The Effects of Splanchnicectomy on the Blood Pressure in Hypertension

A Controlled Study

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The effect of supradiaphragmatic splanchnicectomy on the blood pressure of 294 hypertensive patients followed for 10 to 18 months after surgery is compared with the effects of nonspecific medical management in a control group of 79 patients similarly studied. The data are presented in simple graphic form. It is concluded that 29 per cent of the hypertensive patients had reductions in blood pressure outside the range of spontaneous variation, that the vascular complications of hypertension decreased the likelihood of a good result, and that extension of the sympathetic ganglionectomy upward appeared to increase the frequency of good results without requiring a two-stage operation or producing significant postoperative orthostatic hypotension.

A precise and accurate evaluation of the effects upon the blood pressure in essential hypertension has been complicated in the past by such deficiencies as lack of suitable control studies, variations in number and type of patients selected for surgery, duration of the follow-up observation period, and the methods of obtaining and reporting the changes in blood pressure. The present report of 338 patients studied before and one year after splanchnicectomy and compared with a control group of patients is an attempt at an objective presentation of the effects on the blood pressure to be expected from the procedure of supradiaphragmatic splanchnicectomy and lower dorsal sympathectomy. The data will be presented in a graphic form which lends itself to comparative analysis with the results obtained by more extensive sympathectomies, and finally, our experience concerning the prediction of good and poor results on the basis of preoperative and early postoperative observations will be summarized.

Methods

Three hundred thirty-eight hypertensive patients underwent splanchnicectomy and 79 similar hypertensives were examined but not operated upon during the time interval January 1, 1947, to June 1, 1948. Information concerning the status of these individuals 10 to 18 months later was obtained by return visit or by reply to questionnaires sent to their physician. No patient over the age of 55 was included in the study, nor, with few exceptions, was any patient accepted whose nonprotein nitrogen exceeded 45 mg. per 100 cc. or whose hypertension was secondary to renal disease or complicated by a recent cerebrovascular accident, myocardial infarction, or congestive heart failure. Seven patients who apparently were on strict low sodium diets at the time of the return visit were excluded from the series, but minor degrees of salt restriction and the use of sedatives did not serve to eliminate the patient from the study. The operation consisted of the bilateral removal at one stage of the greater and lesser splanchnic nerves and sympathetic ganglions D-12 and above. The usual upper limit of removal was D-8 but in a number of instances it was possible to remove two or more ganglions above this point. All operations were done by members of the Department of Neurosurgery.

The blood pressure was determined in the following manner: "Casual" blood pressures represented the average of three consecutive determinations in the recumbent position in the right arm, obtained by the physician shortly after seeing the patient in one of the clinics of the University Hospital or by a specially trained technician when the patient was examined in the Cardiovascular Unit.
where this study was carried out for the most part. The resting blood pressure was obtained after 30 minutes rest alone in a quiet room. The cold pressor test and the tetraethylammonium tests were performed as described elsewhere.\textsuperscript{2,3}

**Observations**

1. Variation in Blood Pressure in the "Control" Group

Of 79 patients selected because their initial examination was sufficiently complete and their

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We recognize that these "control" patients are in a sense selected, since in our institution splanchnicectomy is commonly recommended. However, all of these patients were suitable candidates for splanchnicectomy, and 43 had actually been accepted by the Neurosurgery Service for operation. While a certain factor of selection applied, in most cases financial, administrative, or reasons other than those related to the severity of the disease kept them from

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![Figure 1](http://circ.ahajournals.org/)

**Fig. 1.** Effect of nonoperative treatment on the diastolic blood pressure in 59 patients, who received no significant medical or surgical treatment during the interval, re-examined 10 to 18 months after initial visit to Hospital. The graph is so constructed that reductions of more than 20 mm. in diastolic pressure are represented by points above the upper diagonal and increases of more than 20 mm. by points below the lower diagonal. It will be seen that spontaneous reductions in diastolic pressure exceeding 20 mm. over the year interval were rare under the conditions of this study.

