Papers and Originals

Bilateral Upper Thoracic Sympathectomy in Angina Pectoris: Results in 52 Cases

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The treatment of angina pectoris by interruption of the nervous pathways transmitting pain from the heart was first attempted by Jonnesco (1920). The patient was considerably improved after resection of the lower two cervical and first thoracic ganglia of the left sympathetic chain. Subsequent experience with various types of cervical sympathectomy showed that the procedures often gave inadequate relief of pain (Cutler, 1927). White and Bland (1948) stressed that the sensory pathway was conveniently concentrated in the upper four ganglia of the thoracic sympathetic chains. They reported excellent symptomatic relief in 42 out of 75 patients after paravertebral injection of procaine and alcohol, and in six out of eight patients treated surgically by upper thoracic sympathectomy. Further evidence for the value of this operation in angina soon followed. Lindgren (1950) analysed a series of 105 patients, of whom 55 were greatly improved. Burnett and Evans (1956) reported that 13 out of 17 patients who had unilateral or bilateral upper thoracic sympathectomies for angina had significant relief of pain. Palumbo and Lulu (1963) operated on 21 patients with a similar high rate of success.

There are two important reasons why upper thoracic sympathectomy is rarely performed in this country: first, the widespread belief that the operation removes the warning signal of pain, and that the heart can therefore be damaged by excessive exertion; secondly, the operative mortality in most series of 5 to 10%.

Despite these commonly held objections, we have been encouraged by our observations on effort electrocardiograms before and after bilateral upper thoracic sympathectomy to continue treating selected patients with refractory angina in this way. We now report the results achieved in the first 52 cases.

Present Series

The patients comprised 42 men and 10 women aged 36-70, with a mean age of 54. The duration of symptoms of angina ranged from six months to 24 years, with an average of five years.

All the patients complained of severe angina of effort, and 41 (79%) also had episodes of pain at rest. In all cases the angina had proved refractory to adequate medical treatment, and many were so incapacitated that they had been forced to give up their work. Surgery was considered only for patients in a stable phase, and was never attempted within three months of clinical or electrocardiographic evidence of fresh myocardial

infarction. A previous infarct had occurred in 25 (48%) patients, and 14 of them had had more than one. Four had a history of heart failure. Hypertension was present in 14 cases, with a diastolic pressure of 95 mm. Hg or over. The resting electrocardiograms showed ischaemic changes in 44 cases; six of the remaining eight who had normal tracings at rest developed ischaemic changes on effort. Fifteen patients had radiological evidence of cardiac enlargement with a cardio-thoracic ratio of 1:2 or more.

Operative Technique

Bilateral upper thoracic sympathectomy has been performed through the anterior supraclavicular approach. The skin and subcutaneous incisions are kept as short as is conveniently possible (2½ to 3 in.; 6.4 to 7.5 cm.) to avoid division of more than one or two supraclavicular nerves; post-operative anaesthesia or hyperaesthesia of the chest wall in these patients can be very distressing and worrying.

The incisions are centred over the anterior scalene muscles and deepened by dividing as much as is necessary of the clavicular head of the sternomastoid. The scalene muscle is cleared by blunt dissection and the phrenic nerve gently retracted medially. The muscle is divided completely as low as possible and the subclavian artery exposed. The artery is retracted upwards and Sibson's fascia carefully split by digital pressure. The pleura is then displaced downwards by dry gauze dissection as far as can be reached. The stellate ganglion is readily found on the neck of the first rib, and is divided through its "waist" in order to preserve the ocular fibres which apparently leave the sympathetic chain to join the cord by a separate pathway above the level of T 1 (Palumbo, 1957). Scissors and finger dissection of the chain will divide all the rami and permit avulsion, usually to the level of T 4.

The lung is then gently inflated, and the wound closed by suturing the platysma and skin. Bleeding deep in the incision is controlled by hot packs and occasionally by silver clips. If the pleura is accidentally opened the lung is inflated under more pressure and the wound made airtight.

Both sides are done at one session, usually starting on the left.

Results

Extent of Sympathectomy.—The operation was intended to remove the ganglia of both sympathetic chains from T 1 to T 4. It is often difficult at operation to determine the extent of the sympathectomy, but this was assessed in 17 cases by using changes in skin resistance to mark the area of the chest where sweating had been abolished. The chains were removed to T 4 on both sides in 11 of the patients, to T 3 on one or both

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sides in four patients, and to T 2 on both sides in the remaining two patients tested in this way.

