluded by clamping or not occluded. In these experiments there was no increased backflow even from intercoronary arterial channels. When the artery was severed the proximal end bled freely but the distal end yielded either no blood or less than one drop per minute. Vineberg stated that the implant should be made into ischemic myocardium for anastomoses to develop, and that was not done in these experiments.

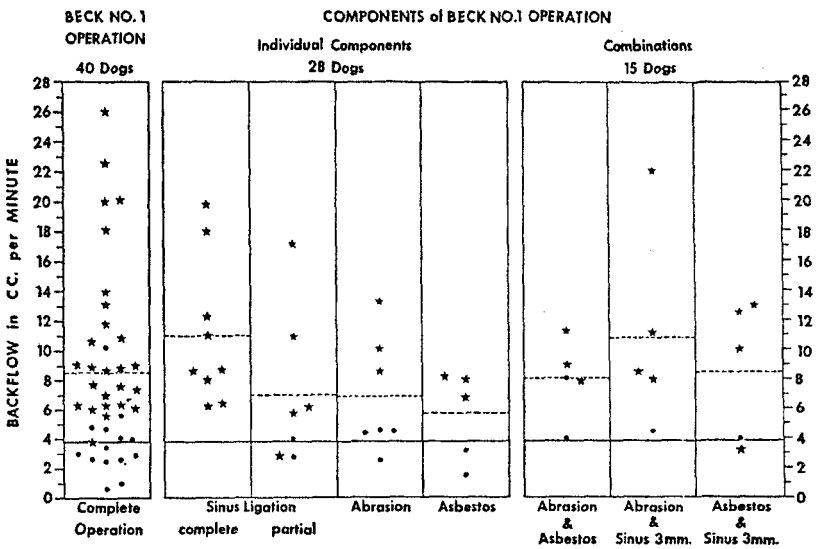

Fig. 5.—Mautz-Gregg backflow and various components of number 1 operation. Solid horizontal line indicates the average normal backflow. Broken lines indicate average backflow in each procedure. Each procedure adds something to backflow.

OPERATION ON PATIENTS

The patient is given 0.6 mg. of atropine sulfate and 10 mg. morphine sulfate one-half hour before being moved to the operating room and in the operating room is given 50 mg. of diphenhydramine (Benadryl) hydrochloride intravenously together with 0.4 gm. of thiopental (Pentothal) sodium and 60 mg. of succinylcholine chloride. He is given 100% oxygen for three to six minutes, and he is then intubated with a properly fitting cuffed endotracheal tube. Ether and oxygen are then given, and respiration is assisted until he breathes on his own. The next step is the intravenous administration of 10.5 mg. of tubocurarine chloride. The Rand-Wolfe mechanical respirator is used and is recommended. Nitrous oxide and oxygen, 5 liters of each, making a flow of 10 liters per minute, are given. A little ether is given, but usually curare and nitrous oxide maintain the anesthesia. The amount of ether used is about 2 to 3 oz. (60 to 90 cc.) per patient. We do not use rebreathing.

The drugs used are as follows: pentobarbital (Nembutal) sodium, 0.2 mg., given the night before operation; digitoxin (Crystodigin), 0.1 mg., given just before the patient is moved to the operating room; and desacetyllanatoside C (Cedilanid-D), 0.2 mg. given intravenously if the heart rate is over 110 beats per minute. This is repeated if necessary, or 0.4 mg. may be given in one dose. This digitalis preparation for intravenous use is an important aid in slowing the heart rate, and its use should not be overlooked. It requires 20 minutes to become effective. Atropine in doses of 0.2 to 0.4 mg. is given intravenously for nodal rhythm. Procainamide (Pronestyl) hydrochloride, 100 mg. diluted 10 times in saline solution, is given intravenously for ventricular extrasystoles. Tachycardia and S-T segment changes in the electrocardiogram are treated by stopping the operation for several minutes and oxygenating the lungs well. The lungs should come up well and then relax with each respiration. If the blood pressure falls, mephentermine (Wyamine) sulfate, 7.5 mg., is given intravenously and twice this amount is given intramuscularly.

The patient is placed on his right side with the left side up. If the blood pressure falls below 90 mm. Hg the operation is not started. Time is taken to observe the blood pressure. If the pressure remains below 90 mm. Hg for the next half-hour, the operation is not done

7. Thompson, S. A., and Plachta, A.: Fourteen Years' Experience with Cardiopexy in the Treatment of Coronary Artery Disease, J. Thoracic Surg. **27**: 64 (Jan.) 1954.