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surgery. This is further borne out by a study of the blood pressure distribution and frequency of retinal, cardiac, and cerebral changes in the "control" series, and the mortality rates over the year interval which were very nearly comparable in the two groups of patients. For this reason we believe that the experience with the patients who were not operated upon serves as a dependable background for judging the effects of splanchnicectomy on the blood pressure.
2. Analysis of the Preoperative and Postoperative Blood Pressure Data

Three hundred thirty-eight patients were operated upon during the period of the study. It was impossible to secure follow-up information one year later on 13 of these patients. Thirty-one had died in the interval. Ten patients died during the operation or a few days thereafter which gave an operative mortality of 3 per cent. Twenty-one patients died during the year following the operation. Thus, it was impossible to secure blood pressure data on 44 of the 338 patients one year postoperatively.

Information concerning the remainder is available. One hundred fifty-four patients lived within the 200 mile radius of Ann Arbor and were re-examined at the Cardiovascular Unit. Figure 2 presents the findings on these patients. One hundred forty patients came to Ann Arbor from outside the 200 mile zone and were largely private patients of one of us (M. M. P.). Information concerning the postoperative blood pressure status of these patients was obtained by correspondence with the patients' private physicians and the findings are presented in figure 3. The median reduction in diastolic blood pressure in the patients re-examined by the home physician was 20 mm. Hg (from 126 to 106) while the reduction recorded in the patients re-examined at the Cardiovascular Unit was 13 mm. Hg (from 127 to 114). For purposes of simplicity in the subsequent analy-

![Figure 2. Changes in diastolic blood pressure in 154 patients re-examined at University Hospital one year after splanchnicectomy.](image-url)
90 mm. Hg in 26 patients, or 7 per cent of the entire series.

Significant reductions occurred more frequently in patients with high initial blood pressures. Of 73 patients whose initial diastolic pressures were between 131 and 145, 29, or 40 per cent, were reduced by more than 20 mm. Hg, and 4 fell to below 90 mm. Hg (figs. 2 and 3). Of 13 control subjects with comparable elevations of blood pressure, only one showed a decline exceeding 20 mm. Hg diastolic; she had gone into congestive failure and a failing cardiac output may have accounted in part for the reduction.

Patients with initial diastolic blood pressures below 110 mm. Hg did not frequently experience significant reductions in pressure after surgery. Of 41 such patients only 6 (15 per cent) had postoperative blood pressures below 90 mm. Hg, and 2 alone had reductions exceeding operated upon, so that a median reduction of 16 mm. Hg (126 to 110) occurred. This is to be compared with a median alteration of 0 (122 to 122 mm. Hg) in the control group.

Because of the greater number of patients who could be studied, we made comparisons of the "casual" readings, but analyses of the blood pressures obtained after 30 minutes rest in a quiet room showed the same degree of improvement. Twenty-six per cent of a series of 88 patients so studied showed reductions of more

![Figure 3](image-url)

**Fig. 3.** Changes in diastolic blood pressure in 140 patients re-examined, one year after splanchnicectomy, by home physician.
than 20 mm. Hg in the resting blood pressure at the one year postoperative examination.

The systolic pressure fell with equal frequency. Ninety-five patients, or 28 per cent of the entire series, had systolic pressure reductions exceeding 30 mm. Hg, which is outside the range of spontaneous variations in the control series.

3. **Type of Patient Most Likely to Obtain a Good Result**

In order to identify any factors of prognostic value, 31 individuals who died in the follow-up year and 40 who had experienced less than a 10 mm. reduction in diastolic pressure were contrasted with 60 patients who had had the most significant reductions in pressure compared with their average blood pressure over two or more months before operation. Patients with diastolic blood pressures of less than 110 mm. Hg and those with malignant hypertension were excluded from both series. A detailed list of these patients with the frequency and range of blood pressure determination and with a comparison of the characteristics of the “good” and “poor” result group has been reported elsewhere, but may be summarized at this point. Age distribution, known duration of hypertensive disease and preoperative response to tests of vasoactivity (cold pressure rise, tetraethylammonium decrease, decline between casual and resting levels) were practically identical in the two groups. Females were found with slightly greater frequency in the good result group. Patients with wide pulse pressures according to Smithwick’s classification were more commonly found in the poor result category, but narrow pulse pressures did not occur more frequently in the cases who were to have a good postoperative outcome.

