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Surgical treatment of coronary disease and angina pectoris

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THE SURGICAL TREATMENT OF
CORONARY DISEASE AND ANGINA PECTORIS

by

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INTRODUCTION

Coronary disease usually occurs in those individuals who are most active in life, those who are urged by desire, ambition or necessity to greater accomplishments; those who are leaders in government, science, industry, business and civic life. It is under their leadership that progress is made and others are driven to better work. Coronary disease is, generally speaking, a disease of those who should live longer, free from distress, in order that their particular field might derive all the benefits possible from them.

The limitations of medical treatment for coronary disease are well recognized, for, at best, only palliative measures can be instituted, which are unsatisfactory, in many cases, since so little is known of the etiology. It often seems to merely maintain them as cardiac cripples, with little chance of restoration to a useful life; which is no reflection on the internist, but emphasizes the dreadfulness of the disease and the need for a better form of therapy.

It is, then, of interest to investigate the progress made in the field of surgery, with its recent developments in armanitarium and technic, in attempt-

ing to ameliorate pain or to cure this deplorable disease, by attacking an organ so long feared by the physician and surgeon. (3). Patients may be operated upon for the eradication of the disease, for the correction of a deformity, or for the relief of symptoms. (70). Attempts to alleviate cardiac pain surgically, up to the present time, have involved three main methods of attack; (75) indirectly, for the relief of symptoms, by (1) Operative Procedures on the Sympathetic Nervous System; and (2) Thyroidectomy; and directly, for eradication of the lesion, by (3) Augmentation of the Coronary Collateral Circulation. These will be reviewed and their relative value compared.

GENERAL CONSIDERATIONS

It is not surprising that with the rapid advances in surgical technic that the surgeon should not turn to the treatment of coronary disease; a disease which is so commonly the cause of death, is so close to the physician, (93) and which causes so much distress to patients; a disease for which no cure is known and amelioration of pain is not satisfactory by medical management. With the development of surgery of the sympathetic nervous systems, the treatment of coronary disease, and cardiac pain becomes of especial interest to the surgeon, particularly in those minority of cases which fail to respond to restriction of activity, avoidance of stress and excitement decrease in weight in obese, and to proper use of sedatives and nitrites. (10).

Since so little is known concerning the cause of angina pectoris, it is only natural that the surgeon should first attempt symptomatic treatment by destroying the pain rather than curative measures. So the aim of proper surgical therapy was to interrupt the nerve fibers carrying the pain impulses from the heart. For as stated by Cutler (29) "stimuli which give rise to pain arise in the heart and are carried by some nervous pathway to the spinal

nervous system where these impulses overflow and stimulate somatic sensory neurons supplying upper thorax, arms and neck."

In 1899, Francois Franck, first suggested dividing this nervous arc so that pain would not be recognized. It was not until 1916, however, when Jonnesco first performed such an operation in a case of angina pectoris removing completely the upper three cervical sympathetic ganglia and first dorsal sympathetic ganglia bilaterally. Fortunately the outcome was brilliant and an impulse was created which resulted in enlightening reports. (29), (54), (75). Subsequent work brought many disappointing failures which led to many divergent and confusing theories concerning the cause of angina pectoris, the routes the pain stimuli follow, and the technic of operation.

It is well known that angina pectoris is a symptom, invented, according to White, (109) by Heberden in 1786, to mean a "strangling or pressing sensation (not a stabbing pain or ache) under the sternum, occurring paroxysmally as the result of excitement, exertion, or other stimuli, and subsiding in a few minutes under the influence of rest or nitrates." Danielopolu (31) thought the term should

be "restricted to a sensori-motor syndrome of the myocardium, sudden in onset, sometimes ending in death and not depending on dilatation of the heart ... Occurring only when the myocardium is healthy and acting well, they diminish or disappear as soon as the heart becomes weak and dilated." He further said that all angina pectoris is the result of inadequate coronary circulation which may occur when arteries are healthy if the demand on the myocardium is excessive, due to over-exertion, but is more likely to occur when the arteries are in a state of sclerosis. The anginal attack arises as a result of a disturbance between the blood available through the coronary artery and the demand made by the myocardium. Pain in an attack of angina is produced by an unphysiological activity of the heart and is due to fatigue of the heart muscle (45). Levine (54) thinks this can explain the overwhelming frequency of angina pectoris in coronary artery disease and may help explain the attacks in patients with pernicious anemia with comparatively normal coronary arteries, for there is an anoxemia due to lack of hemoglobin. In aortic insufficiency perhaps the coronary arteries do not fill properly. Furthermore

patients with arteries which are slowly obstructed by sclerosis may have no anginal attacks for there is no coronary insufficiency, when at rest, but during exertion an attack is precipitated due to failure of adjustment between the work to be done and the coronary circulation, for the cardio-vascular supply brought about by the quickening heart action, with or without an increase of arterial blood pressure, is inadequate. If an attack occurs during rest, there is a decrease in the blood supply to the myocardium and again an umbalance, probably brought about by coronary spasm, (31) with no change in heart action. Levine says, however, that if the coronary view as origin of angina is accepted whether the pain is a result of spasm of the coronary vessel, or due to dilatation of the vessel proximal to the spasm, or from inadequately removed metabolites from the ischemia of the heart, is not clearly understood. Psychic or somatic stimuli may be factors which directly or reflexly lead to an attack, the severity of which is dependent on the blood supply of the heart. (45)

White (109) has outlined "four weighty arguments" which almost prove conclusively that the

symptom of angina pectoris is due to coronary insufficiency: (1) Angina pectoris and proved coronary occlusion give the same kind and location of pain; (2) angina pectoris is often complicated by coronary thrombosis; (3) those cases of luetic aortitis with narrowing of the mouths of the coronary arteries are the ones that show angina pectoris, while those with even much more extensive aortic lesions but without involvement of the mouths of the coronary arteries do not have angina pectoris; (4) constriction of the coronary arteries in the dog produces pain while distention of the aorta does not. (96), (31). It also occurs in nervous hypertensive people.

Coronary Thrombosis and Angina Pectoris

That coronary thrombosis and angina pectoris are very closely associated is well known. Equally as well known is the difficulty in distinguishing the two, therefore, it is hardly within the confines of this paper to consider the entities in detail.

The first records differentiating an attack of coronary thrombosis from angina pectoris were made by Obratzon and Straschesko in 1910, and by Herrick in 1912. (41).

The etiology and symptomatology are similar and a great majority of those with coronary thrombosis have a history of angina pectoris of either short, but usually long duration. (54). The pain of coronary thrombosis is exactly like angina pectoris but is much more prolonged. (109). There are, however many variations which make the two overlap in symptomatology, but one may say, in contrast to coronary thrombosis, a definite pathological entity, which may be painless, angina pectoris is a symptom and if that symptom is absent other symptoms such as giddiness or feeling of oppression, cannot be called angina pectoris even though coronary disease is present. (109). Angina pectoris usually comes on after exercise, is momentary and is relieved by nitroglycerin while coronary thrombosis is severe, may come on at rest, lasts for several hours or days, with a rapid pulse, a lowered blood pressure and is not relieved by nitroglycerin. With the development of electrocardiography there is little need for inaccurate diagnosis. (54), (109), (58).

According to P. D. White, (109) there are three types of angina pectoris: (1) Coronary artery

sclerosis in which the coronary arteries have loss of elasticity with or without much calcification and narrowing. This is most common type and predisposing factors such as exertion, excitement, eating, anemia, and tachycardia (due to thyrotoxicosis or paroxysmally).

(2) Coronary mouth occlusion type which is usually caused by lues and rarely by a ball-valve obstruction due to vegetation. (3) Coronary artery vasoconstriction due to vascular spasm. This type of angina has never been proved. Leriche and Fontaine (51) give the name angina pectoris to all painful precordial crises thus making angina pectoris a common factor in many cardiac diseases, and modify to say "the diagnosis of angina pectoris should never be made without an attempt to verify its etiological indication."

Experimental Angina Pectoris

In normal dogs Sutton and Lueth in 1930 (96) ligated the coronary vessels by compressing them with a glass cannula through which a thread which surrounded the vessel was passed. By drawing on the thread the cannula would compress the vessel so it was either partially or completely occluded, thus interfering with the blood flow to or from that part

of the myocardium the vessel supplied.

They made the following observations:

(1) Temporary, partial, or complete interference with the blood flow in a coronary artery or vein invariably produced pain which was referred to the left foreleg. Characteristic changes in the behavior of the animal closely resembled the manifestations of angina pectoris in man.

(2) The fibers responsible for the pain are in the adventitia of the blood vessel or in the adjacent tissues for if the artery or vein was torn, there was a disappearance of pain.

(3) Pain was not produced by sudden distention of the arterial wall proximal to the point of occlusion. It was shown that closure of the orifice in the aorta produced pain where there was no distention.

(4) Stretching of the parietal pericardium, displacement of the heart, or aorta, did not produce pain, nor did acute mechanical distention of aortic arch, aortic ring, or cavity of the left ventricle.

(5) Their experiments indicated that angina pectoris (or cardiac pain) was the result of

insufficient nutrition to the heart muscle. Temporary occlusion of the coronary artery caused temporary pain, whereas, permanent occlusion did not lead to permanent objective manifestations of pain; that is, sudden diminution in blood flow apparently causes the pain.

White, Garrey, and Atkins (107) also used this method and produced cardiac pain which could be prevented by section of the upper five posterior dorsal nerve roots, or by bilateral removal of the sympathetic ganglia through the fourth thoracic ganglia.

Swetlow (99) observed in experiments on dogs and cats that pinching or pulling the pericardium or the epicardium, or the application of ten per cent ammonia or barium chloride to the left ventricle or to the left coronary artery, definite manifestations of pain were seen, that is, marked movements in defense, increased respirations, and increased blood pressure.

Anatomico-Physiological Considerations

Clinical recognition that, subjectively, the chief pain of angina pectoris was relegated to those areas of the chest wall and the inner side of the left arm in which were distributed nerves from

between the eighth cervical to the seventh thoracic segments (97) has been rather common knowledge.

