

# THE SURGICAL TREATMENT OF ESSENTIAL HYPERTENSION

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IT IS obviously impossible to present, in any comprehensive way, a discussion of the problems of essential hypertension and of its surgical treatment in such an abridged article as this. A fairly complete report of the work which Dr. Irving Page and I have done thus far has been prepared and will appear shortly, to which reference may be made by those who are interested. I wish to report, however, briefly the considerations which led to the adoption of certain surgical procedures, the selection of patients for operation, the methods of control used in studying patients before and after operation, and the results of operation which thus far have been obtained.

The time at which Doctor Page and I became associated in this work, early in 1934, was a period of great activity in the surgical treatment of hypertension; and a survey of the literature showed that American, French, German and Italian authors had published a variety of surgical and other procedures for its cure or amelioration. The therapeutic procedures described consisted in the reduction of the activity of the basophilic cells of the hypophysis by radiation, in denervation of the adrenal glands, in subtotal adrenalectomy, in splanchnicotomy and in anterior nerve root section. While the causation of essential hypertension was, and is not, known, the theories upon which these therapeutic procedures were based were chiefly three: that hypophyseal basophilism played an important rôle in the genesis of the disease; that overactivity of the adrenal glands resulting in a hyperadrenalemia was an essential factor; and that chronic spasm of the arterioles in the splanchnic area was an important cause of the elevated blood pressure. Evidence of whatever nature in support of these theories was sought and subjected to critical analysis; and as a result Page and I concluded that a surgical procedure which had as its purpose the relaxation of the presumably spastic arterioles of the splanchnic area and the denervation of the adrenal glands offered greater possibilities than others which had been suggested and tried. The choice of procedures, then, lay between splanchnicotomy and anterior nerve root section and we decided to make as accurate a study as possible of the results of both procedures. That we selected anterior nerve root section for our first study was the result of a survey of available anatomic and physiologic data. Even granting the possibilities of anatomic abnormalities and "overlap" in the distribution of the sympathetic nerves, it seemed to us that section of the sympathetic fibers at their point of emergence from the cord by division of the sixth dorsal to the second lumbar motor spinal nerves was a more certain method of inhibiting the sympathetic innervation of the

abdominal blood vessels and adrenal glands than section or resection of major and minor splanchnic nerves combined with lower dorsal ganglionectomy. The procedure was therefore attempted or carried out in 21 cases. At the time of the first operation, May 11, 1934, the only case of which we knew who had been treated by this method had just been reported. This was the case of Adson and Brown, and while the results were far from ideal, it was thought that the fault lay in the selection of the case and that the operation should be tried in cases in which the vascular tree was still flexible. It was realized that the operation was the most difficult, the most time consuming and the most dangerous of the procedures which had been suggested. That our fears of the possibilities of harm to patients in this operation have been to some extent realized, I shall indicate later.

In the selection of patients for operation, it seemed probable that those in whom an elevated blood pressure was the only objective manifestation of disease on physical examination, might be expected to respond most favorably to surgical treatment. Nevertheless, it was thought desirable to attempt the procedure in groups of cases, the groups representing stages in the severity of the disease; for aside from determining its value it seemed important to determine, if possible, its limitations. In determining groups of this sort, various criteria were used. The flexibility of the vascular tree was determined by the fall in blood pressure when the patient was put to bed; by the fall in blood pressure after the intramuscular injection of colloidal sulphur or acetyl- $\beta$ -methylcholine (mecholine); after administration of sodium thiocyanate by mouth and after the inhalation of amyl nitrate; and by the daily fluctuations in the level of the blood pressure as determined by a long period of observation. Evidences of cardiac damage, of extensive changes in the ocular fundus and of renal damage with renal insufficiency were criteria which, in addition to vascular flexibility, were used to indicate the stage of the disease or its degree of advancement in the patients who were studied and subjected to operation. Such patients represented examples of the disease which varied from the benign essential hypertension of short duration to the highly malignant hypertension.