Initial Response.—The subjective results were assessed when the patients were seen in the out-patient department three to six months post-operatively. Of the 52 patients 28 (54%) became free from pain or had greatly improved effort tolerance with only slight discomfort on exercise. Fourteen others (27%) were pleased with the operation because their pain was less severe and usually required greater effort to provoke it; 12 of these had pain post-operatively only in the neck, jaw, shoulders, or arms, and not in the chest. Therefore a total of 42 patients (81%) were benefited by surgery. Six (11.5%) had no improvement in the severity of the pain, although it was often changed in distribution. Four patients (7.5%) died—two on the day of operation and two within a fortnight; in three cases post-mortem examination confirmed fresh myocardial infarction.

Subsequent Progress.—The follow-up period for 48 patients extends from six months in the most recently treated cases to nine years. Of the 42 patients who were benefited by surgery, 25 are still alive, 14 are known to have died, and three have been lost to follow-up. Five of the six patients who were not improved by operation are still alive one to five years later,

Overall Results at One, Three, and Five Years After Operation

	Years After Operation		
	One	Three	Five
No. of patients alive	39	21	4
" " " dead	3	6	11
" " " lost to follow-up ..	2	2	2
Total	44	29	17

FIG. 1.—Electrocardiograms (V5) recorded during identical exercise before and 15 months after sympathectomy in a patient aged 40. Effort tolerance was greatly increased with corresponding electrocardiographic improvement. FIG. 2.—Electrocardiograms (CR4) recorded during identical exercise before and 15 days after sympathectomy in a patient aged 55. Pain and ischaemic changes were abolished by operation. FIG. 3.—Electrocardiograms (CR4) recorded during identical exercise before and three months after sympathectomy in a patient aged 46. He was stopped by chest discomfort after walking 629 yds. (575 m.) following operation, and the tracing at this point showed only the same minor ischaemic changes that occurred with anginal pain after he had walked half this distance before sympathectomy.

and the sixth cannot be traced. Ten patients deteriorated symptomatically to their pre-operative state after initial improvement. This occurred four months to two and a half years after surgery, with an average of 13 months. The overall results for patients at one, three, and five years after operation are summarized in the Table.

Objective Changes

After operation the resting heart rate was 70 beats a minute or below in all but seven of the 41 patients for whom there is a record, and in 18 cases the rate was definitely slower than it had been before surgery. The effect of operation on the resting heart rate did not correlate well with the type of result achieved. Resting blood-pressure was not changed in any notable manner. In 43 cases pre-operative resting electrocardiograms were compared with tracings taken three to six months afterwards: there was an improvement in the ischaemic pattern in five patients, changes of fresh infarction were noted in one, but the majority showed no significant change.

The most important objective changes induced by sympathectomy concerned the effort electrocardiogram recorded during carefully controlled treadmill exercise. Two groups of patients have been intensively studied (Apthorp, Wedgwood, and Hayward, 1960; Apthorp, Chamberlain, and Hayward, 1964). Of the 19 patients report in these series 17 had increased effort tolerance post-operatively. It was demonstrated in both groups that increased effort tolerance was always matched by corresponding improvement in the effort electrocardiogram, with abolition of or delay in the ischaemic changes which had been produced pre-operatively (Figs. 1 and 2). When ischaemic changes did occur comparable to those accompanying pain before sympathectomy the patients always experienced a

warning discomfort (Fig. 3) and stopped walking. The changes then regressed more rapidly than they had done previously. There was some slowing in exercise heart rate in 16 of the patients. Two of the three patients in whom there was no slowing did not show any increase in effort tolerance.

Complications of Surgery

Of the 48 patients who survived the operation 10 suffered major post-operative complications, 19 had minor post-operative complications, and 19 made an uninterrupted recovery.

The major complications (two of which occurred in the same patient) were as follows: myocardial infarction in two patients; hemiplegia in two; heart failure in four; pulmonary infarction in three. All eventually made a good recovery and had symptomatic improvement after operation, with the exception of the two who had a hemiplegia; one of these was left with some personality change, and the other has residual weakness of the left arm. Diuretics were continued in the patients who had had evidence of heart failure, although in three of them this was only a transient episode.

Many of the minor complications, which included segmental pulmonary collapse and consolidation, small pneumothoraces due to opening of the apical pleura, pleural effusion, and elevation of the diaphragm from phrenic-nerve damage, were revealed only by routine post-operative chest x-ray examination. They all cleared rapidly and did not delay the patients' discharge from hospital.