8. Vineberg, A.; Munro, D. D.; Cohen, H., and Buller, W.: Four Years' Clinical Experience with Internal Mammary Artery Implantation in the Treatment of Human Coronary Artery Insufficiency Including Additional Experimental Studies, J. Thoracic Surg. **29**: 1 (Jan.) 1955.

and the patient is not acceptable for operation. By experience we learned to regard this as a rule not to be broken.

The incision is placed between the sixth and seventh ribs, extending from a point about 8 cm. from the midline in front to a point about 6 cm. from the midline in back

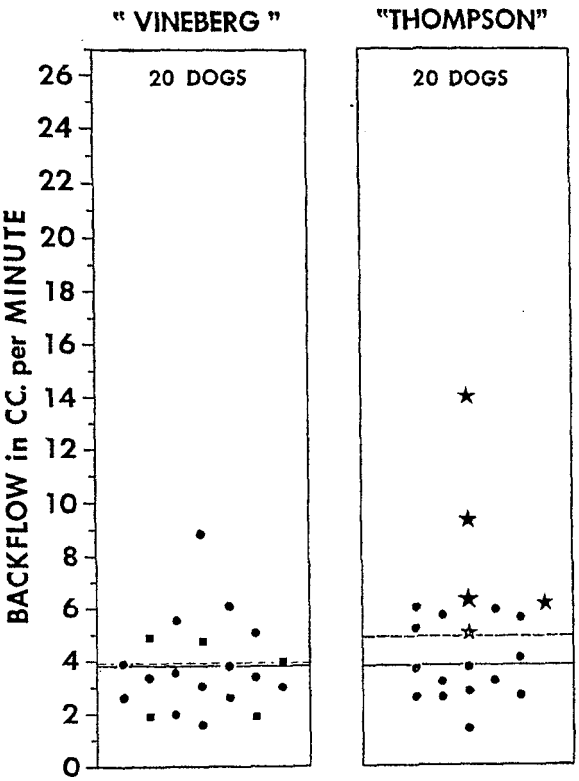

Fig. 6.—Mautz-Gregg backflow measurements in two groups of dogs. In one group the Vineberg procedure was done. Average backflow was 3.9 cc. per minute; in normal dogs it is 3.8 cc. per minute. In the other group the Thompson procedure was done. Average backflow was 4.8 cc. per minute, which is 1 cc. greater than normal.

(fig. 7). The ribs are spread apart by a self-retaining retractor for a distance of 12 to 14 cm. The pericardium is opened by an incision from apex to base about 4 cm. to the right of the left phrenic nerve. Traction sutures are placed in the pericardium and held up by the weight of a hemostat. The lining of the parietal pericardium is abraded everywhere by special burs. Another incision is made parallel to the first incision but to the left of the nerve, and a third incision splits the pericardium at right angles down to the coronary sinus. Traction sutures are applied to the cut edges of the pericardium (fig. 8). Exploration of the myocardium and coronary vessels is carried out. The common left coronary artery is lightly palpated by the right index finger. This vessel is normally patent, thickened but pulsatile, or it may be calcified. The descending ramus is palpated, as is also the first part of the circumflex ramus. The branches of these vessels are observed as to pulsation, beading, or streaking. The myocardium is observed for the presence of an infarct. The infarct is observed for size, location, and paradoxical pulsation. The coronary sinus is observed.

A point is selected between the middle and posterior veins of the ventricle. The epicardium just below the sinus is nicked with scissors, and a small opening is made and the tissues are gently spread with the point of a hemostat, separating the sinus slightly from its bed. A curved needle that contains silk is passed directly into the right auricle parallel to the sinus. This curved needle is then turned 90 degrees so that the point comes out of the auricle just superior to the sinus (fig. 9). The circumflex artery lies close to the passage of the needle, but with care it can always be missed. The ligature is tied around the sinus plus a stilet 3 mm. in diameter. The stilet is removed and partial occlusion of the sinus is accomplished (fig. 10). This ligation is done after the surface of the heart is abraded (fig. 11) and also after 0.2 gm. of coarsely ground asbestos is applied to the surface of the heart (fig. 12). The mediastinal fat is then brought into contact with the heart over as wide an area as possible, and the pericardium is loosely closed (fig. 13). A drainage tube is placed in the left pleural cavity and attached to a water-seal. If a cartilage is broken, it is carefully wired together. The sixth and seventh ribs are sutured with a wire. The soft parts are closed with silk. The patient is given oxygen intranasally or is placed in an oxygen tent for 24 hours and ambulation is started. The patient is discharged in about two weeks.

