Reprinted from
New Orleans Medical and Surgical Journal
pp. 520-529, *Vol.* 90, *No.* 9, *March*, 1938

THE SURGICAL TREATMENT OF CORONARY DISEASE

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The original disquisition of Heberden[1] concerning cardiac pain due to coronary artery disease first appeared in 1786, but this important disorder was not clearly recognized until relatively recently, when Herrick[2] made his first important contribution in 1912. It is indeed amazing that a disease of such vital significance and relatively frequent occurrence, particularly among physicians,[3] should be relegated to almost complete desuetude for over a century and a quarter. However, during the past quarter of a century intensive anatomic, physiologic, and experimental investigations have established a more elucidative comprehension of the fundamental background of the malady and a more rational therapeutic approach.

The present status of the surgical treatment of coronary artery disease and cardiac pain involves a consideration of three main methods of attack: (1) the sympathetic nervous systen; (2) the thyroid, and (3) the development of a collateral blood supply to the heart.

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The rationale of the surgical procedures which attack the sympathetic nervous system is based upon an interruption of cardiosensory and motor pathways. The first successful clinical application of sympathectomy was based upon the physiologic speculations of Francois Franck,[4] in 1899, and first clinically tested by Jonnesco[5] in 1916, in a case of angina pectoris. The brilliance of this first successful result which stimulated universal interest was soon dimmed by many disappointing failures in the hands of other surgeons. As a consequence, various modifications were advocated and divergent theories proposed, which only added to the already existing bewilderment. In order to explain the inconsistent results and better understand the rationale upon which this method of surgical attack is based, it is necessary to review the underlying anatomical and physiological principles in the light of recent investigations.

The presence of typical somatic afferent fibers in the sympathetic cardiac rami is now definitely established. The histologic characteristics of these fibers have been excellently described by Ranson and Billingsley,[6] and Stohr,[7] and corroborated by Heinbecker.[8] Whereas these fibers utilize the sympathetic pathways to the heart to transmit afferent impulses from this organ to the central connection, actually they are true somatic afferent fibers and not a real part of the autonomic nervous system. The neurones to these sensory nerve endings converge in the periarterial plexus of the coronary arteries, traverse the superficial and deep cardiac plexuses, and course in the middle and inferior cardiac nerves which join the corresponding cervical ganglia of the sympathetic chain. They then descend the sympathetic cervical chain to the upper thoracic ganglia, and finally reach their cells in the spinal ganglia by passing through the white rami communicantes into the central portions of the first thoracic and upper four or five intercostal nerves. Brauecker[9] and Ionesco and Enachesco[10] have recently demonstrated that there also exist thoracic cardiac nerves which run directly across the posterior mediastinum to the upper thoracic sympathetic ganglia. According to Ranson and Billingsley,[6] the only purely motor pathway is the superior cardiac nerve. The recent experimental investigations of White, Atkins, and Garrey[11] have further corroborated this concept of the cardiosensory pathways. Thus, it can be readily observed, and this should be particularly emphasized because of its technical importance, that all of the sensory pathways from the heart converge on the upper four or five thoracic sympathetic ganglia.

The vasomotor afferent or accelerator impulses to the heart and coronary arteries differ from the sensory in that they travel in the true sympathetic neurones. Langley[12] demonstrated that accelerator impulses leave the cord by the upper five thoracic pairs of anterior route and white communicating rami. He further assumes

that their transmission occurred by afferent fibers which traveled upward in the sympathetic chain to synapse in the three cervical sympathetic ganglia and send their postganglionic neurones to the heart through the cervical cardiac nerves. Aside from these well established cervical cardiac nerves there also exist the thoracic cardiac nerves which form direct motor pathways between the upper four or five thoracic ganglia and the heart.[9, 10, 11, 13, 14]

There is still considerable controversy as regards the nervous control of the coronary circulation and the experimental evidence seems merely to aid in the confusion. The opinion held by one group of investigators[15, 18] is that vasoconstrictor fibers occur chiefly in the vagus and vasodilators in the sympathetic nerves. On the other hand, Leriche and his co-workers[19, 20] are of the opinion that the innervation of the coronaries follows the general law of vasomotor innervation; that is, that coronary constriction is mediated by the sympathetics.