The prolonged observation and scientific study of patients before and after operation seemed most essential in determining the value of our therapeutic procedures. A study of all case reports in the literature showed the extraordinary difficulties in evaluating the results of different surgical operations, and largely because of the paucity of reported observations before and after operation. The great variability in the manifestations of essential hypertension makes it necessary that repeated observations, comprehensive in their scope, be made by one familiar with the disease in order to determine accurately the effects of any given procedure. What value there is in our work largely lies, I think, in the accuracy and completeness of the observations made before and after operation. The patients subjected to this study were first hospitalized in the Hospital of the Rockefeller Institute for at least 30 days, and frequently for a longer period, for a preliminary or preoperative

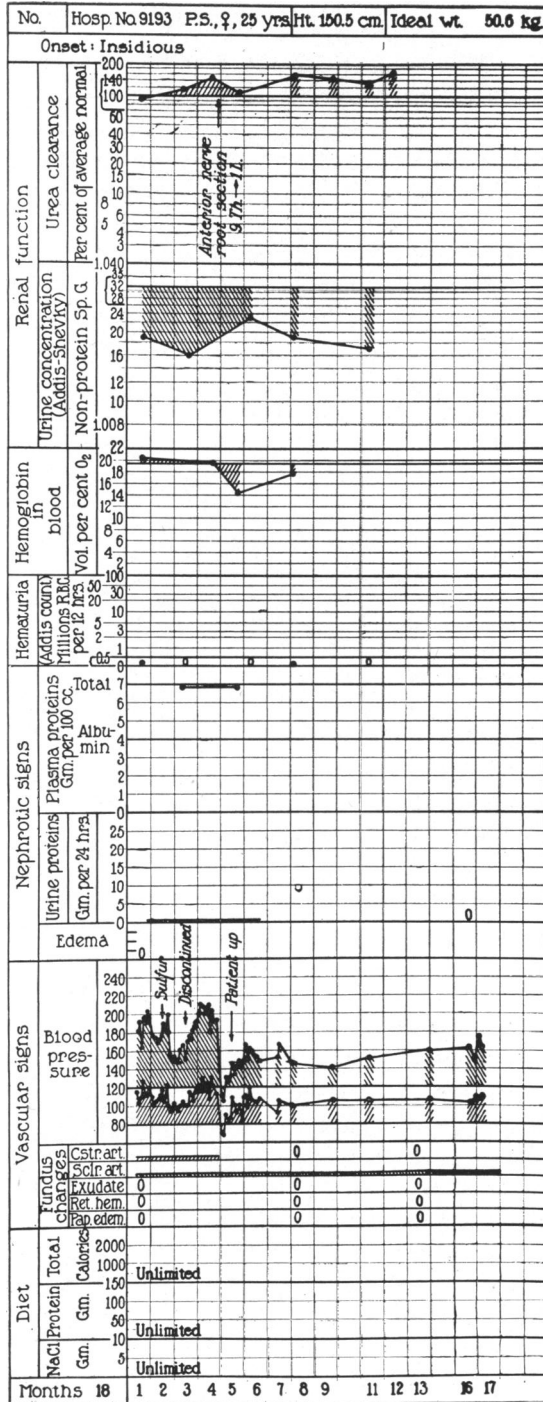


CHART I.—Showing the observations made before and after the operation of anterior nerve root section. It will be noted that the blood pressure has remained at a lower level since operation.

period of study. The flexibility of the vascular tree was estimated by the tests above indicated. The blood pressure was taken daily at a fixed time (9:30 A.M.) with the patient in bed, its fluctuations established and a mean or average blood pressure determined. Changes in the eyegrounds noted were constriction of the arterioles, arteriosclerosis, exudates, hemorrhages and papilledema. Changes in the heart were determined by physical examination, measurements of roentgenograms, and electrocardiographic studies. The basal metabolic rate was regularly determined. Renal efficiency was measured by urea clearance and the ability of the kidneys to concentrate urine. The specific gravity of the urine was determined in a 12 hour specimen voided at the end of 24 hours without fluids; in case proteins were present in sufficient amounts to contribute to the specific gravity, a correction was made for it. The number of formed elements in the urine was determined by the technic of Addis. The urine protein was measured by the method of Shevky and Stafford as modified by MacKay. The plasma proteins were ascertained by the method of Howe; hemoglobin was measured by the method of Van Slyke and Neill. The general study of the patient included observations upon the subjective manifestations of the disease, upon psychic abnormalities and upon evidences of stability of the nervous system. After convalescence from operation, the patients were again transferred to the Hospital of the Rockefeller Institute and all the above observations and examinations repeated. In the follow up, the patients have periodically been hospitalized for a week or ten days and again studied. It would appear that the results we have to report are as accurate as can be determined in the human subject with known methods of examination. An example of the data record incorporating these observations is shown in Chart 1.