Horner's syndrome has usually been avoided by leaving the upper half of the stellate ganglion intact, and in no case has it been severe enough to give rise to symptoms. For the same reason nasal congestion has occurred in only three patients.

Most of the patients experienced some aching pain in the neck, shoulders, or interscapular region after the operation; this usually lasted a few days, but 13 patients still had pain on discharge from hospital, and in two it has been persistent and troublesome.

Despite these complications, post-operative management presented no special problems. Indeed, it has been our practice for patients to go for surgery from a medical ward, and all but a few left hospital within 10 days of operation.

Causes of Death

Eighteen of the 52 patients are known to have died. Four of these deaths were operative or early post-operative. Most of the other deaths occurred at home or in other hospitals; six patients were believed to have died after a further myocardial infarction; three died suddenly, presumably from ventricular fibrillation, with no evidence of fresh infarction; two died from congestive failure; and three died from unrelated conditions.

Factors Influencing Prognosis

When the results were examined with reference to previous myocardial infarction it was found that those patients who had had infarcts did as well as those who had had none. Fifteen (60%) of the 25 patients known to have had previous infarction were greatly improved, compared with 13 (48%) of the 27 without this history. Three of the four post-operative deaths occurred in patients who had not had a myocardial infarct.

There was radiological evidence of cardiac enlargement in 15 patients, and the results in this group were similar to the results in the series as a whole. Four patients had had evidence of heart failure before operation, but in two cases it had been only a transient episode during the acute phase of a myocardial infarction; three of the four were improved by surgery, and in only one of them was there any exacerbation of the failure.

Age and duration of symptoms had no apparent influence on the results.

Discussion

The pain fibres of the heart accompany the cardiac sympathetic nerves. They reach the sympathetic chains by way of the middle and inferior cardiac nerves which join the corresponding cervical ganglia, and also by direct connexions with the upper four thoracic ganglia (Fig. 4). All the sensory nerves then join the spinal cord through the white rami of these thoracic ganglia. The pain fibres are therefore conveniently concentrated in the sympathetic chains from T1 to T4, and resection of this part of the chains will effectively isolate the heart from both its sensory and its efferent sympathetic innervation.

Upper thoracic sympathectomy for severe angina pectoris was originally devised to cut the pain fibres as a method of symptomatic treatment; but our investigations (Apthorp *et al.*, 1960, 1964) have shown that effort tolerance is increased not by masking pain but by improving myocardial performance, with abolition of or delay in the appearance of ischaemic changes in the electrocardiogram during exercise. Our belief that this benefit is due primarily to the coincidental removal of the efferent (motor) sympathetic innervation has recently been supported by experience with β -sympathetic-blocking drugs. These drugs can be used to achieve a pharmacological blockade of the sympathetic action on the heart without affecting the pathways for cardiac pain. Like sympathectomy they will often

increase effort tolerance in angina, with corresponding improvement in the effort electrocardiogram (Dornhorst and Robinson, 1962; Alleyne *et al.*, 1963; Apthorp *et al.*, 1964; Hamer *et al.*, 1964). Examples of this improvement are shown in Figs. 5 and 6. This functional improvement after sympathetic ablation depends upon several factors, but is likely to be due principally to the reduction in tachycardia and the oxygen-wasting increase in contractility which are the normal responses to exercise (Apthorp *et al.*, 1964).

Six of the patients in our series have been studied pre-operatively before and after β -sympathetic blockade, using pronethalol at a dose capable of blocking an isoprenaline-induced tachycardia in normal subjects. These patients were assessed again after sympathectomy. Three of them were not significantly improved by pronethalol, and the same patients had no increase in effort tolerance after operation. The other three did improve with pronethalol, and their effort tolerance was likewise markedly increased by sympathectomy. There was a difference in the measure of their improvement with the two methods of treatment. The slowing in heart rate for identical exercise ranged from 7 to 15% for the drug and from 21 to 25% after surgery; similarly, the percentage improvement in effort tolerance produced by sympathectomy was approximately double that following pronethalol. This suggests that surgical sympathectomy is more effective than drug-induced β -sympathetic blockade in modifying the cardiovascular response to exercise; it is consistent with the belief that sympathetic control of the heart is mediated principally by direct sympathetic innervation rather than circulating catecholamines (Folkow, Löfving, and Mellander, 1956). We have given full doses of pronethalol to two patients after sympathectomy without producing any further fall in exercise heart rate. It is unlikely that circulating catecholamines have any increased influence on the heart in the later post-operative period, because we have found no change in the relative bradycardia during treadmill exercise in patients observed for up to two years.