The total innervation of the heart is comprised of paired vagi and sympathetic nerves which go to make up the cardiac plexus (29), from which nerves pass down the aorta and are distributed to the auricles, then to the coronary arteries along the auriculoventricular groove forming the coronary plexus, then being distributed to the ventricles. (75) The majority of cardio-sensory fibers pass through the stellate ganglion, which also contains motor fibers, to the heart. (29), (52), (98). Afferent impulses are carried to the brain along the vagus nerve to the spinal cord, along the cardiac branches to the middle and inferior cervical sympathetic ganglia, the sympathetic trunk, white rami, and the thoracic nerves. (83). There are no sensory fibers above the middle cervical ganglia, the superior cervical ganglia and their branches having a purely motor function. (29). Sensory fibers eventually end in the stellate ganglion from which emanate direct sensory fibers leading to the spinal cord. Sensory afferent impulses from the middle and inferior cardiac nerves reach the spinal cord through rami communicantes to

enter the first to seventh thoracic segments. These rami contain no motor fibers for the heart. (52), (98).

The superior cervical cardiac nerve communicates freely with the middle cardiac nerve and with the superior cervical cardiac branch of the vagus. The middle cervical cardiac nerve after arising from the middle cervical ganglion (both may be absent) ends in the deep cardiac plexus inosculating with the superior cardiac nerve and the inferior laryngeal nerve of the vagus. The inferior cervical cardiac nerve arises from the inferior cervical ganglion and at times from the first thoracic ganglion and inosculates with the middle cervical cardiac and the inferior cardiac nerves. The lowest cardiac nerve ends in the deep cardiac plexus as does the vagus nerve, thus bringing the sympathetic and parasympathetic systems together. (98) Furthermore, Ionescu and Enachescu, (47), and Ionescu and Teitel-Bernard, (48), have investigated nerve fibers in dogs, sheep, calves, human fetuses, and adults and found nerve fibers which have their origin below the ganglion stellatum of the thoracic part of the sympatheticus (ganglia two to five). In subsequent work they concluded these nerves contain accelerating and sensory fibers of the heart, for when all

the sympathetic nerves which innervate the heart were cut and electrical stimulation was applied to these nerves, there was an acceleration of pulse, an initial rise followed by a fall in blood pressure, an effect similar to stimulation of other sympathetic heart nerves. Irritation of the epicardium and aorta continued to produce pain after removal of the ganglion stellatum, although after extirpation of these thoracic fibers no pain was elicited. (48) The discovery of these nerves reveals the reason for the many variations in results and the many failures that occurred during the progress of surgery of the sympathetic nervous system for the relief of cardiac pain, for if all the cardiac nerves on both sides, and both vagi were cut, impulses from the heart would still pass from nerves below the stellate ganglion into the spinal cord by means of rami through the aortic nerves. (98), (75). Later, Ionescu (46) on experiments in cats and dogs showed that after bilateral resection of the rami communicantes, eighth cervical, first thoracic and thoracic sympathetics up to the sixth ganglion, mechanical and chemical irritation of the epicardium and aorta no longer produce sensations of pain. He concluded that the vagus nerve with the depressor nerve, the

cervical sympathetic and vertebral nerves cannot be considered as sensory nerves of the heart. (46)

These conclusions rather contradicted previous work as to the sensory tracts from the heart, for Ranson, in 1926, (83), thought that pain in the head in certain cases of angina was due to afferent impulses along the vagus referred via the fifth cranial nerve and the third and fourth cervical nerves. Cutler, in 1927, (29), thought that the depressor nerve (certain fibers of the vagus) had afferent fibers, for stimulation of the central end would slow the heart rate, but said these fibers were the only fibers of the cardiac portion of the vagus system which afferent.

Even following Ionescu's observations many authorities insisted the vagus carried afferent impulses, indicating thorough knowledge was yet unknown, for even Ionescu (46), modified his statement to say, that communications between the vagus and sympathetics, superior cervical ganglion, and vagal nerve seem to contain sensory fibers for the heart, in man. Animal experimentation and work on humans did not coincide, possibly because of the varied anatomy as Swetlow (97) said, "such nerves as the depressor nerve,

and vertebral nerve, rarely observed in humans, if stimulated in animals fail to incite painful reactions."

Later experimental and clinical studies by White (104), White, Garrey, and Atkins (107) Heinbecker (40), although still somewhat controversial whether the vagus contains afferent fibers or not from the heart, are definite in stating that pain fibers from the heart and first portion of the aorta are conveyed to the sympathetic trunk by fibers entering the central nervous system via the rami communicantes and by the dorsal roots of the eighth cervical and upper six or seven thoracic spinal nerves. White, Garrey, and Atkins (107) after experiments on twenty-one dogs thought all sensation from the heart could be interrupted by bilateral removal of the sympathetic ganglia from the stellate through the fourth thoracic ganglia or by section of the upper five posterior dorsal nerve roots.

Concerning by which manner the coronary arteries are dilated or constricted, Greene (38) states that " efferent neurons of the coronary vessels that are vasoconstrictors are distributed to the heart via the cervical vago-sympathetics, the inferior cervical ganglia, and nerves of the cardiac

plexus, and the vasodilators are distributed via nerves of the cardiac plexus." There is much variation in the dog. Oschner and Debakey (75), however, are more definite, for they say, although there is considerable controversy as regards the nervous control of the coronary circulation, experimental evidence indicates that the vasoconstrictor fibers are carried chiefly in the vagus and the vasodilators are carried in the sympathetic nerves.

OPERATIVE PROCEDURES UPON THE SYMPATHETIC NERVOUS SYSTEM FOR RELIEF OF CARDIAC PAIN

The sympathetic nervous system has been attacked by two main procedures in the alleviation of cardiac pain, namely, (1) Sympathectomy, and (2) Paravertebral block by use of alcohol. They will be discussed separately.

It is quite obvious these measures could never be advocated as a cure for angina pectoris or as a preventative against furthering complications but are merely performed in an attempt to give the patient relief from the agonizing tortures caused by cardiac angina. As a matter of fact one of the early objections was that abolition of pain was undesirable for the danger signal is lost and the underlying process progresses more rapidly, (58) for the patient would not restrict his activities as he would if he were fearing attacks of pain.

Whether the mechanism of the production of anginal attacks in man is due to disease of the aorta, spasm of the coronary arteries, neurosis, heart fatigue, or more likely anoxemia of the myocardium, no matter how brought about the pain in itself clearly indicates there is irritation of the sensory fibers in the heart wall or in the immediately associated arteries. (54), (83). According to Danielopolu (31)

it is a sensori-motor syndrome of the myocardium. Nevertheless, as stated by Ranson (83), there is irritation of the sensory fibers of the heart.

I Sympathectomy

Reviewing the anatomico-physiological literature it is little wonder that considerable controversy followed Jonnesco's operation concerning what fibers were necessary to sever in order to ameliorate cardiac pain, and how extensive the surgery should be. There were many failures even though the same procedure, by other operators, was followed as was used by Jonnesco. Whether due to less skilled operators' technic or variations in anatomical structures, or failure to identify the nerve fibers properly, remained to be worked out.

No reports were made in the United States until Coffey and Brown, in 1923, (27), had operated upon five cases of angina pectoris severing the left cervical sympathetic trunk below the superior cervical ganglion and the superior cardiac branch in four cases, merely removing the superior cervical ganglion in the fifth case. The third patient was operated upon a second time and the superior ganglion removed.

The fourth patient had pain recur in the left forearm although his substernal pain was relieved. They reported eight additional cases in 1924 (23), of which six were "brilliant successes, all being restored to comfort and some degree of usefulness." Two died, one within a few hours after operation, from an unexplainable cause, and one died in two weeks from heart failure. In six of the fourteen operations, on thirteen patients, there appeared occasional pains in the jaw due to traction on anterior auricular nerve during operation, and the left shoulder which were of no great significance and disappeared in all but two within a few weeks. They say that the main symptom, substernal pain, is due to vasoconstrictor influence of the superior cardiac nerve from the superior cervical ganglia, resulting in spasm of the first part of the aorta, to which it is largely distributed, as well as the coronary. Referred pains are accounted for by the fact that the constrictor impulses are relayed to some extent by the middle ganglion which may give off a branch to the superior cardiac nerve below where it has been severed.

The Coffey-Brown operation merely severs the left superior cardiac branch of the superior cervical

sympathetic ganglion and the main trunk below the ganglion. This operation removes the main cause of angina based on the supposition that, (1) it is due primarily to spasm of the aorta but may be also of coronary; (2) the superior cardiac nerve is of constrictor action and cutting prevents spasm.

Whether or not the stellate ganglion should be ext^{er}pat^{ed} or not, as Jonnesco had advocated, caused considerable controversy. Danielopolu (31) stated that

the synapse of nearly all the sympathetic nerve fibers of the heart is situated in the stellate ganglia and its removal in angina pectoris is incompatible with life as shown by the high mortality....

In summary he outlined a procedure which " at present is the only one which seems legitimate."

.....cut the cervical sympathetic cord, the vertebral nerve above the inferior cervical ganglion, the depressor nerve of Hofer (originates from two roots, one from vagus, one from superior laryngeal nerve) or corresponding nerve, and the nerves which spring from the cervical sympathetic cord above the superior cervical ganglion and pass to the heart.

Later Danielopolu (32), stated that Jonnesco's operation should be abandoned for three reasons: (1) It interrupts important groups of cardiac accelerator fibers, coronary and pulmonary vasomotor nerves; (2) It

has high mortality (Jonnesco practised this operation in Epilepsy and Basedow's disease). The cases of survival are explained on the assumption that the myocardium had not degenerated to the same extent in all anginal cases.

Ionescu (45), however, disagreed with Danielopolu regarding extirpation of the ganglion stellatum for all the centrifugal impulses are removed which force the heart to "unphysiological" work. The electrocardiograph shows the function not to be damaged and the thoracic nerves provide the heart with sufficient accelerator impulses.

That the superior cervical ganglion and its superior cardiac nerve, although they have a purely motor function, are concerned in anginal pain, cannot be denied for in patients in which they were not extirpated along with the sensory pathways, anginal attacks have recurred with radiation of the pain into the face and neck which is the area supplied by the superior cervical ganglion - a motor autonomic reflex (29). Levy and Moore (61) thought vasoconstrictor impulses, via cutting the superior cardiac nerve, were blocked which cause the painful seizures due to coronary spasm.

In 1927, Levine and Newton, (58) "deliberate-

ly" selected seven patients for operation. Two to three months after operation all were alive, four with no anginal symptoms, two with milder anginal symptoms than previously, and one unimproved but no worse than before. Details as to type of operation are lacking.