Since Jonnesco's[5] original operation of removing the entire cervical sympathetic chain, including the stellate ganglion, a number of operations have been advocated on the cervical sympathetics, based upon divergent rationales with varying degrees of success. Coffey and Brown[21] advocated simplifying the procedure to extirpation of the superior cervical sympathetic ganglion or cutting the cardiac branches of this ganglion. Although Kerr[22] is still an enthusiastic advocate of this procedure, it is difficult

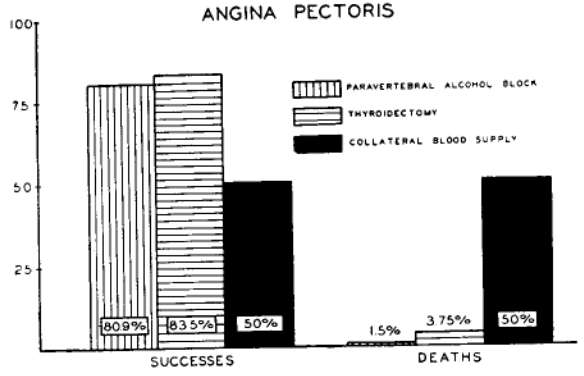
to explain the good results claimed by these authors in the light of recent investigations. Because Danielopolu[23] contends that accelerator and dilator impulses pass through the stellate ganglion, he strongly condemns its removal and recommends that the cervical sympathetic chain be sectioned above it, that the vertebral nerve be also severed as well as the depressor nerve of Hofer or any corresponding nerve present, and the nerves which spring from the cervical sympathetic chain above the superior cervical ganglia and course to the heart. Whereas Leriche[24] originally conformed to this view, more recently he[25, 26] advocates stellate ganglionectomy. Although other modifications have been suggested, in the main, the attack has been upon the cervical sympathetic chain and the stellate ganglion.

RESULTS

The results of these various procedures have been excellently summarized by Leriche and Fontaine[27, 28] in a collected series of 172 cases including their own. Of 163 cases in this group in which the results were known, 85, or 52.5 per cent, obtained good results, 33, or 20.2 per cent, showed some improvement, 21, or 12.9 per cent, showed failures, and 24, or 14.7 per cent died. Thus, a little over 70 per cent will show some improvement to a greater or lesser extent. The recent anatomic and experimental investigations discussed above clearly reveal the explanation for the inconsistent results of cervical sympathectomy and the fact that better results

are not obtained. Obviously, unless the accessory pathways through the thoracic cardiac nerves are interrupted, cervical sympathectomy alone is doomed to failure in a large number of instances.

Although the ideal procedure would be resection of the upper four or five thoracic sympathetic ganglia, because in this way all fibers carrying sensory impulses from the heart would be interrupted, such a procedure in patients who are admittedly poor risks would undoubtedly carry an unjustifiably high mortality. However, this difficulty has been obviated by the method of Mandl[29] which consists of the paravertebral alcohol injection of the thoracic sympathetic ganglia. In this country, Swetlow[30] was the



Graph 1. Comparison of three methods of treatment in coronary artery disease and cardiac pain. The figures on paravertebral alcohol block are those tabulated by White[33] and Marvin[34] on a series of 68 cases; those on thyroidectomy are the results obtained in a collected series reported by Parsons and Purks[48] and the results on collateral blood supply were reported by Beck[58].