In respect to two characteristics, however, the two groups differed significantly. Patients with higher initial blood pressures tended to fall more frequently in the “good result” category, while those with lower initial pressures were more apt to have a “poor” postoperative response. The second point of significant difference lay in the more frequent occurrence of the vascular complications of hypertension in the patients who had poor postoperative results. This might have been anticipated, since among the poor results were included 31 who subsequently died. The problem was therefore studied from a different viewpoint by examining the postoperative outcome of patients with various types of hypertensive complications and comparing them with the control material. This data is presented in table 1. It will be seen that a major complication of hypertension reduces the likelihood of a postoperative blood pressure reduction, but that such improvement occurs more frequently than would be expected from the course of the disease in the untreated hypertensive patient.

As would be expected, patients with malignant hypertension did far worse than those with uncomplicated essential hypertension. We were persuaded to operate on 7 cases who had marked azotemia in addition to papilledema. Only 2 survived one year and only 1 of these had a reduction in pressure. Almost one-half of the 18 patients with papilledema whose non-protein nitrogen could be kept below 45 mg. per 100 cc. by medical management survived the one year interval, and a number of these reported symptomatic improvement and disappearance of papilledema. One-fourth of the survivors had substantial reductions of blood pressure as well. Control material from this clinic is not available to follow the natural course of this form of the disease since we have believed that these desperately ill patients deserve the chance of surgical intervention.

4. **Prediction of Ultimate Course from Early Postoperative Observation**

Certain patients living near Ann Arbor have been re-examined repeatedly up to one year since operation, in an attempt to learn at what time the blood pressure becomes stabilized at the level to be expected one year after operation. Only 3 to 7 per cent of patients whose diastolic pressure nine days, three months, or six months after operation had risen to within 20 mm. of their preoperative level could be classified as “good results” at the end of one year. A reduction in the early postoperative blood pressure, however, by no means guaranteed a favorable result. From table 2 it will
be seen that the percentage of "good" results falls off steadily as the observation period lengthens. It might be supposed that if such a decline continued the number of good results at two years would be negligible. Fortunately such is not the case. A previous study of 30 "good result" patients who have been followed for more than two years indicates that only one has shown a significant increase in the blood pressure in the second postoperative year. It appears, therefore, that at the end of one year the blood pressure had become reasonably stabilized and it is then possible to estimate the frequency of good results.

5. Extent of Denervation as a Factor in Postoperative Result

According to the operative note, removal of D-12 bilaterally was accomplished in every

patient. L-1 was occasionally removed but so rarely as to preclude any statistical analysis of the results. The upper limit of ganglionectomy, however, varied widely with the difficulty of the operation and the skill of the operator. Fifty-four cases were reported to have had bilateral excision including ganglia D-6 or above: 27, or 50 per cent, of these patients had significant reductions in blood pressure one year later. On the other hand, it was impossible to remove any ganglia above D-9 in 43 instances: 9, or 21 per cent, of these patients experienced a good postoperative result. Examination of the operative notes in the 60 cases of "certainly good" results listed in our previous report revealed that 43 per cent had had bilateral removal of ganglia D-6 to D-12 compared with 21 per cent of the "poor" result cases.
6. Characteristics of the Postoperative State

(a) Blood Pressure. The operation reduced only slightly the spontaneous or induced fluctuations so characteristic of the disease. The median response of the diastolic blood pressure to the cold pressor stimulus was plus 20 mm. Hg preoperatively and plus 20 mm. Hg postoperatively in 65 patients so studied. The "good result" patients still showed considerable vascular lability. They had a median response of plus 17 mm. Hg.

The response of the postoperative patient to tetraethylammonium chloride was unchanged. Reductions of about 20 per cent in the diastolic blood pressure continued to occur even in the "good result" cases. In an attempt to determine whether significant vasomotor tone persisted in the thoracoabdominal area after splanchnicectomy, we tested the tetraethylammonium responses of a number of patients in whom the legs and one arm had been previously excluded from the circulation by tourniquets inflated for three minutes to 40 mm. above arterial pressure. While the occlusion was continued, 300 mg. of tetraethylammonium was injected. A reduction in blood pressure continued to occur, particularly in those patients whose hypertension had not been materially reduced by splanchnicectomy. This observation suggests the persistence of significant vasomotor tone to the thoracoabdominal area in these individuals.