Cutler, (29) in 1927, evaluated the various operative procedures in 120 cases selected from the literature, summarizing his findings in the following chart:

Operation	No. Cases	Operative Mortality	Results				Late Mortality
			Good	Improved	Not Relieved	Unknown	
I <i>Jonnesco</i> <ul style="list-style-type: none"> A-Bilateral B-Unilateral 	9	0---0.0%	9				2, 4 days, no pain 1, 4 days
	18	3---16.6%	8	5	2		
	27	3---11.1%	17---62.9%	5---18.5%	2---7.4%		
II <i>Cervical Sympathectomy</i> <ul style="list-style-type: none"> A- Superior cervical ganglion either excision of ganglion or division of superior cardiac nerve or ramus A'- Division of main connecting trunk-ramus comm. B- Middle cervical ganglion either excision of ganglion or division of superior cardiac nerve or ramus communicantes C- Inferior cervical ganglion either excision of ganglion or division of inferior cardiac nerve or ramus communicantes A+B B+C A, B+C 	29	2---6.9%	10---34.4%	11---37.9%	4---13.8%	2---6.9%	1, 2 months, 1, 8 days 1, 2 weeks 1, 13 days
	2	1---50.0%	1				
	3			3			
	0						
	4		3		1		
	2			2			
	13	1---7.6%	8	3	2		
	53	4---7.5%	22---41.5%	19---35.8%	6---11.2%	2---3.8%	
III <i>Depressor</i>	12		9		2	1	{ 1, 12 days 1, 2 weeks 1, 1 1/2 years
IV <i>Combination II and III</i>	2			2			{ 1, 6 months 1, 16 days
V <i>Posterior Nerve Root Procedures</i>	26			26(?)			
	120	7---5.8%	48---40.0%	52---43.3%	10---8.3%	3---2.5%	

Results of a large series of cases, reviewed in the literature, are difficult to evaluate accurately, in that each author has an individual method of recording observations. Leriche and Fontaine (52) attempted this composing the following material:

1925- 94 cases collected by Leriche and Fontaine-

1. Disappearance of crises in 59 cases---62.7%
 - a. Relief over 3 months in 29 cases---30.8%
 - b. Relief less than 3 months in 17 cases---18.1%
 - c. Relief for unknown period 13 cases---13.8%
2. Temporary disappearance of crises.....3 in 3 cases---3.2%
3. Marked improvement in 6 cases---6.4%
4. Slight improvement in 2 cases---2.2%
5. Failure in 6 cases---6.4%
6. Unknown results 5 cases---5.3%
7. Operative mortality in ... 13 cases--13.8%
(due to operation, not to progress of disease)

An additional 100 cases collected later showed essentially same results.

1926- 120 cases collected by Cutler-

1. Good results in 47 cases--40.0%
2. Improvement 52 cases--43.3%
3. No improvement... .. 10 cases-- 8.3%
4. Unknown result 3 cases-- 2.5%
5. Operative mortality 7 cases-- 5.8%
(death within 24 hours)

Recent - 52 cases - by Diaz Sarazola-

1. Clinical healing in 16 cases --- 30.0%
2. Clinical improvement in 16 cases --- 30.0%
3. No result in 7 cases --- 13.4%
4. Operative mortality 13 cases --- 25.0%

Although the following results must be discounted considerably, for the type of operation, the type of patient and the degree of improvement, are extremely variable, a summary of the above reports of approximately 366 cases reveals an approximate estimation of the value of the procedure:

1. Good results----- 36.0%
2. Improvement----- 36.0%
Total benefitted ----- 72.0%
3. Failures----- 9.3%
4. Operative mortality----- 14.9%

Leriche and Fontaine (52) thought the best results could be obtained by cutting the rami communicantes going to the stellate ganglion, for in this way the cardio-sensory fibers, for the most part, were severed. Since the rami contain no motor fibers, the motor fibers were saved. They suggested the procedure should be completed by cutting the cervical trunk just above the stellate ganglion, and the vertebral nerve, and, if present, the depressor nerve, but preserving

the ganglia for their removal was followed frequently (25%) by pain in the cervico-facial region.

Richardson and White, in 1929, (84) reported eight cases of sympathectomy for the relief of cardiac pain:

1. Number of cases-----8
2. Number of operations ----11
 - a. Lasting benefit in -- 4 cases---- 50%
 - b. Greatly relieved in - 2 cases---- 25%
 - c. Deaths ----- 2 cases---- 25%

Resection of the upper thoracic sympathetic ganglia obtained "striking relief" in four cases according to White, (104) but concluded the procedure is "too severe for the average patient suffering from angina pectoris." The operative risk is too great for routine use. (107).

The general interest waned for uniform results were lacking. No matter which of the operations was employed, owing to the numerous anastomoses of the cardiac nerves in the neck with each other, with the inferior laryngeal nerve and the vagus, and due to frequent anatomical variations, it is almost impossible to interrupt all these tracts. (104), (61), (106). These conclusions have been borne out clinically and experimentally. (107), (49).

Ransohoff, however, in 1939. (82) said "that left cervico-thoracic sympathectomy is the method of treatment which should not be discarded." He reported seven cases, all of which, were completely relieved of pain; one case lived eleven years after operation, two cases lived six years after operation, one case was still living five years later. One died of heart failure one year after operation, and one lived only eight months. One, on which a paravertebral alcohol block was done first without relief, was subjected to sympathectomy with complete relief and was living two years later.

Undesirable Effects

Little has been mentioned of the untoward effects which result from operation on the sympathetic system, most attention being focused on whether or not cardiac pain recurs. Brown and Adson (82) noted that following excision of the first and second thoracic ganglia there was, (1) marked vasodilatation of the arteries of the hands, (2) marked vasodilatation of the face, neck, and upper trunk (as measured by increases of surface temperature), and (3) loss of reflex sweating and pilomotor reaction in, roughly, the same areas. Horner's syndrome is regularly produced, if the oper-

ation is done properly, but is variable in intensity and persistence, occasionally being a complaint. (22), (84). Painful hyperesthesias are not infrequently found. (84). When absence of pain does occur there usually remains a substernal tightness or a sense of distress which comes on with over-exertion (82), and may be a welcome sign to prevent hazardous over-activity. Diaz called attention to atrophy of the pectoral, deltoid, trapezius, supraspinous and infraspinous muscles following resection of the middle, inferior cervical, and first thoracic ganglia and trunk, according to Brown and Adson (22). This becomes recognizable in from one to three months.

II. Paravertebral Injection of Alcohol For Angina Pectoris

Sympathectomy as a means of alleviating pain of cardiac origin was not successful enough to attract physicians to use it as a general procedure, for the surgical operation was too extensive to be used by the average surgeon and as a rule it was not advisable to submit patients suffering from incurable coronary disease to such an operation. (61), (107). Furthermore, it quite generally agreed that cervical sympathectomy,

even if the stellate ganglion were removed, could not interrupt all the pathways of cardiac pain. (104), (61), (106), (97).

In Germany, von Bergman suggested and, in 1922, Brunn, and Mandl, (24) studied the method of injection of procaine hydrochloride into the dorsal rami for treatment of angina pectoris. Swetlow (98) says, Mandl, in 1925, reported sixteen cases in which novocaine ($\frac{1}{2}\%$) had been injected, paravertebrally, with excellent results, giving long time relief with no deaths or severe complications. Swetlow was the first to attempt paravertebral alcohol block for cardiac pain in this country, and thought the situation should be solved by ascertaining definitely the point of entrance of the pathways of cardiac pain into the spinal cord or brain, as indicated by the areas to which pain was referred. He said, in quoting Head, the patient would also have hyperesthesia "for cells in the dorsal root ganglia that are bombarded are hyperirritable to external stimuli." He suggested protopathic and epicritic sensory tests to determine the root ganglia being bombarded by pain stimuli. He reported eight patients with severe cardiac pain who received prompt and satisfactory relief after being treated with alcohol

injections, without serious after effects or complications.

This created new energy for the relief of heart pain and was based on the assumption that the chief connections between the cervico-dorsal sympathetic chain and spinal cord are through the rami communicantes of the upper dorsal nerves. (108). Also this was the safest method available with practically no mortality.

Swetlow and Swartz, (100) reported five cases with complete relief for from two to six months. All were varied cases of precordial pain and none with the true Heberden's angina. In 1929, Swetlow, (97) reviewed forty-one cases which had severe cardiac pain treated by paravertebral block; injections were confined to those rami communicantes between the eighth cervical and seventh dorsal spinal segments. The results suggested that the true pathways of cardiac pain impulses were carried to the spinal cord by these rami. Experimental work on animals supported this fact, for such nerves as the depressor and vertebral, rarely observed in humans, when stimulated, failed to incite painful reactions. In nine patients treated by alcohol injections by Mixter and White (71) showed inter-

esting results:

1. In three patients--relief--90% or over.
2. In three patients--relief--35 to 90%.
3. In two patients----relief--less than 35%.
4. Days in hospital--two to three.
5. Deaths or serious complications--none.
6. Post-operative hyperesthesia and/or pain-----seven.
7. Died since----- two.
8. Failure----- one.

Other attempts by White (108), (105), (107), (104), at various times showed results very similar. In thirty-eight cases over a period of six years, he found good results in 70.3%, fair results in 16.2%, improvement in 5.4%, failure in 8.1%, and death in one case. (75). Cattell and Hurxthal, (35) reported an individual case with complete relief after para-vertebral injection.

In 1931, Levy and Moore, (61) analyzed thirty-seven cases including their own from a view point other than whether relieved or not with very interesting findings:

1. Number of injections-----41
 - a. Left side-----38
 - b. Right side----- 3
2. Etiologic Type of Heart Disease

a. Arteriosclerotic-----	32
b. Syphilitic-----	4
c. Rheumatic-----	1
3. Relief Obtained	
a. Complete (49%) -----	18
(1) Permanent-----	15
(to death or last known status) (six died within 6 months)	
(2) Temporary-----	3
b. Partial (43%) -----	16
(1) Permanent-----	15
(2) Temporary-----	1
c. None (8%) -----	3
4. Horner's Syndrome	
a. Present-----	7
b. Absent-----	8
c. Not noted-----	22
5. Untoward Effects	
a. Pleural Effusion-----	2
b. Post-operative collapse-----	2
c. Blood expectoration-----	1
d. Operative deaths-----	0
6. Duration of Follow-up	
a. Less than six months-----	20
b. Six to twelve months-----	12
c. One to two years-----	1
d. Two to three years-----	4

Undesirable Effects

The untoward effects and discomfort have not been emphasized by advocates of paravertebral block for relief of cardiac pain any more than the advocates of sympathectomy brought out the ill-effects of their methods. As can be seen from the analysis by Levy and Moore, although the patient may get re-

lief from the anginal pains, bothersome, distressing, and discomforting effects may result from an error in technic by the operator. But further, undesirable effects may come about physiologically due to hemisection of the sympathetic system, as Horner's syndrome. The individual response varies considerably but nearly always the patient experiences pain and hyperesthesia. (108), (61), (71), (84). This hyperesthesia may be mild or severe and may last from a few days to five or six weeks, although the relief from angina is immediate. This is apparently due to an intercostal neuritis and is unavoidable, although may be helped somewhat by diathermy. (61), (82).