It follows that if the benefit from upper thoracic sympathectomy is due in part to removal of the sympathetic efferent fibres the operation must be bilateral to achieve its maximum

FIG. 4.—Illustrating the central connexions of the cardiac sympathetic nerves. The shaded area represents the portion of the chain removed in upper thoracic sympathectomy.

success. In the past, sympathectomy has often been unilateral when the distribution of pain was limited to one side of the chest, because of a justifiable reluctance to submit poor-risk patients to anything but the minimum necessary operative procedure. This is a less important consideration when the supraclavicular approach is used, for it involves much less trauma and hazard than does bilateral thoracotomy. The principal disadvantage is the technical difficulty in resecting the sympathetic chains as low as T 4.

The improvement which follows sympathectomy for angina pectoris is not limited to increased effort tolerance. Angina decubitus and pain evoked by excitement are usually completely

this respect it is reassuring that only two patients in the present selected series are known to have died from heart failure.

Thirdly, there is no reason to believe that sympathectomy will modify the progress of the pathological changes in the coronary vessels, and patients with rapidly advancing disease and recurrent infarction would not be expected to benefit from surgery.

Finally, the operative mortality and morbidity must be weighed against the benefit which may be expected. A method of predicting which patients are likely to show objective improvement would be valuable. The observations we have made in a small number of cases suggest that β -sympathetic-blocking drugs might provide a reliable guide to the value of sympathectomy in individual patients, as well as providing an alternative but perhaps less effective method of treatment for those in whom operation is contra-indicated. If it is confirmed that the results of sympathectomy can be predicted further improvement may be expected in the results achieved by this method of treatment of refractory angina.

Summary

Of 52 patients with refractory angina pectoris treated by bilateral upper thoracic sympathectomy 28 became free from pain or had greatly increased effort tolerance, 14 had some decrease in the severity and usually in the frequency of their pain, six were not improved symptomatically, and four died at or soon after operation.

Evidence is presented to show that effort tolerance is increased not by masking pain but by improving myocardial performance, with abolition of or delay in the appearance of ischaemic changes in the electrocardiogram during exercise. We believe that this benefit

is due primarily to the removal of the efferent (motor) sympathetic innervation rather than section of the sensory pathways.

The operation should be considered for patients with stable severe angina which has proved refractory to medical treatment.

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FIG. 5.—Electrocardiograms (CR4) recorded during identical exercise after placebo and after pronethalol in a patient aged 61. After pronethalol he was consistently able to walk further, and on this occasion developed neither pain nor abnormalities in the electrocardiogram. FIG. 6.—Electrocardiograms (CR4) recorded during identical exercise after placebo and after propranolol in a patient aged 62. Effort tolerance was increased by propranolol, with improvement in the exercise tracing.

relieved. Angina, when it does occur, is limited in distribution; reduced in severity, so that it is usually described as a discomfort rather than as pain; and is relieved more rapidly by rest. These benefits are achieved without removing the warning signal of myocardial ischaemia, so that the heart is not damaged by excessive exertion. The pathway for the sensation which remains after sympathectomy is not known; the suggestion has been made that it is transmitted by the vagi (White, 1943). It is of interest that many patients are more grateful for the change in the nature of the anginal pain than for any increase in effort tolerance; there are a few patients in whom we have demonstrated little or no increase in effort tolerance who have nevertheless been very pleased with the results of the operation.

Despite the benefits which can follow upper thoracic sympathectomy, it should be considered for only a small minority of patients with angina. There are several important reasons for this.

First, angina is a condition with an unpredictable natural history; in many patients the pain improves spontaneously—either slowly, or sometimes abruptly, after infarction of a limited area of ischaemic myocardium. For this reason all patients should be managed for a prolonged period with conventional medical treatment, and operation limited to those with persistent stable angina.

Secondly, although sympathetic drive has little influence on cardiac output during exercise in health (Chamberlain and Howard, 1964; Chamberlain, unpublished observations), it is believed to be a valuable compensatory influence on the failing myocardium, and sympathetic blockade has been shown to precipitate heart failure (Gaffney and Braunwald, 1963). We also have observed the sudden onset of heart failure after sympathectomy and following the first dose of pronethalol. In