Orthostatic hypotension was rarely observed two weeks or more after surgery. The blood pressure was measured in the recumbent position and during three minutes or more of motionless standing in the first 122 patients examined at 3, 6 or 12 months following operation. Reductions were observed so infrequently that the procedure was thereafter discontinued.

(b) Postoperative Disability and Symptomatic Improvement. As previously mentioned, patients were discharged from the hospital on about the tenth day following surgery. They were usually able to return to work in two to three months' time. Orthostatic syncope was not reported. Postoperative back pain was the chief disabling symptom referable to surgery. It was mentioned as an occasional annoyance in 35 per cent of patients six months after operation, but in 9 per cent of individuals it was sufficiently severe to interfere to some extent with the patients' normal activity or occupation. At the one year check-up examination this symptom was rarely disabling.

Relief from the symptoms of hypertension was frequently gratifying and out of proportion to the improvement in the blood pressure. Of a series of 97 patients who had had headaches of varying severity preoperatively, 5 were unimproved, 43 improved, and 49 had complete relief one year following surgery. Dizziness, nervousness, and irritability were likewise reduced to a significant extent. It was less certain that dyspnea, blurring of vision, or hypertensive encephalopathy was improved, owing to the difficulty of defining these symptoms accurately, or of establishing their frequency of occurrence before operation, but it was our clinical impression that improvement was often gratifying. Angina pectoris was not frequently relieved. In addition to this symptomatic relief, improvement in electrocardiogram and in heart size by teleroentgenogram was encountered. Such improvement occurred with greatest regularity in patients whose blood pressure was reduced significantly. It also occurred in occasional patients who had little reductions in pressure, but not at all in the control group. Ninety-five per cent of the patients who were asked whether they were glad they had had the operation replied in the affirmative. Even allowing for individual optimism, this is a gratifying response.

Discussion

1. Evaluation of Various Forms of Sympathectomy for Hypertension

This study indicates that supradiaphragmatic splanchnicectomy will lower the blood pressure significantly in about one third of hypertensive patients, but will rarely be "curative." Since the operation can be completed in one stage with minimal postoperative disability, it is worthwhile to inquire whether the results of the more extensive two stage procedures justify the added hospitalization and the postoperative orthostatic hypotension. Table 3 has been constructed for this purpose. While such comparison cannot be very ac-
curate, owing to the different indications for surgery, to the varying follow-up intervals, and to the different criteria of improvement used. Removal of ganglions D-6 and above improved the results are in accord with this finding and suggest that a wider thoracic splanchnicectomy may be as useful as extending the operation to include the lumbar ganglions.

The effects of splanchnicectomy are as likely to persist as are those of the other surgical

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Table 3.—Reported Effect of Various Forms of Sympathectomy on the Blood Pressure in Hypertension

<table>
<thead>
<tr>
<th>Authors</th>
<th>Extent of Ganglionection</th>
<th>No. Cases Reported</th>
<th>Follow-up (years)</th>
<th>&quot;Good&quot; Results</th>
<th>Definition of &quot;Good&quot; result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grimson&amp;</td>
<td>Stellate through L-1 or L-2</td>
<td>113</td>
<td>1-8</td>
<td>66</td>
<td>Comparable pre- and post-operative data for each patient not presented. Median reduction in diastolic readings of all patients exceeded 20 mm. Hg at 1 year and appeared sustained in subsequent years. Deaths included.</td>
</tr>
<tr>
<td>Evans and Bartels7</td>
<td>D-3 or 4 through L-1</td>
<td>173</td>
<td>1/2-3</td>
<td>47</td>
<td>Casual diastolic blood pressure fell more than 20 mm. and to less than 120 mm. in &quot;good result&quot; cases.</td>
</tr>
<tr>
<td>Smithwick8</td>
<td>D-8 through L-1</td>
<td>439</td>
<td>1-5</td>
<td>37</td>
<td>Postoperative blood pressure fell 20 mm. or more below resting preoperative diastolic blood pressure. Deaths included.</td>
</tr>
<tr>
<td>Hammarstrom9</td>
<td>D-8 through D-12</td>
<td>55</td>
<td>1/2-61/2</td>
<td>59</td>
<td>Mean of 24 hourly diastolic blood pressure readings in hospital reduced more than 25 mm. Deaths included. More extensive sympathectomy improved results in males particularly.</td>
</tr>
<tr>
<td>Present Series</td>
<td>D-6, 7, 8 or 9 through D-12</td>
<td>338 (54)</td>
<td>10-16 mos.</td>
<td>29</td>
<td>Casual diastolic blood pressure reduced more than 20 mm. Hg. Deaths included.</td>
</tr>
</tbody>
</table>