Other effects are a moderate degree of fever (100-102~~7~~ degrees) which persist for seven to ten days. (61), (71). White and White (108) thought the severe pain on the left side, feeling of faintness, and weak pulse, pulse of which some of their patients complained, was due to the intravenous procaine hydrochloride. This passed off in about one hour. The alcohol injections produce an area of necrosis about one to two centimeters in diameter where injected. (61), (106), (108). This may be a cause for the moderate fever which usually follows. (61).

Reasons For Failure

Unsuccessful results by either sympathectomy or paravertebral block may be divided into four groups, although the failures may not be necessarily due to any one reason but rather an inter-relation of the four:

(1) Anatomy

It is quite generally agreed that all the pathways for cardiac pain cannot be interrupted. (40), (105), (99), (97), (106), (75). As has been shown in the discussion on anatomy. It will suffice to say here that this is probably the main reason for failure, for injections or operations will stop painful impulses to the spinal cord but they can still be transmitted to the cranial nerves through the vagus and vasoconstriction may still be possible via the superior cardiac nerve. (61), (107).

(2) Selection of Patients and Erroneous Diagnoses.

Whether the procedure is to be sympathectomy or alcohol block the selection of the patient is most important from the standpoint of the patient and in order to evaluate the true worth of the operative measures.

Those patients must be selected from

the point of view that the operative mortality should be slight and their expectancy great enough to warrant any beneficial results which may follow the operation. He should be selected not only from the standpoint of diagnosis but prognosis. (58). If there are signs of myocardial damage sufficient to produce congestion heart failure which is not relieved by adequate conservative medical treatment the chances of recovering from a surgical procedure is not good. Since paravertebral block is not such an operative shock as sympathectomy, the patient may be used advisably when it would be incorrect and poor judgment to attempt a sympathectomy.

Most authorities feel that cases of angina pectoris in which the myocardium is not damaged by infarcts are proper cases for surgery providing they cannot be alleviated by medical treatment. (58), (52), (84). The best results are obtained, however, in those cases in which the attacks are rare. Leriche and Fontaine (52) feel that no one is justified in requiring a long period of medical treatment before undertaking a surgical procedure. "In the early stages of the disease, cervical sympathectomy is a very benign operation and our experience leads us to believe that medical treatment is of little benefit."

They think that waiting may be disastrous in that the correct time for the operation, when surgery is indicated, will be passed up, thus increasing the operative mortality.

According to Levine and Newton (58), the actual size of the heart need not be considered a danger signal unless a marked enlargement would arouse suspicion of a myocarditis. The rhythm should be normal for a pulsus alternans or a gallop is not a good sign, and, if auricular fibrillation is present, especially the transient type, an infarction is not uncommon. Levine also says that presence or absence of systolic murmurs or areas of precordial hyperesthesia are not significant. A low blood pressure, however, may be due to a previous infarction of the heart. (54), (58).

There is no need for errors in diagnosis (as has been discussed in a previous section) with proper history, examination, and laboratory procedures. (54), (58), (52).

(3) Types of Operation.

Sympathectomy is a neurosurgical procedure which demands the greatest precision and execution. A good many operations are failures because the proper structures have been improperly identified.

The technic has varied with the individuals but in general it is agreed that operative procedures are of little value on the cervical sympathetics, (40), (105), (107), (99), (97), (106), (75) and that treatment should be confined to the dorsal spinal segments.

(4) The Operator.

The surgeon in expecting to get 100% relief is already handicapped by the above three factors which make it all the more necessary for him to be a man of skill. It is important that he learn his technic thoroughly, and as stated by White (106) and others (71), (108), unless he is very well experienced in paravertebral anaesthesia he should not attempt the operation without first practising on cadavers.

TOTAL THYROIDECTOMY FOR THE RELIEF OF CARDIAC PAIN

Relationship Of The Thyroid And Cardiac Disease

That the thyroid gland had a direct influence in cardiac disease has been known for as long as 150 years (75) but it was not until this century that the relationship was studied sufficiently to make known the mechanism.

Levy (59), in 1916, concluded, after experimenting with cats, that stimulation of the cervical sympathetics, or adrenine injection, induced secretory activity in the thyroid gland, and in turn, thyroid secretion rendered the sympathetic structures, acted on by adrenine, more excitable. Riesman (85) noted the relationship of thyroid activity to cardiac disease without evidence of disease of the gland. In a study of 200 cases of heart disease in hyperthyroidism in the Lahey clinic, Hamilton (39), in 1922, found there were two large groups. One which showed no evidence of heart damage, death being directly due to the toxicity and not from heart failure, and one in which there was definite cardiac hypertrophy with either paroxysmal or ~~re~~established auricular fibrillation, without evidence of rheumatic or other heart disease, and in which signs

of heart failure were seen. About ten per cent of those cases of hyperthyroidism had auricular fibrillation as a more or less direct result of the toxicity. These cases would be relieved by thyroidectomy, for the hearts of thyrotoxic patients are not equal to the demands made upon them and congestive heart failure results. (14). Rosenblum and Levine (88) reported studies on sixty-nine patients who had significant heart disease and hyperthyroidism. Nine had angina pectoris and sixty had other forms of heart disease. They studied them over an average period of twenty-one months following sub-total thyroidectomy and found an "enormous improvement" with only two deaths. All nine angina patients were improved.

Lahey and Hamilton (50) called these patients "thyrocardiacs" and said they were the end-results of untreated hyperthyroidism. Investigations by Blumgart, Gargill and Gilligan (13) revealed there was an extremely rapid velocity of the blood flow in patients with thyrotoxicosis which may be a factor in producing the signs and symptoms of circulatory insufficiency, for the work of the heart consists mainly in expelling blood into the aorta and pulmonary arteries against existing pressures, and imparting to the blood a certain velocity.

Christian (26) recognized the relation of decreased metabolism and decreased work of the heart in patients with myxedema and thought that "the decreased activity of so many bodily functions serves as a conservative force so far as the circulation is concerned," for when the metabolism is increased by feeding thyroid, an immediate burden was put on the heart. Morris (74) noticed thyrotoxicosis states in those with even subnormal basal rates in which sub-total thyroidectomy would be indicated.

It was noticed by Lev and Hamburger (53) that in patients with myxedema when fed thyroid extract, anginal attacks were not infrequently produced which were absent in the hyperthyroid state. Those patients with anginal pain, when given thyroid, had an exaggeration of their symptoms, and four out of five of those with hyperthyroidism, with angina, were relieved of the latter following thyroidectomy. (12).

Boas and Shapiro (16) performed thyroidectomies on patients with cardiac disease without evidence of thyroid disease, whose characteristic feature was diastolic hypertension. These received no relief. Collier and Arn (28), performed thyroidectomies on patients with nodular goiters, but with normal, subnormal, and low normal basal metabolic rates, with improvement of symptoms

(nervousness, palpitation, and dyspnea) produced by dyscrasia of thyroid secretion," and not caused by lack of thyroid function.

Rationale of Total Extirpation of the Normal Thyroid Gland

This procedure has never been advocated as a curative measure, nor does it in any way alter the disease process, but is merely a palliate measure, to alleviate pain.

As was shown by Blumgart, Levine and Berlin, (14) in patients with congestive heart failure but with a normal basal metabolic rate, the basal velocity of the blood flow is greatly slowed. In patients with myxedema, the blood flow may be similarly slowed, due to the low metabolic rate, although they show no evidence of congestive heart failure. Hence, their circulation is evidently adequate for the decreased demands of the body.

In angina pectoris a similar discrepancy was found to exist between the tissue demands and the blood supply. (75). If angina pectoris is due to insufficient blood supply to the heart (as discussed in a previous section) when there is an increased demand on the heart due to exertion or emotion, even though the blood is adequate during rest, this demand would be diminish-

ed by thyroidectomy, so the lessened flow through the coronaries would be sufficient even during strain. (13), (75). Furthermore, the heart which is overburdened may be helped if the burden is reduced (69) and Blumgart, Levine and Berlin (14) suggested, that if the metabolic rate were lowered significantly by removal of the thyroid, even though normal, in patients with a normal basal metabolic rate but with congestive heart failure, they might get improvement. These hearts cannot supply the ordinary demands of a normal basal metabolic rate but might meet the demands of a lowered basal metabolic rate. Since the heart's capacity might be benefitted if their hearts worked less. (69), (75).

Experimental studies (13), (11) on thirteen patients with thyrotoxicosis showed the following facts:

(1) There was an inexact relation between the degree of elevation of pulse rate and increased basal rate.

(2) With a decreased basal rate the vital capacity of the lungs tended to increase.

(3) The velocity of the blood flow strikingly increased or decreased in direct relation to the metabolic rate.

In feeding patients thyroid extract, after thy-

for the ordinary needs in daily life. (14). (11).

On the other hand, Lourie (63) thoroughly rebukes the rationale of such a treatment quoting Kocher that "an efficient heart gradually becomes inefficient" when the metabolism is lowered by total thyroidectomy. He did not think total thyroidectomy should be performed, for (1) the function of the thyroid is not limited to acceleration of metabolism, (2) a comfortable useful active life cannot be maintained at a permanently low metabolic rate, and (3) the patient having less demands to meet becomes efficient, but cannot last long, for the heart muscle must suffer along with the rest of the body tissues. So if the demands of the heart are less, the activity of the heart may become also less.

Mechanism of Relief of Cardiac Pain by Total Thyroidectomy

Relief of painful manifestations of cardiac disease following thyroidectomy was thought at first to be due to the lowered metabolic rate. In angina pectoris, however, the relief of pain was not due entirely to a slowing of the circulation for the angina disappears long before the basal metabolic rate has

begun to fall. (92). The immediate post-operative relief of pain precedes and is distinct from the lasting relief due to the development of hypothyroidism. (110).