The operation of anterior nerve root section consists in the bilateral division of the anterior roots of the sixth dorsal to the second lumbar spinal nerves. The positive identification of the spinous process of the first lumbar vertebra and its relation to the overlying skin has been helpful in determining the lower limit of the incision. The identification of the last digitation of the dentate ligament after the dura has been opened has aided in determining the roots to be divided; for it is attached to the dura between the twelfth dorsal and the first lumbar nerves. In our early experience the entire operation was performed at one sitting. The disadvantages of this were found to be chiefly two: its duration and its consequent hardship upon both patient and surgeon; but more important the fall in blood pressure as the result of the laminectomy, so that the essential part of the operation—the division of the anterior nerve roots—sometimes could not completely be carried out. In our later experience the operation has been divided into two stages, the first terminating with the completion of the laminectomy and the complete exposure of the dura; the second consisting in the opening of the dura and the division of the anterior nerve roots. An interval of several days to a week is allowed to elapse between these stages, during which the blood pressure will have returned to its preoperative level. In the division of the

nerve roots every precaution has been used to avoid injury to the cord and every effort has been made to preserve the small nutrient blood vessels entering the cord along the nerve roots. A sketch of the essential part of the operation is shown in Figure 1.

The operation of splanchnic nerve resection has been performed according to the technic of Max Peet. It is a supradiaphragmatic approach through a vertical incision with the subperiosteal resection of the mesial portion of the eleventh rib. The pleura is stripped from the bodies of the vertebrae, the major splanchnic nerve is identified and a section 7 to 8 cm. long is removed. The tenth, eleventh and twelfth dorsal ganglia with the minor splanchnic nerve are then removed. The operation has been performed bilaterally and has been done either at one or at two sittings, separated by a week's interval. The subdiaphragmatic approach suggested and used by Craig and the more recent subdiaphragmatic approach with resection of the splanchnic nerves, two upper lumbar ganglia and portions of the adrenal glands, as described by Adson, have not yet been employed by us.

In the reports of results of various surgical procedures, observers have commented upon both subjective and objective improvement. By subjective improvement is meant the amelioration or disappearance of such symptoms as headache, vertigo and palpitation of the heart; by objective improvement, the actual lowering of blood pressure, disappearance of papilledema, and so forth. Experience shows that improvement in subjective symptoms may take place without marked lowering of the blood pressure; it shows also that improvement in subjective symptoms practically always occurs in conjunction *with* a fall in the blood pressure. In an appraisal of the value of surgical procedures in the treatment of hypertension, it would seem obvious that procedures which cause a per-



FIG. 1.—The operation of anterior nerve root section. The dura mater is held apart with a series of silk sutures. The clamps grasp the digitations of the dentate ligament, traction upon which rotates the cord, and bring the anterior spinal roots into view. An anterior nerve root is shown divided between ligatures of fine silk. A blunt hook is shown lifting up a root preparatory to ligation and section.

manent or long continued reduction in the level of the blood pressure are the procedures of choice.

*Results of Anterior Nerve Root Section.*—Up to April 1, 1936, anterior nerve root section had been attempted in 18 cases. The results are summarized in Table I. Certain comments upon these cases may be added by way of elaboration of the data shown.

In three cases the operation was not carried beyond the first stage. One patient (No. 17 in Table I) recovered promptly from the operation but thus far has refused to submit to the second stage. It will be observed that his

TABLE I

Summary of Clinical Data of 18 Patients on whom Root Section was Performed.

No.	Age	Duration of Hypertension	Retinal Changes	Urea Clearance	Average Blood Pressure before Operation	Number of Pairs of Roots cut	Average Blood Pressure after Operation	Subjective Improvement
	yrs.			Percent of normal	mm. Hg.		mm. Hg.	
1	25	18 mos.	0	104	190/122	9	150/94	Very marked
2	24	+ 2 yrs.	+	80	206/148	5	162/98	Very marked
3	17	18 mos.	+	106	180/122	5	140/90	Very marked
4	52	8 yrs.	0	101	210/150	5	154/104	Marked
5	55	5 yrs.	+	88	190/122	6	176/114	Marked
6	25	3 yrs.	+	91	184/116	9	156/106	Marked
7	40	2 yrs.	++	72	250/142	4	210/122	Marked
8	25	2 yrs.	++	74	210/150	6	162/110	Marked
9	24	7 mos.	+++	92	190/120	5	162/110	Marked
10	26	+ 5 mos.	+++	50	190/124	5	190/138	No symptoms before op.
11	55	10 yrs.	0	90	258/140	6	182/116	Moderate
12	46	15 yrs.	+++	68	270/160	5	250/142	Marked
13	57	2 yrs.	+++	55	270/170	6	210/140	Moderate
14	44	3 yrs.	+++	88	200/152	6	158/106	Marked
15	26	1 yr.	+++	18	200/110	7	Patient died shortly after dura was closed.	
16	21	2 yrs.	0	119	200/152	0	140/100	No symptoms before op.
17	57	7 yrs.	+	42	250/140	0	252/140	Questionable
18	59	6 yrs.	+++	96	270/148	0	Patient died from Streptococcus Meningitis	