INDICATIONS FOR AND LIMITATIONS OF OPERATION

Operation is indicated in the treatment of coronary artery disease. Any patient in whom the diagnosis of this disease is established is a candidate for operation

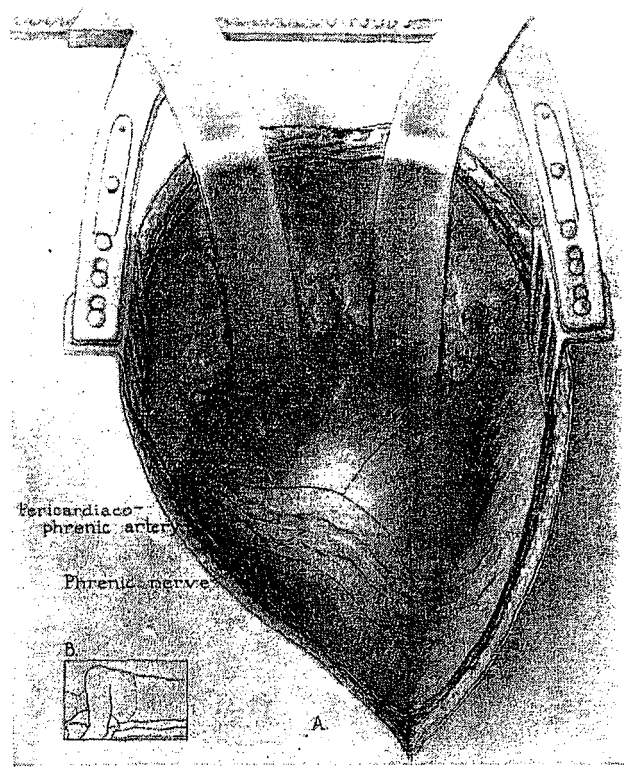

Fig. 7.—Left side of chest is opened by incision between the fifth and sixth or sixth and seventh ribs as indicated in the inset. The pericardial incisions are indicated by the broken lines.

provided the disease has not advanced to the point where the risk of operation is too great. Diagnosis will not be discussed. The problem is to determine the stage of the disease when the operation should or should not be

done. Patients with signs of failure, nocturnal dyspnea, and marked enlargement of the heart are almost automatically excluded. Patients with slight or moderate enlargement of the heart without failure are accepted. Operation is delayed in patients with rapidly increasing pain and disability because these symptoms may indicate progress of the disease and an impending infarct. If decision for or against operation is difficult, it is advisable to delay decision for several months after which reappraisal is made. Patients with status anginosus have been accepted. We prefer not to accept patients addicted to drugs, but in several patients this habit, if present, was broken. Operation is indicated early in the course of the disease rather than late. The experience usually has been that the disease is worse at the operating table than anticipated.