Such observations led to experimental investigations as to another cause for the anginal pain. It was suggested by Levine, Cutler, and Eppinger, (55), that removal of the thyroid gland might be producing a fundamental alteration in the response of the circulation to adrenalin, and that a previously positive response might possibly become negative after such an operation. (34). Levine and Ernstene (57) had previously observed that in patients with angina pectoris, an attack of typical anginal pain could be elicited after the injection of one centimeter of epinephrin subcutaneously. They concluded, this could be a diagnostic test for angina pectoris, since in normal patients no pain response was obtained after administering epinephrin. Using Sutton and Lueth's method for producing experimental angina pectoris in the dog, Shambaugh, (91) with subminimal traction by pulleys around a coronary artery produced a typical angina response after the injection of adrenalin. He believed the discomfort produced probably simulates the attack

of angina pectoris in humans more closely than the older method in which direct traction alone was used. He found, however, it was possible to elicit a typical response after thyroidectomy as well as before. Eppinger and Levine (34) after studying five patients with total thyroidectomy which gave a typical anginal response following injections of adrenalin, concluded that removal of the thyroid completely alters the response of the cardiovascular system to adrenalin and that this effect is dependent of changes in the basal metabolic rate or velocity of blood flow. They also suggested that this decreased sensitivity to adrenalin may be responsible for the relief of cardiac pain following total thyroidectomy, as did Phillips and Milliken. (81).

Further studies by Riseman, Gilligan and Blumgart (86) with epinephrin showed the response of the systolic blood pressure was closely related to the rate of injection of epinephrin. The sensitivity to epinephrin remained unchanged after total thyroidectomy so long as the basal metabolic rate was not lower than a negative thirty per cent but when the basal rate did go below thirty there was a decreased response of systolic blood pressure and heart rate to

epine hrin. They were led to believe that sensitivity to adrenalin had little to do with the clinical relief of pain following total thyroidectomy for the basal rate could never be allowed to go to such a low point. Two ways adrenalin, either secreted or injected, might precipitate an attack are: (1) By causing constriction of the coronary arteries and producing myocardial ischemia; (2) by increasing the blood pressure and heart rate so that the vascular demands of the myocardium were too great for the narrowed vessels, causing a relative myocardial ischemia. (92). Levine and Ernstene (56) suspected increased blood pressure was an important factor in producing anginal attacks.

The immediate relief of cardiac pain following total thyroidectomy cannot be due to changes in circulating thyroxin has been shown by Weinstein and Hoff (110) and others (103), (92), (12), (11). They believed it was due to the interruption of nerve impulses and was temporary for (1) the loss of hyperesthesia and hyperalgesia of the chest wall and the subjective relief of precordial pain occurred immediately after operation and frequently reappeared after three to six weeks; (2) unilateral relief of the anginal pain by hemithyroidectomy constitutes striking evidence of interrup-

tion of afferent impulses from the heart; (3) is closely analogous to the early effects of cervical sympathectomy. Weinstein and Hoff (110) concluded after their observations that the immediate relief of pain in patients with angina pectoris is due to injuries to the superior and middle cardiac nerves and the nerve plexuses on the posterior surface of the thyroid and its vessel.

A decreased vasomotor tone, as pointed out by Schnitker, Van Raalte and Cutler (90), with relaxation of the smaller blood vessels is most pronounced shortly after the removal of the thyroid gland which may be a factor in the early relief of cardiac pain.

The permanent relief of cardiac pain following total thyroidectomy is a separate factor and is due to a lowered metabolic rate, occurring coincidentally with the hypothyroid state. (12), (75), (81). Experiments indicate that thyroidectomy has influence favorable to the action of the embarrassed heart, because the decreased rate of the response to various stimuli necessitates the use of less oxygen and the heart muscle has a greater opportunity to recover (89). Sawyer and Brown (89) further noticed a change in the character of the heart sounds after thyroidectomy which

were returned to normal after administration of thyroxin which suggested that the strength of the contraction may be diminished as well as the rate, thus insuring a greater coronary blood supply.

Another possibility to account for the relief of pain following total ablation of the thyroid was suggested by Bourne and Ross (18). They noticed that after administration of thyroid extract, in thyroidectomized patients, attacks of pain were delayed for three or four days. Also there was a lag of three or four days after discontinuing the medication before the patients were free from pain. For these pain stimuli to be adequately or for the stimuli to rise into consciousness, it is possible that there must be a certain amount of thyroxin present in the circulating blood stream.

Survey of Progress in the Treatment of Cardiac Pain by Total Thyroidectomy

The first attempts to alleviate cardiac pain by thyroidectomy were done by Berlin (37), (8), (75), and Cutler and Schnitker (30), (75) by partial removal of the gland. It was, however, evident that sub-total thyroidectomy was not sufficient, for after the basal metabolic rate had been decreased for three weeks, it

again increases with the condition growing worse. (55) Berlin (8), (37), perfected a one stage operation under gas-analgesia with preliminary medication of morphia and sodium amytal in which the thyroid gland was removed completely.

Blumgart, Berlin, Davis, Riseman and Weinstein (12), reported sixty cases of intractable heart disease upon which they had performed a total ablation of the thyroid gland, twenty of which were suffering from angina pectoris. Of these twenty there were no deaths. Ten had no recurrence since operation, seven were much improved and three had little or no clinical improvement. Since the heart after complete thyroidectomy performs less work and starts at a lower oxygen consumption level, it can withstand a greater increment of work before reaching the upper limit of oxygen supply set by the relatively fixed coronary vessels. (11). The relief was related to the degree of lowered basal metabolic rate. In a series of twelve patients, all hopeless cardiac cripples, four with angina pectoris, four with valvular heart disease and auricular fibrillation, and four with non-valvular heart failure, Levine, Cutler, and Eppinger (55) reported the following results:

1. Improvement in six patients ---marked.
2. Improvement in three patients--slight to moderate.
3. Improvement in one patient-----none.
4. Improvement in one patient-----insufficient time to judge.
5. Improvement in one patient-----died. (patient was moribund at time of operation)

Cutler and Schnitter (30) studied and operated on twenty-nine patients with angina pectoris which upon analysis shows:

- (1) Immediate Surgical Risk:
 - a. 6 deaths in 29 cases-
 - (1) 2 (6.8%) immediate and presumably related to surgical procedure.
 - (2) 4 (13.7%) late and presumably not related to surgical procedure.
 - (a) 1- 8.75 months-congestive heart failure.
 - (b) 1- 18 days- acute pulmonary edema.
 - (c) 1- 5 days- coronary closure.
 - (d) 1- 4 months- coronary closure.
- (2) Complications:
 - a. 4 (13.1%) recurrent laryngeal nerve injury- voice compensated but cord paralyzed.
 - b. 3 (10.3%) parathyroid tetany- not severe, easily controlled.

Chart of the results of those patients which survived and could be accounted for are shown on the following page.

CHART OF RESULTS
(21) Patients

Excellent (90-100%)	=	10	(47.6%)	}	14 (66.6%)	}	19 (90.4%)
Good (75-89%)	=	4					
Fair (50-74%)	=	5					
Poor (0-40%)	=	2					
				}	7 (33.3%)		

Per cent still taking nitroglycerine.

None-	47.6%
Yes, occasionally-	19.0%
Yes, but less-	33.3%

Excellent- no real pain- no nitroglycerin-full activity.
 Good- occasional attacks of modified pain, almost full activity. 2 patients in this group have taken nitroglycerin on rare occasions.
 Fair- daily attacks of modified pain relieved by nitroglycerin. All have resumed active life, that is, women do housework, men do occupations.
 Poor- frequent attacks of modified pain for which nitroglycerin is taken. Activity limited.

In a statistical resume of 133 cases of angina pectoris operated by total thyroidectomy, Parsons and Purks (80) found:

Excellent results-----	55.46%
Moderate improvement-----	28.12%
Slight improvement-----	3.9%
Failures-----	12.05%
Operative mortality-----	3.75%

A similar review of 100 cases by Weeks (102)

Number of cases	
Deaths -----	100
Immediate-----	3 or 3%
Late, not related to operation.	15 or 15%

Clinical Results in 82 Patients.

Markedly improved -----	42 or 51.2%
(no pain, nitrites, normal activity)	
Moderately improved -----	33 or 40.2%
(mild attacks of pain at irregular intervals, occasional use of nitrites)	
No improvement -----	7 or 8.5%

Parson's and Purk's review shows that 83.58% were benefitted while in Week's cases 91.4% were improved.

Results in more recent years by Bourne and Ross (18), (19) show the procedure to be definite value for, of twelve patients treated, all were definitely improved, with no deaths during or immediately following the operation. Bothe, in 1938, (17) studied results by Gallie, Heuer, and himself which were all favorable. He suggested that total thyroidectomy should be considered in those patients which were potential cardiac failures in an effort to prevent or postpone the development of congestive heart failure. In 1939, Phillips and Milliken (81) reported fourteen cases which they had operated at least two years previously, a total thyroidectomy being performed. All were suffering from angina pectoris of the most severe form. They feel that none was cured but " the present level of improved status fully justifies the use of total ablation of the thy-

roid gland in properly selected cases." All were improved and one had a post-operative gangrenous appendix which was operated upon successfully, and one patient conceived and carried a pregnancy to term without decompensation or pain.

The production of the many undesirable effects as well as the hazard of the surgical procedure in patients who at best are not good operative risks led many men to look upon the method of treatment with disfavor. (64), (60). After observing "thyrocardiacs" and recurrent hyperthyroid cases, Lyon and Horgan (64) believed that cessation of the hyperthyroidism and disappearance of its effects upon the heart were not alone due to the excision of the major portion of the gland but that division and ligation of the superior and inferior thyroid arteries, by severing the pathways of nerve stimuli from the sympathetic nervous system to the thyroid, and by diminution of the amount of blood entering the gland, diminished thyroid activity and prevented regeneration of the remaining tissue. They observed this operation decreased the basal metabolic rate, reduced the demands on the circulation, and lessened the work of the heart. This procedure also severs the interrelation between the innervation of the heart and the thyroid gland.

Five cases of angina pectoris were operated upon with complete relief and without occurrence of the effects that result from total ablation of the gland.

In experimental research on animals, Friedman (36) showed that when the blood supply of a gland was curtailed, necrosis and absorption of the functional tissue occurred which was followed with connective tissue replacement. Since the thyroid is such a vascular organ and its end-arteries are without anastomoses, its viability was much more quickly effected by a sudden loss of its blood supply. Post-operative histologic sections showed complete necrosis of the gland except at its medial attachment, nearly throughout the gland. He also operated one case of angina pectoris with very satisfactory results, requiring no post-operative medication. The superior and inferior thyroid arteries were ligated and cut, the capsule being carefully separated from the entire area except on the postero-medial aspect.

Weeks (102) operated two cases of angina pectoris attempting to "denervate the thyroid" following the suggestion of Lyon and Horgan. One died on the third post-operative day of proved coronary thrombosis without relief of pain in the three days; one lived but received no relief of pain.