\* The elapsed time since operation in the first 14 cases varies between 1 and 2 years.

blood pressure remains at the preoperative level. Clinically he represented an advanced stage of the disease. One patient (No. 18) developed symptoms of meningeal irritation following the first stage and died from a Streptococcus meningitis. The dura had been opened only in the sense that a hypodermic needle had penetrated it for the purpose of withdrawing some cerebrospinal fluid. The meningitis probably was the result of a gross error in technic. One patient (No. 16), during his recovery from general anesthesia after the first stage, is said by two observers to have moved his legs; but when observed the morning following operation there was clear evidence of a transverse lesion of the cord at the level of the upper end of the incision. Believing that extradural hemorrhage causing compression of the cord might be the cause of his condition, the wound was reopened and a considerable clot was evacuated. There was no hemorrhage beneath the dura, as demonstrated by its color and by the aspiration of clear cerebro-

spinal fluid. Hoping that the extradural clot was sufficient to explain the symptoms of cord compression, the wound was again closed without opening the dura. For a period of eight days we awaited some evidence of returning function; then reopened the wound, removed the laminae of two dorsal vertebrae above the upper limit of our previous exposure and opened the dura throughout the entire length of the operative defect in the spine. There was not the slightest hemorrhage beneath the dura and the most careful examination of the spinal cord failed to reveal any trauma of the external surface of the cord or evidence of hemorrhage or other lesions within the cord. Since this operation (three months) there has been a slow return of function; but that there will be a restoration to normal function seems at present very doubtful. It is to be noted that as the result of a cord lesion at the level of the sixth dorsal, a fall in blood pressure has occurred and persisted as in cases in which the anterior nerve roots have been divided.

In 15 cases the operation of anterior nerve root section was completed in one or two stages. One patient died at the termination of an operation performed in one stage; and for want of a better explanation the death is ascribed to surgical shock. The autopsy showed generalized arteriosclerosis, arteriolar nephrosclerosis, detachment of the retinae with retinal hemorrhage, partial atelectasis of the lungs, persistent thymus and cholelithiasis. The case was one of our early ones, and was the most advanced case of malignant hypertension in the series; it is doubtful, in retrospect, whether the operation should have been undertaken.

Of the 14 patients who survived the completed operation, three are improved, but the duration of time is not sufficient to warrant comment on the results; 14 have been observed for from one to two years since operation. Of these 14, five have roughly been grouped on the basis of duration of the disease, retinal changes, evidences of arteriosclerosis and of renal damage, as mild or moderately severe examples of essential hypertension; while nine have been classified as examples of advanced and severe hypertension or as malignant hypertension.

In Table I the first five cases represent the mild and moderately severe examples of the disease, the sixth to the fourteenth cases, inclusive, represent the advanced and severe examples of the disease. Subjective improvement has been very marked in three, marked in eight, and moderate in two of the cases. Improvement in subjective symptoms has, therefore, occurred in 100 per cent. Objective improvement—the lowering of the blood pressure during the period of observation, the improvement in the condition of the eye-grounds, and so forth—has varied appreciably, and in order to form a just estimate of the results, it is necessary to analyze each case separately. Perhaps a general idea of the results may be obtained from the appended summary.

**SUMMARY.**—In four out of the five cases of mild or moderately severe hypertension, the systolic pressure before operation varied between 180 and 220 and averaged 196.5; the diastolic pressure before operation varied be-

tween 122 and 148 and averaged 130.5. The permanent (during period of observation) fall in systolic pressure after operation varied between 40 and 56 Mm. and averages 45 Mm. The permanent fall in diastolic pressure after operation varied between 26 and 50 Mm. and averages 34 Mm. The lowering of the blood pressure represents 22.6 per cent of the preoperative systolic level and 25.5 per cent of the preoperative diastolic level. The patients represent a group which, having had a blood pressure before operation of 196/130, have had since operation a blood pressure of 150/95; a blood pressure which approaches, but is not, normal.