first to advocate paravertebral alcohol block for cardiac pain and to describe the technic in detail. More recently, Mixter and White[31, 32] have perfected the technic and placed it upon a more rational basis. The combined results of paravertebral alcohol injection for angina pectoris in 38 cases reported by White[33] and 30 cases reported by Marvin [34] are illustrated in graph 1. It will be observed that successful results were obtained in 80.9 per cent, failures in 17.6 per cent, and fatalities in 1.5 per cent. A comparison of these results with those of cervical thoracic sympathectomy emphasizes more strongly the advantages of the former procedure. There is a higher percentage of successful results, and the mortality is considerably lower. Another advantage is the simplicity of performance, which of course makes it a procedure attended with little or no danger, particularly in those patients who are obviously poor risks. However, a fair, critical analysis of the procedure must not fail to mention a few of its disadvantages. Fortunately, these are not very significant. The effect of the alcohol is not permanent and in some instances will necessitate re-injection. The fact that it is a procedure employing the blind injection of a destructive solution will in some cases produce certain complications. The difficulties of limiting the effect of the injected alcohol will occasionally produce a painful neuritis, and pleural injury is a constant hazard.

TECHNIC OF PARAVERTEBRAL ALCOHOL INJECTION

The technic of paravertebral alcohol injection

as described by White[33] is relatively simple. He prefers to have the patient lying on his side with the knees drawn up, the shoulder at the edge of the bed, and the head deflected forward as in performing a spinal puncture. In our own experience it has been found more desirable to have the patient lying face downward with the chest supported by pillows, as shown in figure 1A. The bony landmarks consist of the spinous process, of the seventh cervi-

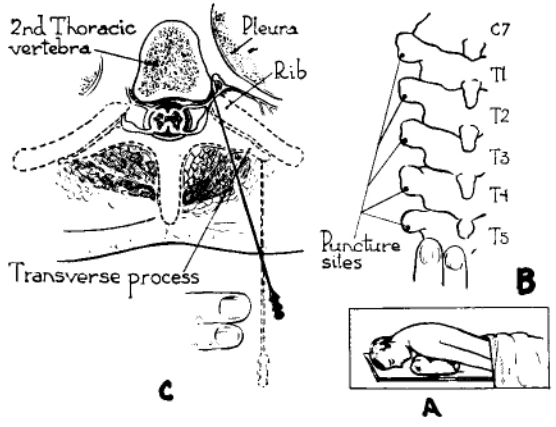


Fig. 1. Diagrammatic representation of technic of paravertebral alcohol injection. (A). Patient lying in prone position with pillow supporting chest so as to produce hyperflexion of neck. (B). Puncture sites are on a horizontal line approximately two to two and a half fingerbreadths lateral to spinous processes of the seventh cervical to fifth thoracic vertebrae, inclusive, (C). Dotted needle indicates first position with point touching transverse process or angle of rib. Needle in bold type indicates final correct position, which is approximately two fingerbreadths deeper than first position and directed medially towards midline about 20 degrees. Point of needle is in contact with lateral aspect of body of vertebra immediately adjacent to sympathetic ganglia and chain.

cal vertebra, and the first to the fifth thoracic inclusive. In this region, the spinous processes are imbricated like shingles on a roof, and the tip of each one of these spinous processes lies at an exact horizontal level of the transverse process and the posterior angle of the rib next below, and as shown in figure 1B, the highest prominent vertebral spine, the seventh cervical, marks the level of the first rib. By means of a fine hypodermic needle an intracutaneous wheal of novocaine is formed at the points of injection. These are made from 3½ to 4 cm. lateral to the spinous processes. This is approximately two to two and a half fingerbreadths (Fig. 1 B). The points so marked lie opposite the seventh cervical and the upper three thoracic spines. Needles 8 to 10 cm. in length are then inserted at these points perpendicular to the surface of the back and at a depth varying from 3 to 3½ cm. to touch the upper four transverse processes. The needles are then inclined slightly in a caudal direction so as to slip beneath the transverse process or the angle of the rib, directed medially about 20 degrees towards the midline, and inserted deeper for about 3 cm., or approximately two fingerbreadths (Fig. 1 C). At this depth bone is usually touched, indicating that the needle is in contact with the lateral aspect of the body of the vertebra. At this stage aspiration should always be done in order to determine whether the needles lie in a blood vessel or the subarachnoid space. Obviously, if blood or spinal fluid is aspirated then the posi-