Weinstein and Hoff (110) had tried to determine the mechanism of relief of pain by testing areas of hyperesthesia and hyperalgesia in different stages of the operation. They concluded that the immediate relief of pain was due to injury to the superior and middle cardiac nerves and nerve plexuses on the posterior surface of thyroid and its vessels. They thought this had nothing to do with the permanent relief of pain. It appears, however, to be interrelated as is shown by Lyon and Horgan's studies.

Hazards and Undesirable Effects of
Total Thyroidectomy in Patients
With a Normal Thyroid Gland.

For an operation in the relief of cardiac pain to be successful, it is essential that (1) every bit of thyroid tissue be removed, (2) the parathyroid glands be preserved, and (3) that bilateral paralysis of the vocal cords be avoided. (111). Obviously, then, any such operation is going to be a hazardous, difficult procedure.

In the first place the patients are cardiac cripples, usually in the age when life's expectancy is none too great, so that any operative procedure must be done with a feeling of apprehension for the

surgical risk is greatly increased. Besides the operative hazard, which is indeed great, because of the technical difficulty in removing every particle of functional thyroid tissue, the surgeon must contend with post-operative cardiac failure and terminal broncho-pneumonia, recurrent laryngeal nerve injury and parathyroid insufficiency. (12). If the operation is successful, myxedema must be treated, while if unsuccessful, the operation cannot be repeated for the post-operative adhesions so obscure the functioning thyroid tissue that it cannot be found at subsequent operation. Irradiation of the partial gland with heavy doses of Roentgen rays is ineffective. (37).

The greatest surgical hazards are the recurrent laryngeal nerves for they not infrequently course through the gland. (12), (9). Mixer, Blumgart and Berlin (70) thought no operation should be performed unless the larynx could be examined by a competent laryngologist after completion of hemithyroidectomy, and said "the sole indication for stopping the procedure was paralysis of the vocal cord on the operated side after hemithyroidectomy." Of seventy-five patients operated upon, Blumgart, Berlin, Davis, Riseman, and Weinstein (12) report twelve uni-

lateral injuries to the recurrent laryngeal nerve of which nine were a transient paralysis and three were permanent. In practically all with only one cord paralyzed there had been no alteration in spoken voice, so the voice test can not be substituted for laryngoscopy. (12). Of twenty-nine patients operated by Cutler and Schnitker (30) four showed recurrent laryngeal injury, but the voice compensated.

Parathyroid deficiency, due to extirpation of the glands during operation, had no serious complications in the seventy cases reported by Blumgart et al (12). Parathyroid extract was never required and only sixteen had transient paraesthesias, positive Chvostek's or Trousseau's signs. These were readily controlled by calcium medication. Parathyroidectomy is not severe if the operator adheres closely to the gland in dissection, clamping the vessels near the capsule. (70). Severe parathyroid tetany does not cause much worry and is never much more severe than an increased irritability which is efficaciously controlled by five drops of viosterol once or twice daily and four to six grams of calcium lactate daily. (30), (102). This may be due to injury rather than removal of the gland for it is usually mild and later on no medication

is needed. (9).

Myxedema is the important complication which is necessary in order to obtain relief from the pain and inevitably results in every case which has been done properly. The extent of the permanent relief of pain is related to the degree of hypothyroidism as indicated by lowered basal metabolic rate. (12). The degree of myxedema due to total thyroidectomy depends on the time following operation and the amount of thyroid administered. Manifestations are not seen until the basal rate is below a negative twenty. (55). In Week's cases (102) myxedema did not appear for six or eight weeks and the first sign is the characteristic pallor of the skin and puffiness. Coldness of the extremities, dryness of the skin, fatigue, drowsiness and irritability then follow. Post-operative muscle pains in the legs follow total thyroidectomy which are relieved by thyroid medication and exercise. (90).

Thyroid extract often either does not suffice to overcome the lack of thyroxins or the metabolism is thereby elevated to such a point that attacks of pain recur. (60). "Nothing is more tragic than a patient with myxedema who cannot be brought to a com-

fortable existence from the thyroid point of view without producing angina attacks," said Hurxthal. (44). Moreover congestive heart failure may result from the myxedema for it must suffer along with the rest of the bodily tissue. (63).

Several psychoses have followed the development of myxedema which are not cured by administration of thyroid extract. (63). Most myxedematous have dulled senses and the mentality is markedly abnormal. (44).

Selection of Patients for Total Thyroidectomy

Great care should be used in the selection of cases and careful consideration should be given as to the advisability of producing myxedema, (44) for the progress of the underlying pathological condition is not altered by the induction of hypothyroidism. The procedure is of little value in individuals with a low basal metabolism rate (12), (76), (11), and Mixter, Blumgart, and Berlin (70) hesitate to operate when it is a minus fifteen refusing to operate at a minus twenty, for it has been found these patients do not get relief from angina as readily as those with a higher basal rate, without becoming myxedematous.

In general the operation for relief of angina pectoris is indicated only in a small group of patients with a certain type of pain. (18). It is quite certain that those suffering from true angina pectoris are more likely to obtain considerable relief, particularly if they have no additional congestive heart disease. (55), (18). No patient in whom a classical picture of angina of effort is not present should be treated by thyroidectomy, according to Bourne and Ross. (18). They further say that the pain must be of such a severity as to incapacitate the patient, and should have been observed over a long period of time to be certain it is growing worse and not better. The treatment of angina pectoris is successful over a period of time with rest in bed, nitrites prodromally, and sedatives. If patients show progression in the number of attacks of coronary pain with frequent seizures at bed rest, thyroidectomy will probably not give lasting results. (9). A recent coronary attack, within three months, is likewise a contraindication for thyroidectomy, (9), (70), (75) although a healed coronary thrombosis does not make the operation so precarious. (9), (12).

Also due regard must be paid to the presence

or absence of those complicating conditions which are in a measure independent of the heart such as, renal insufficiency, or nephritis, cirrhosis, active infection as bronchiectasis and lung abscess, advanced arteriosclerosis, syphilitic cardio-vascular-renal disease, or acute rheumatic infection. (9), (14), (55), (75), (18), (70), (12), (76). Patients with hypertension are not acceptable. (12).

The selection of patients should be advised by a cardiologist and only those used which had failed to respond to all the conservative medical measures usually employed. (9), (76). Ochsner and Gillespie (76) are convinced the operation is not of value in the patient with the cardiac reserve so depleted no improvement can be expected even though the demands upon the heart are decreased.

An ideal patient with angina pectoris for operation would be one in which the attacks of pain occur upon slight exertion but not at rest. None of the unfavorable factors mentioned above are present. The result would probably be complete freedom from attacks of angina pectoris, or development of attacks only after moderately severe exertion. (12).

Management of Selected Cases

In cases selected for operation the first essential is to know the patient, by questioning and observing, to be positive the diagnosis is correct, and to be certain none of the contraindications are present which might decrease the opportunity for recovery of an already poor operative risk.

Pre-operative care consists mainly in aiding the patient to reach the optimum condition for operation and recognizing the condition when it arrives. The process varies with each individual patient but is primarily one of rest. Since it is inadvisable to operate those with congestive failure, for they are likely to develop serious post-operative pulmonary complications, or die too soon to justify the procedure, surgery should be deferred until edema free. (9), (12). Digitalis should be used as necessary for edema or fibrillation if in failure. Nitrites should be used when prodromal signs of anginal pain are felt. Intensive pre-operative sedation should be avoided as much as possible to prevent accumulation of tracheobronchial secretions. (9), (70). On the eve of the operation, Berlin (9) suggested three grains of sodium amytal and one-sixth grain of morphine in the morning. This minimum sedation prevents the

cough reflex, as well as, lowering pulmonary complications. (70).

For the operation, Berlin (8) devised a one stage procedure using gas-oxygen anaesthesia, which proved to be unsatisfactory, for in the first twenty-eight cases operated there were six operative deaths. He then substituted this by a local anaesthetic with which there were no operative deaths in the following sixty-two patients. (9). Local infiltration also aids in separating the fascial planes so dissection is easier, and gives less chance for injury to the recurrent laryngeal nerve. (70), (55). Inspection of the vocal cords after hemithyroidectomy has been emphasized previously.

The aim of the post-operative treatment is to keep the patient as comfortable as possible with sufficient fluids by mouth, and nasal oxygen if dyspneic, and, again with a minimum amount of sedation. (9). Mixter, Blumgart and Berlin (70) advise rest in bed until the basal metabolic rate is at least twenty per cent below the pre-operative level. Thyroid extract is then given in one-quarter or one-half grain doses as needed to maintain myxedema free and still free from pain. The warning signs to give thyroid extract are when the patient is slightly lethargic, or slightly sensitive to

cold, or shows progressive increase in weight.

AUGMENTATION OF THE CORONARY COLLATERAL CIRCULATION
IN THE TREATMENT OF CORONARY DISEASE

Although the heart is one of the most important organs in the body, it has a minimum of direct continuity with the rest of the structures. It is anchored to the rest of the body by the great vessels, some fat, a few nerves, and lymphatics, while the entire surface lies free within the pericardial cavity being in contact with the pericardium, but only attached at its reflection.

There are three sources by which the heart muscle normally receives its blood supply; namely, (1) the right and left coronary arteries which is the main source, (2) the vessels of Thebesius which open directly from the left ventricle cavity, and (3) through extracardiac anastomoses present in the tissue at the base of the heart, that is, around the root of the aorta, the base of the pulmonary arteries and pulmonary veins, the ostia of the superior and inferior venae cavae, and in the intervascular pericardial reflections. (1), (43). Whether the Thebesian vessels are important in supplying the muscle of the heart is disputed for some think they are compressed or possibly completely collapsed by the tension of the contracting muscle fibers during systole, while during diastole the pressure in the ventricle synchronously falls with the relaxing muscle,

thus prohibiting the vessels from filling. (1), (87). The extensive vascularity around the base of the heart was well illustrated by Hudson, Moritz, and Wearn (43) by the injection of a colloidal suspension of carbon particles into the coronary arteries of human hearts excised at autopsy.

Rationale of Increasing the Coronary Collateral Circulation in the Treatment of Coronary Disease

As the coronary arteries occlude with age, due to sclerosis, thereby reducing the blood supply through them, a compensatory circulation arises to nourish the myocardium. (73). The degree of collateral circulation established is directly proportional to the gradualness of the occlusion. If this occlusion is sufficiently slow to allow new sources of blood supply to develop, partial or even complete closure of the coronary arteries is compatible with life. Unfortunately, however, the usual mechanism is that occlusion is too rapid and the patient dies. (1), (73), (87). Bilateral occlusion of the coronary orificies was found at autopsy with which also was found a network of dilated vessels extending from the adventitia of the aorta and pulmonary artery to the non-occluded portions of the

coronary artery, indicating a long period of obstruction. (1), (73).