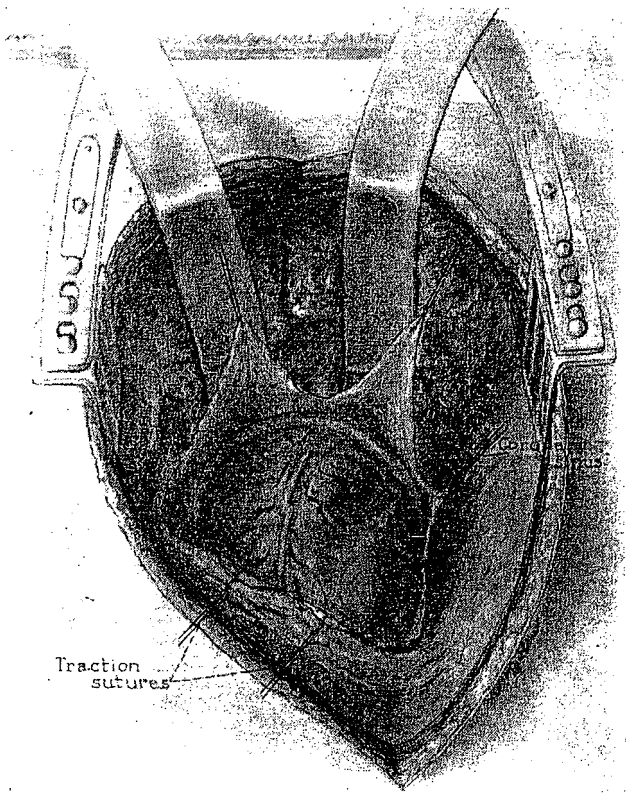

Fig. 8.—Pericardium opened for observation of coronary arteries, myocardium, and coronary sinus. Common left coronary artery and circumflex ramus of left artery cannot be seen but can be palpated. Right coronary artery cannot be seen or palpated.

After an infarct has occurred, a period of four to six months is given before operation is done. This delay serves several purposes. It affords time for intercoronary channels to develop after the low pressure bed has been established by the occlusion, and clinically it gives the patient time to "level off" so that his condition can be compared before and after operation. Also, electrical instability accompanies occlusion, and an anesthetic plus manipulation of the heart at operation may lead to ventricular fibrillation. This instability becomes less after the scar has formed and has become electrically inert. Another reason for delay applies to patients in whom one occlusion is followed by another. These patients have progressive arterial disease, and they are not candidates for operation. The disease is more likely to be progressive in patients in the 20's and 30's than those in the 40's, 50's, and 60's. The youngest patient operated upon was 27 years of age and the oldest 71.

The operation has limitations that, if properly understood, will make its beneficial effects more readily acceptable. It does not treat coronary arteriosclerosis; it

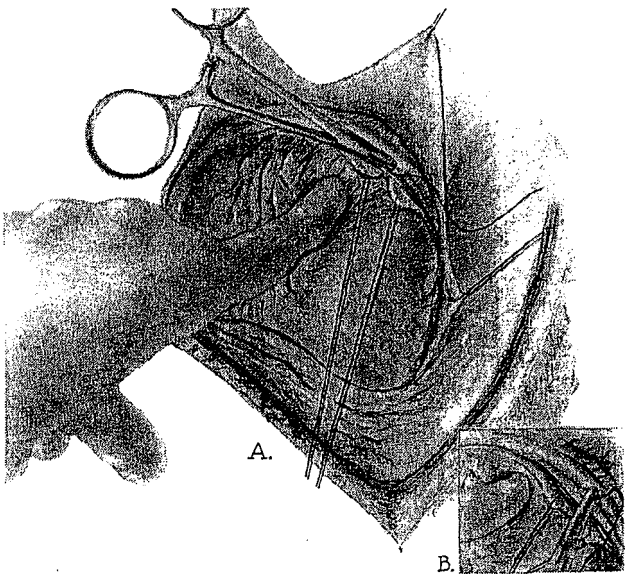

Fig. 9.—Placing a suture around the coronary sinus; *B*, needle penetrating the left atrium in a direction parallel and close to the sinus. Needle is then turned in a clockwise direction 90 degrees to emerge just superior to the sinus. Temporary traction sutures are in the fat to expose sinus.

treats alterations in inflow produced by the disease. It therefore does not reduce the disease in the arteries, nor does it stop its progress. It may become more marked after operation. A similar statement may be made about the myocardium. Operation does not restore an infarct to functional myocardium; however, it does reduce the size of the infarct or even prevent the formation of an infarct if another artery becomes occluded. It is possible for the symptoms to become worse in a patient who has shown clinical improvement after operation. This is brought about by the progress of the