tion of the needles must be changed. When the needles have been placed in the correct position, 2 c.c. of 3 per cent novocaine adrenalin solution should be injected in each. Within a period of fifteen minutes anesthesia should appear in the axilla, a short distance down the inner surface of the arm, and over the third and fourth ribs. A well defined Horner's syndrome and anhydrosis of the entire arm and the side of the neck and head should be present. The failure of these signs to develop indicates that the needles have not been correctly inserted, and a re-insertion should be done. After it has been determined accurately that the needles have been properly placed, it is preferable to inject 3 c.c. more of novocaine through each in order to secure widespread anesthesia and to make the final injection of alcohol painless. Three to four cubic centimeters of 95 per cent alcohol is then slowly injected in each needle.

THE THYROID

Whereas the relationship between thyroid activity and cardiac disease has been implicit in the expositions of numerous authors for over a century and a half, it was not until relatively recently that total thyroidectomy in the treatment of chronic non-thyrogenous heart disease has been placed upon a rational basis. The rationale of total thyroidectomy in the treatment of cardiac disease is based upon two factors: first, a decrease in tissue metabolism consequent to the removal of thyroid secretion, and second, an interruption of cardiosensory impulses which is coincident to the operative removal of the thyroid and depends upon the anatomic relationship of the cervical cardiac to the thyroid glands.

In the normal individual the speed of blood flow has been shown by Blumgart and Weiss[35] to be directly dependent upon the metabolic demands of the body. It is now a well established fact that hyperactivity of the thyroid gland results in increase in tissue metabolism, and conversely, hyposecretion of the thyroid gland produces a diminished tissue metabolism. Blumgart and his co-workers[36, 37] showed that in thyrotoxicosis not associated with cardiac disease there was a commensurable increase in speed of blood flow, and conversely, in uncomplicated myxedema there was a considerable decrease in speed of blood flow. It is further observed that in cardiac insufficiency and in angina pectoris this normal relationship between speed of blood flow and metabolism no longer exists. Because it appears that in cardiac disease the heart is unable to meet the metabolic demands of the tissues, it seems reasonable to assume that this situation should be relieved best by simply correspondingly diminishing these metabolic demands. This could readily be done by removing the thyroid which so influences tissue metabolism.

The mechanism of relief of pain immediately after total thyroidectomy is still controversial. Blumgart and Berlin[38] are of the opinion that this early relief from pain is the result of a

coincidental division of cardiosensory fibers at the time of operation. The anatomic and clinical investigations of Weinstein and his co-workers[39, 40] have further corroborated this concept. On the other hand, Levine and his associates[41, 42] as the result of their studies on the altered sensitivity to epinephrine, are of the opinion that the relief of pain immediately following total thyroidectomy is due to a lessened sensitivity to epinephrine. Cutler and his associates[43, 44, 45] have offered experimental evidences of the truth of this view.

RESULTS

During the past four years since Cutler[46] and Berlin[47] independently performed the first ablation of a normal thyroid for heart disease, a large number of operations have been done and the results reported by numerous investigators with a consequent better understanding of the indications, limitations, and selection of cases. In an attempt to form a thorough evaluation of the procedure, Parsons and Purks[48] tabulated data on a large group of patients on whom the operation had been perfomed. The details were obtained from a fairly complete survey of the literature and from inquiries sent to various clinics throughout the country. Of 133 patients with angina pectoris on whom operation had been performed 71, or 55.46 per cent, showed excellent results, and 36, or 28.12 per cent, were moderately improved; 5, or 3.9 per cent, were slightly improved, and 15, or 4.5 per cent, were classed as failures. The operative mortality was

3.75 per cent (Graph 1). These results correspond fairly closely with those reported by Weeks[49] in a somewhat similar tabulation of 100 patients on whom the operation had been done in twenty-six clinics. If the excellent results and moderately improved groups are considered together as satisfactory it will be observed that 83.58 per cent showed good results in the series reported by Parsons and Purks, and 91.4 per cent in those collected by Weeks. Thus, these statistics indicate that it is undeniably a distinctly valuable procedure in relieving cardiac pain. Whether the procedure prolongs life or not cannot be answered. It is admittedly a procedure attempting to relieve symptoms and not to affect cardiac pathology.