by various clinics, it would appear that extension of sympathectomy improves the postoperative results as far as the blood pressure is concerned. Our observations that...
procedures. Patients in our series who had had a good result at one year maintained their improvement in subsequent years almost without exception. This conforms with the opinion of the majority of observers\textsuperscript{4, 6, 10} but Evelyn and co-workers\textsuperscript{11} pointed out that recurrences were frequent between the first and fifth year after lumbodorsal sympathectomy, so that in their experience the ultimate percentage of "good" results\textsuperscript{*} fell to only 21 per cent.

2. Mode of Action of Splanchnicectomy in Hypertension

The fact that the blood pressure reduction, if it is to occur at all, is observed in the early postoperative period implies that the operation removes immediately an important area of increased vascular resistance. This could be accomplished indirectly by altering the output of, or vascular response to, adrenal or renal secretions, but it might also be the result of decreasing the splanchnic vascular resistance by interrupting splanchnic vasomotor tone.

A postoperative return to hypertensive levels could occur by means of (1) compensatory vasoconstriction in nondenerated areas, (2) by restoration of neural control of the splanchnic bed, and (3) by recovery of intrinsic vascular tonus within the denervated vascular bed.

While increased vasoconstrictor tone may occasionally develop in the undenerated areas of the body following splanchnicectomy, it appears unlikely that such compensatory vasoconstriction is a common cause for return to hypertensive levels, since blockade of vasomotor tone by tetraethylammonium in such persons does not produce excessive increases in blood flow to the extremities.\textsuperscript{12} Restoration of neural control to the splanchnic area via a ganglionic pathway may be a factor in operative failures. This hypothesis is supported by the experiment wherein tetraethylammonium reduced blood pressure in the splanchnicectomyed subject after exclusion of the extremities from the circulation by arterial tourniquets, and it is also implied by the studies of Ray and Console\textsuperscript{13} who showed that sweat activity returned to the denervated area but could again be interrupted by ganglionic blocking agents. Such vasomotor tone could reach the splanchnic vessels via alternate neural pathways or by regrowth of sectioned postganglionic fibers. In either event a wider sympathetic ganglionectomy might reduce the chances for restoration of such neural control, and this might explain the apparent improvement in postoperative results achieved by upward extension of the sympathectomy. Finally, recovery of intrinsic tonus in the denervated splanchnic bed may be responsible for the late return of hypertension after splanchnicectomy. Observations following sympathectomy of the extremities indicates that this recovery proceeds rapidly in the first few weeks, and that blood flow finally stabilizes at or above preoperative levels in two to three months postoperatively.\textsuperscript{14} It is possible that we are dealing with such a situation after splanchnicectomy. Wilkins' splanchnic blood flow measurements have demonstrated that a progressive reduction in blood flow occurs after operation, although he could not relate these changes to the success or failure of surgery.\textsuperscript{15}