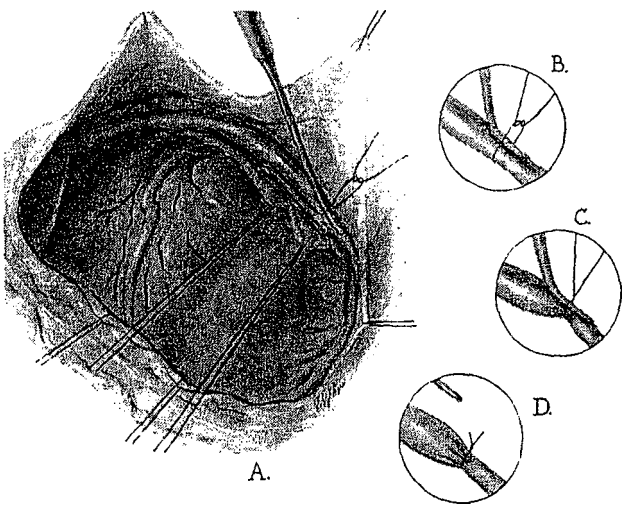

Fig. 10.—Partial ligation of the coronary sinus. The ligature is tied on a stilet 3 mm. in diameter, as in *A*, *B*, and *C*, and the stilet is removed after the ligature is tied, as in *D*.

arterial occlusion, so that it is possible for the patient to be in worse condition clinically sometime after operation; yet the operation has saved the patient's life. The patient may die of coronary disease sometime after operation, but the experience so far seems to indicate that the operation prolongs life.

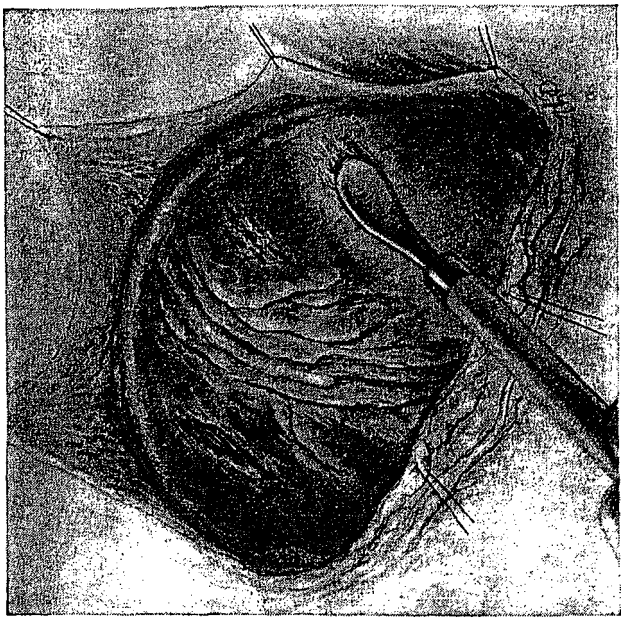

Fig. 11.—Epicardium removed by special burs. Necrotizing chemicals should not be used for this purpose.

RESULTS OF OPERATION

The results of operation can be determined by three measurements, as follows: (1) symptoms before and after operation, using the patient as his own control; (2) ability to work and to exercise, again using the patient as his own control; and (3) prolongation of life after operation. The first two items are shown in figure 14. Approximately 90% of the patients have less anginal pain or no anginal pain after operation. Several patients were operated upon who did not have any pain before operation, and these are not counted in these results. Some patients state that the angina is better three days after the operation. This improvement may be mental, but early changes in the circulation, as shown by experiment, do occur. When such mild therapy as a small quantity of whiskey or a glyceryl trinitrate (nitroglycerine) pill can reduce angina, it is not inconceivable that a few drops of blood to ischemic muscle could also give relief. As a rule the patient operated upon for coronary artery disease complains less of incisional pain than does the patient operated upon for mitral stenosis, and the incision in each is almost the same.

Some patients do not show improvement for several months after operation. The explanation for this cannot be given. A small percentage of the dogs failed to show increased backflow after operation. About 10% of the patients do not show any improvement after operation, and this aspect of the problem requires further investigation. Some of our patients are classified as salvage. These patients have severe arterial disease in the common left coronary artery or in each of the major branches of this artery. They also have extensive infarcts, sometimes with aneurysm of the myocardium. In these patients not only is the operative risk high but it is often difficult for us to understand how they can be helped by the operation, and yet some of the best clinical results are obtained in this salvage group.

The best results are almost unbelievably good. In some patients pain and disability are completely relieved. Such almost miraculous results are occasionally seen in patients without operation, and the explanation is the same as in the operated patients. Each patient develops a good set of intercoronary channels, one without operation, the other after operation, and the occlusive disease does not get worse. The end-result is the same. Indeed, operation accomplishes what nature can do but fails to do in a sufficiently large number of patients. In about 90% of the patients the ability to work is improved. Many of the patients return to jobs that they could not do before operation. It is gratifying to see this type of result; however, the patient is advised before operation that there is a good probability he will be better after operation but that he will not be cured of his disease.