There are certain disadvantages of the procedure that must be considered in its proper evaluation. Total ablation of the thyroid is difficult in any type of case, and in those patients who are admittedly poor risks it will carry a very definite mortality. There will also be a fairly high incidence of complications. In the collected series reported by Parsons and Purks, recurrent laryngeal nerve injury occurred in 8.6 per cent and tetany in 10.3 per cent of the cases. Myxedema is also another disadvantage of the procedure. Whereas the undesirable consequences of artificially induced myxedema can be alleviated to some extent by the proper administration of thyroxin, it must be remembered in order to obtain the full benefit of the operation these individuals must be kept at a

low basal metabolic rate. Adequate doses of thyroxin to obviate the effects of myxedema may cause the patient to suffer from angina and a reduction of thyroxin to relieve the angina may result in the ill effects of myxedema.

The criteria for the selection of these patients for operation have become better understood with increasing experience. Blumgart[50] advises against the operation in the presence of rapidly progressing cardiovascular disease, such as malignant hypertension or syphilitic cardiovascular disease. The operation is also contraindicated in the presence of a low preoperative basal metabolic rate. Mixter, Blumgart, and Berlin[51] hesitate to operate upon those patients in whom the preoperative basal metabolic rate is below 15 per cent and consider a basal metabolic rate of 20 per cent or more a definite contraindication to operation. The presence of a recent coronary occlusion and renal insufficiency, active infection, such as bronchiectasis, lung abscess and active rheumatic involvement, are further contraindications to operation.

TECHNIC OF TOTAL THYROIDECTOMY

Although no attempt will be made here to give a detailed technical discussion of total extirpation of the normal thyroid gland, there are certain aspects of the technic which demand consideration. The procedure is not one that can be undertaken lightly, and should never be performed by one who is not thoroughly familiar with the normal anatomy of the thyroid gland and its relationship to the surrounding structures, as well as the variations which may occur. The surgeons who have had greatest experience with the procedure advocate the use of local analgesia in preference to general anesthesia. Avoidance of injury to the recurrent larnygeal nerves and the parathyroid gland necessitates extreme care in dissection. Cutler et al.,[52] advise removing each lobe of the thyroid by working from that side of the patient because of the fact that in their first few cases they injured two left recurrent nerves while doing the procedure according to their previous method of operating entirely from the right side. We[53] have also made a similar observation and consider this a valuable suggestion.

COLLATERAL BLOOD SUPPLY

The development of a collateral circulation by the production of a new blood supply to the heart by grafting tissues to the myocardium as devised and advocated by Claude S. Beck[54] is an entirely new principle in the surgical treatment of coronary disease. The rationale of this procedure is based upon the attempt to correct the decreased myocardial vascularity which invariably occurs with coronary sclerosis. Because the compensatory circulatory mechanisms of the heart are dreadfully inadequate due to the peculiar anatomic arrangement of the vascular supply of the myocardium, it seems reasonable to assume that if other anastomotic channels to the heart could be surgically produced the previously inadequate compensatory mechanism might be changed into one that is adequate.

The apparent difficulties confronting this procedure were fully appreciated by Beck, but he states that there were two encouraging facts which seemed to indicate the feasibility of this method. Hudson et al[55] demonstrated the presence of blood vessels in the fat at the base of the heart anastomosing the coronary system with branches of the aorta, and Moritz, Hudson, and Orgain[56] established the existence of blood vessels in pericardial adhesions. Beck and his co-workers began an extensive series of experiments in 1932 which definitely established the possibility of deliberately producing anastomotic channels which could serve a functional purpose.