It will be noted that the above hypothesis does not assume that certain hypertensive patients are benefited by sympathectomy simply because they have excessive neurogenic vasomotor tone. Rather, it assumes that all patients with hypertension (and probably normotensive patients as well) have a certain normal neurogenic support to their peripheral vascular resistance. This accounts for the fact that spinal anesthesia or autonomic blocking agents will lower the blood pressure of most patients with hypertension,\textsuperscript{2, 16} that such procedures will even lower the blood pressure of dogs with Goldblatt kidneys\textsuperscript{17} and that these reductions occur regardless of the degree of arteriosclerosis or of apparent renal participation in the hypertension. In this view, sympathectomy will have a tendency to reduce the blood pressure in all patients with elevated blood pressure, regardless of the cause or duration of the disease. That this occurs is demonstrated by the slight lowering of almost all postoperative blood pressures shown in figures 2 and 3. Furthermore, the frequency of significant reductions in blood

\textsuperscript{*} Criteria not stated, but it would appear that 20 mm. reduction in median diastolic blood pressure would qualify.
pressure would depend to some extent on the completeness of the initial removal of neurogenic support but to a greater extent on the degree and magnitude of compensating influences which develop in the postoperative period. Since these influences are essentially unpredictable by any preoperative maneuver, it would explain our failure to find any method of preselecting patients for splanchnicectomy. If we assume, on the other hand, that certain hypertensive patients are "neurogenic" in the sense that their peripheral vascular resistance is elevated by excessive vasoconstrictor tone, it becomes much more difficult to explain the observations discussed above.

3. Indications for Surgery

No preoperative test was found of predictive value. However, on the basis of experiences reported in this paper, certain trends were observed. Patients with high diastolic blood pressures were more likely to experience improvement, and it was therefore usually recommended for this group. Individuals with the vascular complications of hypertension (previous cerebrovascular accident, cardiac enlargement, papilledema) experienced blood pressure reductions less frequently (11 to 20 per cent) but since they carry a more serious prognosis surgical therapy was usually advised for this group. Finally, relief of certain hypertensive symptoms, particularly headache, was so frequent as to be an important consideration in recommending this form of treatment.

We found that only 15 per cent of patients with initial diastolic pressures below 110 mm. Hg fell below 90 mm. Hg after sympathectomy. Conservative therapy was therefore advised for this group. Patients with an elevated non-protein nitrogen due to poor renal function were found to have such a high mortality rate and such poor postoperative results as not to justify surgery.

If these indications are kept in mind, and it is recognized that sympathectomy is more apt to be palliative than curative in hypertension, we believe that supradiaphragmatic splanchnicectomy has a definite place in the management of the hypertensive patient.

Summary and Conclusions

1. Three hundred thirty-eight hypertensive patients were followed 10 to 18 months after supradiaphragmatic splanchnicectomy and 79 similar patients who did not undergo surgery were followed for a comparable period to serve as control subjects.

2. Only one of the controls showed a reduction of greater than 20 mm. in the diastolic pressure, while 29 per cent of the patients who were operated upon showed such a reduction in blood pressure, and 7 per cent showed a return to normotensive levels.

3. The preoperative data on 60 patients with the most marked reductions in blood pressure were compared with 71 who had had poorest results from surgery. No significant differences in the preoperative characteristics of the two groups could be established. Patients with diastolic blood pressure below 110 mm. or hypertensive vascular complications (cardiac enlargement, cerebrovascular accidents or papilledema) were less likely to experience significant blood pressure reductions following surgery.

4. If the blood pressure returned to preoperative levels by the ninth postoperative day, a negligible number of patients showed significant reduction one year postoperatively. On the other hand, blood pressure reductions in the early postoperative period often returned to hypertensive levels at a later date, so that an ultimate good result was not assured until one year had elapsed. Patients who had had good results at one year did not experience further elevation in the second postoperative year.

5. Patients in whom the denervation had been extended upward from D-12 to include D-5 or above bilaterally had a better postoperative result (50 per cent) than those in whom the conventional ganglionection (D-5 to D-12) had been performed.

6. The magnitude of the response to cold pressor tests was not reduced by operation. Orthostatic hypotension was not encountered and general postoperative disability was minimal after this type of sympathectomy, while symptomatic relief was as frequent as reported for more extensive operations.

7. While blood pressure reductions were perhaps not as common as those which are reported
to follow other types of sympathetic surgery, we believe that this less radical operation has a real place in the routine treatment of established hypertensive disease which does not respond to medical management.

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