It is difficult to make definite statements concerning the prolongation of life after operation. The arteriosclerotic process in the coronary arteries follows a variable and unpredictable course. These variable factors were eliminated in the experimental work because by use of the ligature the arterial occlusion was a known factor. In the dog it would be undesirable to reduce coronary artery inflow by the arteriosclerotic process even if it were possible to do so. This study of coronary artery occlusion would not exist if it were not for the fact that controlled occlusion by the ligature was used. It is a fact that a surgical operation can be done on a normal dog heart, and sometime thereafter a coronary artery can be ligated completely and in one step, and the dog has a

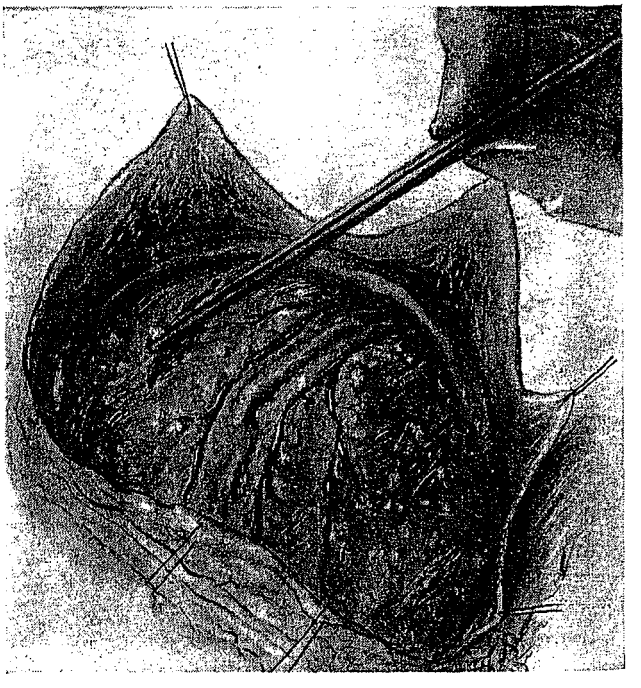

Fig. 12.—Sprinkling of an inflammatory agent (0.2 to 0.3 gm. coarsely ground asbestos) over the entire surface of heart.

better chance to continue to live than it would had the operation not been done.

It is desirable to present information on the patients concerning arterial occlusion and mortality subsequent to operation, but it is scarcely possible to do this with the data available at the present time. Our medical cardiologist, Dr. Bernard Brofman, is working on this subject, and our belief is that arterial occlusion occurs after operation and the clinical evidence is often not adequate to make a diagnosis. This is favorable for the operation. It is likewise our belief that the operation prolongs life, but to prove this statement on a statistical basis requires two identical groups of cases. Lindgren reported mortality in a group of 88 patients who were acceptable candidates for sympathectomy for angina pectoris, but the operation was not done in these patients because of nonmedical reasons.[9] The mortality was 17%

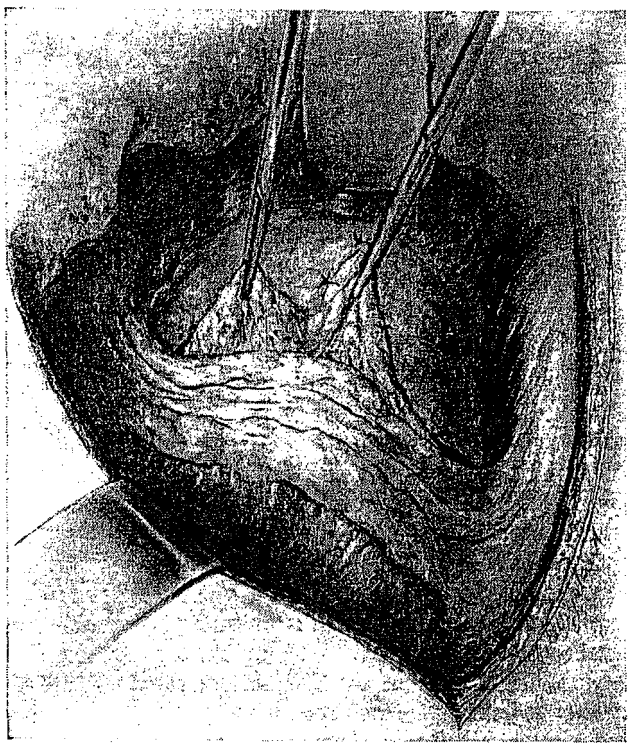

Fig. 13.—Pericardium partially closed. Mediastinal fat is used to cover the heart as much as possible. Here it is brought beneath the bridge of pericardium containing the pericardiacophrenic artery and vein. In most instances it is attached to the right border of this bridge of tissue.