According to Beck, (1) Thorel, in 1903, first suggested the possibility of the heart receiving a collateral blood supply through adhesions. Although Beck had been surgically experimenting on the heart since 1923, in animals, and had observed that blood vessels extended between the heart and the adherent scar tissue, he gives credit to Alan R. Moritz for directing attention to the subject of the vascularity of cardio-pericardial adhesions. Moritz, Hudson and Orgain, (73) in 1932, examined four hearts, with partial or complete obliteration of the pericardial sac by fibrous adhesions. After injections of a colloidal suspension of lamp black they found the extracardiac anastomoses of the coronary arteries were increased owing to the presence of the adhesions. They concluded that extracardiac anastomoses constitute a significant reserve for coronary circulation, which is augmented by pericardial adhesions. In experiments on dogs, Robertson (87) found that when the main source of blood to the heart is decreased myocardial nutrition depended distinctly on the vessels contained in the pericardial adhesions, and there was no evidence that anastomoses between the epicardial or

coronary vessels and the thoracic vessels via the vasa vasorum of the aorta, nourished the heart.

Since the pathology of coronary disease is essentially a deficiency of blood to the myocardium, it was conceived that, theoretically, the disease could be cured by revascularization of the heart. As discussed previously, other forms of therapy for cardiac pain were aimed in alleviating the symptoms with no attempt to eradicate the underlying pathological process. Furthermore in a study of ninety-four human hearts in which a major coronary artery had been occluded, Moritz and Beck (72) found there was a period in the lives of forty-three individuals, after the first coronary occlusion, in which the production of an extracardiac coronary collateral circulation might have been feasible and beneficial, thereby preventing the subsequent myocardial ischemia which caused death.

In February, 1932, Beck (1), (16) performed the first experiments to produce a new source of blood supply to the heart by operation. For the vascular bed, he used parietal pericardium and pericardial fat. In later experiments he used pedicle grafts of skeletal muscle together with pericardial and mediastinal fat. The epicardium and lining of the parietal pericardium

was removed with a burr for he thought "it acted as a barrier to growth of blood vessels into the heart."

A summary of his findings:

(1) Almost total occlusion of the right or left coronary artery near the aorta was compatible with life if the heart had been provided with a collateral vascular bed.

(2) Dye penetrated the myocardium through the collateral bed.

(3) A pressure differential was necessary to promote anastomoses between the cardiac and extracardiac vascular beds, that is, a physiologic need for blood in the myocardium was necessary for the anastomoses to develop.

(4) The presence of a collateral vascular bed protected the heart from the ravages of sudden occlusion of a major coronary artery.

(5) Distribution of the blood to every part of the myocardium is of vital importance for it must be equal to maintain function. If one small area is rendered ischemic, ventricular fibrillation will develop.

In dogs living two years later he proved that a collateral circulation could be produced, which could be a compensatory mechanism to protect a faltering

heart. (7).

In studying the dynamics of collateral circulation in animals following chronic occlusion of the coronary arteries, Mautz and Gregg (68) believed the collateral circulation developed because of the (1) large increases in peripheral coronary pressure over the normal values, (2) the peripheral coronary flow was far in excess of normal, (3) there was a minimum of infarction together with macroscopic evidence of contraction, and (4) enlargement of the pre-existing or new anatomical connections between the occluded and non-occluded arteries.

At this time O'Shaughnessy, in England, with his assistants, were experimenting with dogs, using omental grafts to revascularize the heart. (78). The first omental graft was done by Downes in 1933. O'Shaughnessy used omentum for he thought there was a greater chance for vascularization since the "omentum is the only structure in the body with the specific property of vascularization." Greyhounds suffered ligation of the descending branch of the left coronary and were able to chase an electric hare around a full course (525 yards) without distress, following cardio-omentopexy. They found vascularity occurred whether

the graft was applied to the normal heart, to a recent, or an old infarct. O'Shaughnessy used the great omentum separated from the pedicle graft, in later experiments, thus not leaving the diaphragm subject to herniation, and found these grafts developed a blood supply, which supplied the heart. (77).

Other modifications followed (79) in an attempt to produce vascularity without too extensive surgery and with less shock, such as, aleuronat adhesions by pericardotomy, grafting to aleuronat adhesions, fixations of omental graft with aleuronat, rather than sutures, which were dangerous in degenerative myocardium; and cardiopneumopexy. The results were variable.

Survey of the Value of the Surgical Procedure on Patients

The first patient to be operated upon in an attempt to re-establish the collateral coronary circulation was performed by Beck on February 13, 1935, using a pectoral muscle graft. Seven months later the patient was working as a gardner without precordial pain, was taking no medications and claimed he was cured. In the next year Beck operated ten more patients with angina pectoris, all with advanced coronary sclerosis, two show-

ing extensive and permanent degenerative changes in the myocardium. (2). Three had brilliant results being completely free from pain; one was moderately improved, the attacks less frequent and less severe; one was only slightly improved, the result being questionable. There were five deaths.

By 1937, Beck had operated upon twenty-five patients, with various modifications of his original technic. (41), (35). He inserted powdered beef bone to induce a low grade foreign body in several patients, with satisfactory results. The mortality rate was lowered significantly by selecting the patient more carefully, by decreasing the magnitude of the operation, using a unilateral rather than a bilateral approach, and by using a pedicle graft from only one pectoralis major muscle instead of two. The last five patients went through the operation favorably, although they were extremely bad risks.

Lockwood (62) using the Beck technic operated upon two cases which were practically incapacitated with coronary sclerosis. He felt the muscle flap was more efficient and a simpler procedure than cardio-omental pexy. Six ounces of ground bone were rubbed into the mediastinal flap, after the epicardium had been buffed

and the muscle inserted. His results are striking in that death of both patients was not due to the operation. One, in splendid post-operative condition, died after a pneumo-thorax occurred following puncture of the chest, to remove air, at the end of the operation. One recovered uneventfully, was symptom free, and was about his work, but died nineteen weeks post-operatively after a three week drinking debauché.

In January, 1938, O'Shaughnessy (33) had operated upon twenty patients, which he could divide into two groups:

Group I- Fifteen patients with Angina Pectoris.

1. Ten living, eight free from attacks, and seven back to work.
2. Five deaths-
 - a. Age 72, uremia, three months after operation.
 - b. At operation, from rupture of a friable ventricle.
 - c. Pulmonary infarction, two months post-operatively.
 - d. Pneumonia, empyema, two months post-operatively.
 - e. Suddenly, two months post-operatively, no apparent cause.

Group II-Five patients without angina pectoris but with cardiac ischemia. All chronic invalids.

1. Now leading normal life.
2. Improved.
3. No longer confined to bed.
4. No longer confined to bed.
5. Died, nine and one-half months later.

O'Shaughnessy used many varied operations:

- (1) Cardio-omentopexy with aleuronat only-----6
- (2) Cardio-omentopexy by suture only-----3
- (3) Cardio-pneumopexy with aleuronat only-----1
- (4) Cardio-pneumopexy by suture with
aleuronat-----4
- (5) Pericardiotomy for insertion of aleuronat-2
- (6) Transpleural pericardiotomy for insertion
of aleuronat-----3

In comparing the results of the forty-five patients operated upon by Beck and O'Shaughnessy, accurate results are lacking, but an approximation reveals:

	<u>Beck</u>		<u>O'Shaughnessy</u>
Operations-----	25	-----	20
Improvement-----	16 (?) (64%)		14 (70%)
No improvement-----	1 (?) (4%)		1 (5%)
Deaths-----	8 (32%)		5 (25%)

This summary shows that the mortality is extremely high by either method. It is somewhat gratifying then when O'Shaughnessy showed the outcome of a series of cases which he investigated but did not operate:

Sex	Age	Diag.	Reason for non-intervention	Result
1. M	58	A.P.	Chronic bronchitis	Died suddenly in bed.
2. M	48	A.P.	Awaiting admission	Died at car wheel.
3. M	54	A.P.	Chronic bronchitis	In statu quo.
4. M	53	A.P.	Patient refused	In statu quo.
5. M	64	A.P.	Nephrosclerosis	In statu quo.
6. M	47	A.P.	Chronic bronchitis	In statu quo.
7. M	39	A.P.	Gangrene of foot	In statu quo.
8. F	60	A.P.	Nephrosclerosis	Died- uremia.
9. F	65	A.P.	Patient refused	Died suddenly in bed.

	Sex	Age	Diag.	Reason for non-intervention	Result
10.	F	73	A.P.	Age	In statu quo.
11.	F	74	A.P.	Diabetes	In statu quo.
12.	M	77	C.T.	Acute stage	Died.
13.	M	74	C.T.	Acute stage	Died.
14.	M	71	C.T.	Acute stage	Died.
15.	M	53	C.T.	Symptom free	Under observation.
16.	M	65	C.T.	Symptom free	Under observation.
17.	M	64	C.T.	Symptom free	Under observation.
18.	F	71	C.T.	Acute stage	Died.
19.	F	64	C.T.	Symptom free	Under observation.

Here is shown the appalling mortality from coronary disease, for forty per cent have died; a death rate equal to those who were operated. Furthermore, the present condition of those not operated upon is not as favorable as those who were relieved by operation for medical treatment is at best palliative. (94). The fact can be accepted that the operation itself is relatively safe procedure, and does not entail even an alarming mortality rate. (62).

Surgical Hazards

Three reasons that the surgeon has avoided operating upon the heart (3) are: (1) The heart is always in motion; (2) it has a frightful capacity for hemorrhage; (3) every time the heart is touched it responds with an extra systole and it may fibrillate fatally. With refinements in instruments and technic the surgeon

has been able to overcome these objections.

According to Streider, Clute and Graybiel (94), Hochrein was reputed to have said, "We have learned to recognize that pericarditis is not a complication of coronary thrombosis but a natural attempt at healing its presence is to be welcomed rather than deplored." Physicians were apprehensive as to the value of producing a therapeutic pericarditis with adhesions, for fear they might cause circulatory embarrassment. It was found, however, these adhesions per se do not cause circulatory embarrassment unless they are extensive enough to cause cardiac compression, angulation, or torsion. (42). The circulation can be interfered with in several ways: (1) A constricting bed of scar tissue may produce chronic cardiac compression; (2) it may be between the heart and the chest wall and act as a harness through which the heart pulls and expands energy; (3) the heart may be sharply angulated from its normal axis by such adhesions so it cannot function effectively. (1). In general, cardiac adhesions do not play a significant role in the production of cardiac hypertrophy, (42) and cardio-pericardial adhesions are usually silent lesions of little or no clinical significance for in none of the experiments by Beck (1) was the heart extensively and inti-

mately bound to the chest wall.