These investigators first produced a collateral vascular bed by destroying the mesothelial envelope around the heart by roughening the lining of the parietal pericardium and the epicardium. Various tissues, such as fibrous pericardium, pericardial fat, pedicle grafts of pectoral muscle and omentum, were used for the new vascular bed, and within three weeks anastomoses between the grafts and the heart could be demonstrated. This was established by the presence in the myocardium of a dye previously introduced by way of the graft and also by injecting a solution of barium sulphate into a coronary artery and tracing the location of the solution in the chest by roentgenograms[57]. In one group of experiments, it was found that the vascular graft could act as a protective measure against subsequent complete occlusion of one of the coronary arteries. They were also

able to show that it was extremely important to maintain a uniform distribution of blood flow, and from their experiments they believe that a collateral vascular bed effects an equal distribution of blood flow to the myocardium by transporting blood from extracardiac sources into the myocardium and from one part of the heart where the circulation is good to another part of the heart where the circulation is deficient.

Encouraged by these successful experimental investigations, they performed the operation for the first time on a patient with coronary sclerosis on February 13, 1935. This patient was a white male laborer, 28 years of age, who had typical substernal pain of two years' duration and was finally forced to give up his work. The patient made an excellent recovery from the operation and for the past year has been employed as a gardener, doing the work of a man in good health. He has no pain and takes no drugs.

In his most recent communication, Beck[58] states he has performed the operation upon 16 patients with a mortality of 50 per cent. In justification of such a high mortality the author states that this was an extremely bad group of patients with advanced stages of coronary sclerosis. They were patients who had previously concluded that they had nothing to risk because life without improvement was not worthwhile. However, the author is of the opinion that this frightfully high mortality can

be reduced, first by a careful selection of patients who do not have a too far advanced coronary sclerosis, and second, by reducing the magnitude of the operation. He has already simplified the technic, and in the last five patients in whom this was done there were no operative deaths.

The technical procedure consists of grafting a part of the pectoral muscle upon the myocardium. The skin incision is made transversely over the precordia, and the pectoral muscles are separated from the chest wall by blunt dissection. The pectoral muscle is transected laterally about four inches from the sternum to make a graft with the pedicle attached along the sternal margin. The fifth and sixth costal cartilages are removed and the parietal pericardium is opened. By means of a burr, the lining of the pericardium and epicardium is roughened. More recently, he has employed powdered beef bone in the pericardial cavity for the purpose of producing a low grade foreign body reaction. The muscle graft is divided into two parts by incising parallel with its fibers along the lower margin of the third rib and the upper part of the graft is placed beneath the sternum to the right ventricle, while the lower is applied to the left ventricle. The pericardial cavity is then widely opened so that the adjacent vascularized tissues are in contact with the anterior aspect of the heart.

SUMMARY

The three main methods of attack in the surgical treatment of coronary artery disease and cardiac pain have been considered and discussed. Any attempt to compare the advantages and disadvantages of these three methods will meet with certain difficulties. However, their evaluation from the standpoint of successful results and mortality reveals that thyroidectomy has a slight advantage over paravertebral alcohol and both have a marked advantage over collateral blood supply. On the other hand, the mortality from paravertebral alcohol block is practically negligible, with thyroidectomy having a mortality two and a half times as high. The 50 per cent mortality in the collateral blood supply method limits its practicability (Graph 1).

Because these three surgical methods of attack have different rational bases, and because coronary artery disease and cardiac pain varies in its pathologic physiology, it is possible that each method may be appropriately applied to certain groups of patients. A critical analysis of each method and its rationale and a correlation of this with the various types of coronary artery disease and pain suggest the possibility of certain indications for each method. Sympathectomy is probably best indicated in patients who are obviously poor risks. They are usually elderly individuals with marked sclerotic changes and fibrotic myocardial degeneration. They also include those patients who have very severe pain, or whose angina is particularly aggravated by emotional disturbance rather

than by effort, and those whose basal metabolism is very low. Thyroidectomy is probably best indicated in patients who have a normal or high basal metabolic rate. They should be relatively good risks, and their angina should be one of effort rather than of emotion. The group of patients which is best suited for the collateral blood supply method should be individuals who have had a recent thrombosis, or show litttle evidence of arteriosclerosis or fibrotic muscular degenerative changes.

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