the first year and 13% the second year, for a total of 30% for two years. These figures may be compared to our experiences, but the two groups probably are not strictly comparable. The operative and postoperative mortality with the number 1 operation in 75 patients was 6.6%. This mortality rate is lower than our previous figures. In the last 49 patients operated upon at Mount Sinai Hospital, Cleveland, the mortality was 2, or about 4%. The mortality in 136 patients occurring from the time of discharge from the hospital up to one year was 6.6% and in 83 patients from one year to two years was 4.8%. If these figures are added together the total operative and two year postoperative mortality is 11.4%, which is lower than Lindgren's figures without operation. We expect life to be prolonged by operation, and this is the most important purpose of our extensive studies on this subject. It is desirable to measure this aspect of the work by operating on alternate patients and determining mortality in both groups, but this is for the future.

SUMMARY AND CONCLUSIONS

Uniform distribution of oxygen to myocardium produces an electrically stable heart; lack of this uniformity produces an unstable heart. Differences in electrical potentials of the heart are produced by "oxygen differentials." The term "current of injury" is probably not correct. A uniformly cyanosed heart is not an injured or an unstable heart. With the number 1 operation for coronary artery disease, operative mortality has been reduced to 6.6%. The more important component of this so-called operative mortality is the disease rather than the operation. Operation relieves symptoms in 9 out of 10 patients. So far the trend of experience seems to indicate that operation prolongs life. Operation adds 282 cc. of blood per hour to ischemic myocardium, and this blood is present at the crisis of arterial occlusion. This is comparable to a transfusion of arterial blood into ischemic muscle. There is no experimental evidence to indicate that medical therapy adds or subtracts a single drop of blood to ischemic areas of myocardium. In view of this limitation the patient with coronary artery disease should be told there is a more effective treatment. Operation should be done early in the course of the disease before irreparable damage occurs in the myocardium.

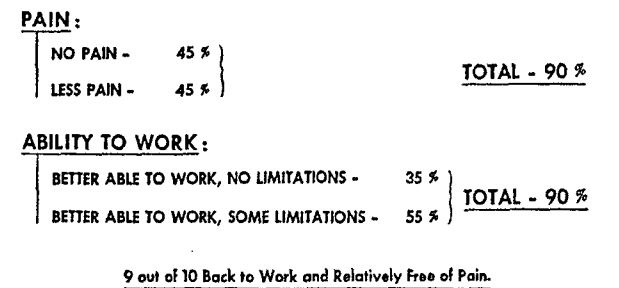

Fig. 14.—Clinical results in 103 patients who could be evaluated six months or more postoperatively.

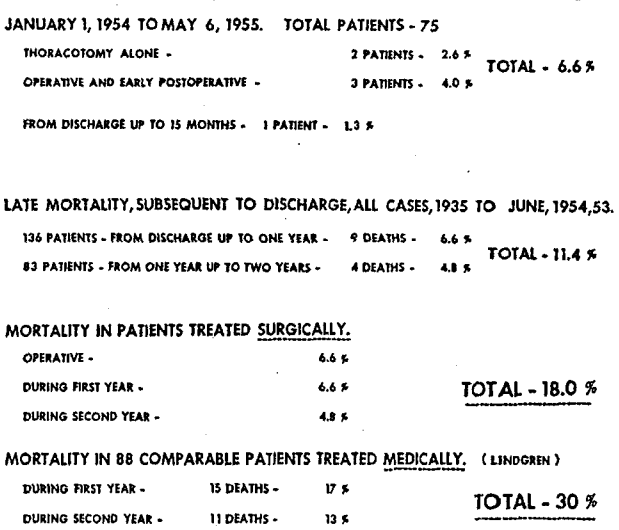

Fig. 15.—Mortality in several groups of patients.

2065 Adelbert Rd. (6) (Dr. Beck).

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