In the first sixteen cases operated by Beck (4) there was an operative mortality of fifty per cent. In the following nine patients he had no operative mortality. (35). He attributed the decline mainly to the proper selection of patients but also to a change in his operative technic. He used quinidine sulphate up to thirty milligrams per kilo, twice a day, pre-operatively and post-operatively as needed, as suggested by Mautz (65) to decrease the irritability of the heart. Mautz also had shown that ventricular fibrillation could be successfully stopped in practically every case by the local application of procaine (or intravenously) along with the direct stimulation of the heart muscle by electricity and gentle massage. (65), (66), (5). Beck used this routinely at the operating table.

Hemorrhage can be kept at a minimum by proper approach and careful use of sutures. (4). Continuous oxygen by nasal tube should be used post-operatively (35), (94) and the water balance kept up. The blood pressure should be checked routinely every fifteen to thirty minutes for a few hours post-operatively and fluid removed from the chest as it accumulates. (94).

In the procedure of cardio-omentopexy an addi-

tional hazard of diaphragmatic hernia must be watched for during the operation and prevented by careful suture. (94). The anaesthetis should be prepared to inflate the lung if needed. (62).

Selection of Patients for Operation.

As for other surgical procedures on the heart, the final word as to the advisability of operation rests with the cardiologist. (94) There are, however, certain primary considerations with which the surgeon should be familiar to ensure the patient that the procedure will be of value to him.

The age should be the first consideration, and Davies, Mansell and O'Shaughnessy (33) believe it not advisable to operate on a patient over sixty-five, regardless of patient's condition, for the expectancy of life at that age does not warrant subjecting the individual to such an extensive operation. Streider, Clute and Graybiel (94) think the patient should be over sixty and should not be obese. Those patients operated upon by Beck ranged from forty-two to sixty-nine in age.

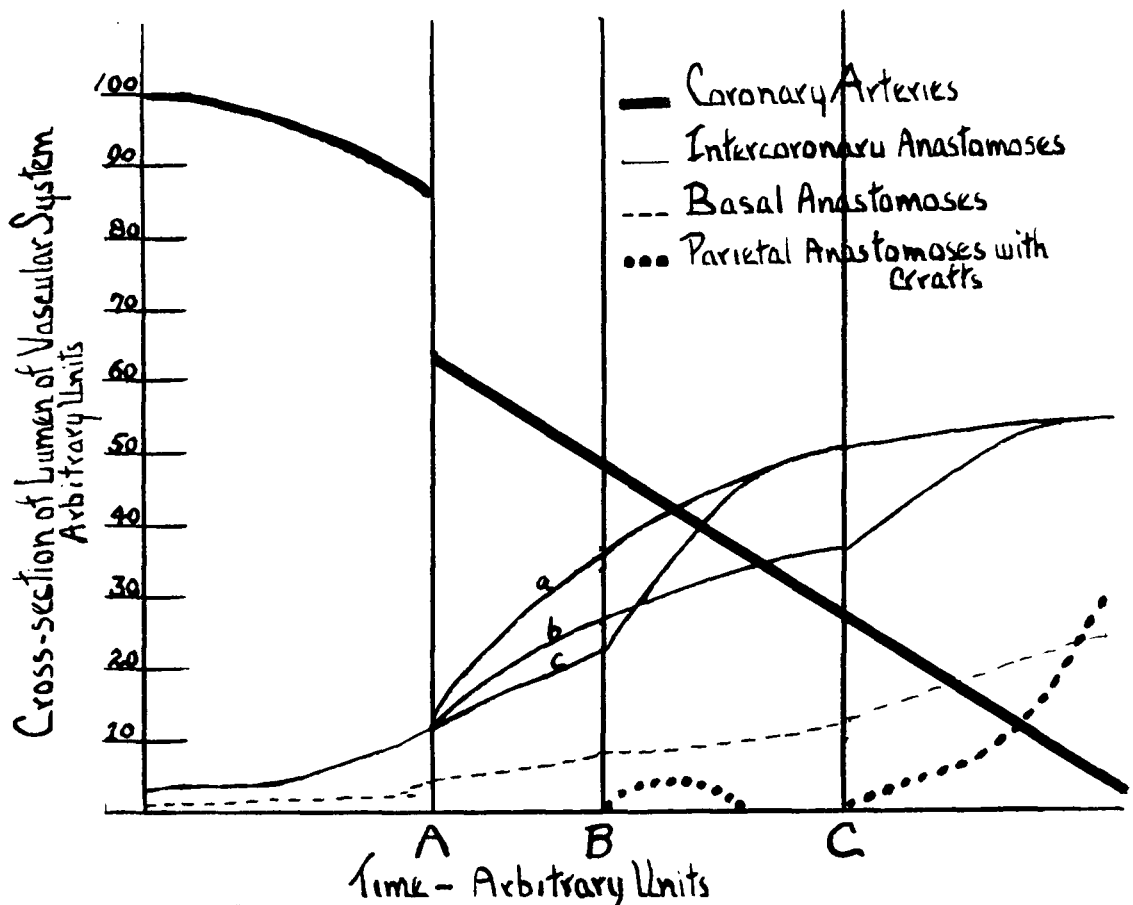
There should be unequivocal evidence of coronary sclerosis with angina pectoris and cardiac ischemia as elicited by history, electrocardiogram, and x-ray.

(33), (35), (94). The angina of effort should be pre-eminent and at the same time there should be no recent infarcts. (35). O'Shaughnessy (33) thinks it is not hazardous to operate if six months have elapsed since the attack of coronary thrombosis in patients with a clear history previously, and who are between forty-five and fifty-five years of age. The sclerosis should not be so advanced that the myocardium does not have sufficient reserve to carry the patient through the operation. No evidence of congestive heart failure should be present. (35), (94).

Operation should not be considered if there is other organic dysfunction present as cirrhosis, nephrosclerosis, or any pulmonary pathology as chronic bronchitis, bronchiectasis or lung abscess. O'Shaughnessy thinks it is permissible to operate on patients with hypertension, or syphilitic aortitis providing the heart is not enlarged to any great extent, (94) and Beck believes that diabetes if controlled is not a contraindication. (35).

Not only should the patient be properly selected but it is also important that the time for operation should be chosen with care. Mautz and Beck (67) have shown in experiments on dogs the effect of gradual

or rapid closure of the lumen on the establishment of a collateral coronary circulation. Their chart below indicates the importance of a promptly chosen time to operate, for coronary arteries are gradually reduced in lumen, the main branches being effected in sequence rather than simultaneously.



Effect of sudden occlusion, as thrombosis is indicated at A. As refusion in the lumen progresses the intercoronary anastomoses enlarge. After sudden occlusion at A there are three courses, (a) rapid increase in size of the intercoronary anastomoses which compensate for the obstruction, (b) intermediate course, (c) a poor response,

as is believed to be associated with persistent symptoms, which might lead to a relatively early operation at B at which time occlusion would be limited to one branch. Operation would improve the intercoronary anastomoses by (1) dilating the existing channels and (2) creating new ones which would gradually enlarge. The only extracardiac anastomoses which would be likely to survive and develop are those grafts directly on the local ischemic area, and even these (indicated by dots) might repress or not enlarge significantly if intercoronary adjustments were adequate.

If an intermediary course were followed, the circulation may not improve rapidly enough and the other arteries would tend to decrease in the size; an operation at C should increase the intercoronary anastomoses sufficiently to arrest the progress of the coronary occlusion and the myocardial infarction.

CONCLUSION

That the surgical treatment of coronary disease is as yet to be reserved by medical therapy, is generally agreed, but it can also be said that in properly selected cases surgical procedures have been of definite value. (7), (21). It is best to select those cases who would be in fairly good health except for attacks of pain. (34). It must be kept in mind, however, that coronary disease is a disease of sudden catastrophes, and patients frequently die suddenly before, as well as, after operation.

Authorities are found to favor and rebuke all procedures. The advocates of the procedures are apt to be overenthusiastic in their conclusions and tend to overestimate their true value. On the other hand many men are inclined to conclude, without thorough and adequate investigation, that a procedure is unworthy.

So many varied opinions, as to the relative merit of each operation, warrants an analysis of each procedure from the three main viewpoints of general interest, that is, Beneficial Results, Failures, and Operative Mortality. Beneficial results include all cases of improvement from mild to excellent.

Beneficial Results

Sympathectomy-----	72.00%
Paravertebral Alcohol Block-----	81.70%
Thyroidectomy-----	86.30%
Augmentation of Coronary Collateral Circulation-----	66.00%

Failures

Sympathectomy-----	9.30%
Paravertebral Alcohol Block-----	27.10%
Thyroidectomy-----	10.27%
Augmentation of Coronary Collateral Circulation-----	4.05%

Operative Mortality

Sympathectomy-----	14.90%
Paravertebral Alcohol Block-----	0.87%
Thyroidectomy-----	3.81%
Augmentation of Coronary Collateral Circulation-----	28.60%

A similar study by Ochsner and DeBakey, (75), in 1937, showed a higher mortality (50%) in operations for augmentation of the coronary collateral circulation, than was found in this study, while their

other results were similar. That investigations in the past two years have been of value, is apparent, for the mortality has been significantly lowered (28.6%), which makes the type of procedure especially of interest because it is a therapeutic measure which eradicates the pathology. Although the results are encouraging many more patients must be operated upon before definite conclusions can be drawn.

Ochsner and Debaquey (75) thought that each type of operation should be fitted with a certain type of patient:

I. The therapeutic attack on the Sympathetic Nervous System is indicated in (1) cases in which there is increased cardio-sensory and cardio-motor sympathetic innervation, which is associated with vasoconstriction and pain; (2) cases in which there is marked fibrosclerotic myocardial change indicative of advanced cardiac disease.

II. Thyroidectomy is indicated in cases with some fibrosis of cardiac muscle and occlusion of the coronary arteries which is due to thrombosis rather than vasoconstriction, and have angina of effort rather than emotion, as in I. There is also an increase in cardio-sensory innervation.

III. Augmentation of Coronary Collateral Circulation is indicated in those cases in which the cardiac musculature is little involved, with thrombosis and occlusion of the coronary arteries not extensive.

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