In one of the cases of mild or moderately severe hypertension, the blood pressure before operation was 190/122 and since operation has been 176/114. There has been, therefore, a fall of only 14 Mm. in the systolic pressure and 8 Mm. in the diastolic pressure. The result in this case is far less satisfactory than in the other four.

In four of the nine cases of advanced, severe hypertension, the systolic pressure before operation varied between 200 and 270 and averaged 235; the diastolic pressure before operation varied between 130 and 170 and averaged 143. The permanent fall in systolic pressure after operation varied between 42 and 76 and averaged 56.5 Mm.; the permanent fall in diastolic pressure after operation varied between 20 and 30 and averaged 25 Mm. This lowering of blood pressure represents 23.8 per cent of the preoperative systolic level and 17.5 per cent of the preoperative diastolic level. The patients represent a group which, having had before operation a blood pressure of 235/145, have had since operation a blood pressure of 178/118, a pressure considerably above normal. It will be noted that the percentage fall in the systolic pressure in this group is equal to that in the mild and moderately severe group, but that the percentage fall in diastolic pressure is less than that in the previous group. Although the operation achieved the same percentage fall in systolic pressure as in the preceding more favorable group, the fact that the blood pressure before operation was considerably more elevated leaves this group with a greater degree of hypertension. (One of these patients has since died of apoplexy. That the reduction in blood pressure prolonged his life cannot of course be stated; that the operation hastened his end we do not think likely.)

In four of the nine cases of advanced, severe hypertension, the systolic pressure before operation varied between 184 and 270 and averaged 218; the diastolic pressure before operation varied between 116 and 160 and averaged 134.5. The permanent fall in systolic pressure after operation varied between 20 and 40 and averages 29 Mm.; the permanent fall in diastolic pressure after operation varied between 10 and 20 and averages 14.5 Mm. This lowering of blood pressure represents 13.3 per cent of the preoperative systolic level and 10.5 per cent of the preoperative diastolic level. The patients represent a group which, having had before operation a blood pressure of 218/135, have had since operation a blood pressure of 189/120, a pressure again considerably above normal. It is to be noted in



this group that the percentage fall in systolic and diastolic pressures following operation is very much less than in the preceding two groups of cases. (Of these cases one has since died of apoplexy.)

In one of the nine cases of advanced, severe hypertension, the systolic pressure before operation was 190 and the diastolic pressure 124. Following operation the systolic pressure has continued to be 190 but the diastolic has increased to 138. The operation in this case has had no effect upon the blood pressure. (The patient has since died of uremia.)

It will be noted that in all cases except one, anterior nerve root section has been followed by a fall in blood pressure which has persisted for from one to two years. In mild and moderately severe hypertension, four out of five cases, or 80 per cent, have shown a satisfactory reduction in blood pressure. In severe and malignant hypertension, four out of nine cases, or approximately 45 per cent, have shown a fairly satisfactory reduction in blood pressure; while one out of nine, or ten per cent, has failed to show any reduction in blood pressure. The attempt to determine the reasons for fairly good results in 80 per cent of the mild and moderately severe cases and 45 per cent of the severe, advanced cases does not at present lead to any definite conclusions. Our experience thus far shows that neither in the mild nor severe cases can anterior root section be expected to cause a permanent reduction of more than 25 per cent of the preëxisting systolic and diastolic pressures. Perhaps in part because of this, we have found that patients whose disease is benign without advanced morbid vascular changes and young patients exhibiting signs of the hypertensive diencephalic syndrome are fairly certain to be greatly benefited by operation; patients with benign hypertension of long standing with marked arterial thickening form a more uncertain group from the viewpoint of results; while patients with malignant hypertension form a very uncertain group in whom the outcome cannot at present accurately be predicted.

Aside from the results with respect to the blood pressure, the objective findings following operation may be stated as follows: Morbid changes in the eyegrounds when present before operation quite generally disappeared. Relaxation of constricted retinal vessels, absorption of exudates and hemorrhages and reduction in the grade, or disappearance of papilledema was noted, not in all, but in many instances. The heart, as measured in preoperative and postoperative roentgenograms decreased in size after operation in a number of cases in which it was enlarged previous to operation. The renal function present before operation was not changed as a result of the operation.

The supposed untoward effects of the operation which might give rise to disabilities after operation have, thus far, in our experience been of very little significance. The paralysis of the abdominal muscles, the result of the section of the motor roots, was expected to give rise to a protuberant abdomen. While enlargement of the abdomen has occurred, it has been neither unsightly nor disabling. On the other hand, it has been observed that the blood pressure after operation in some cases is higher in the prone than in

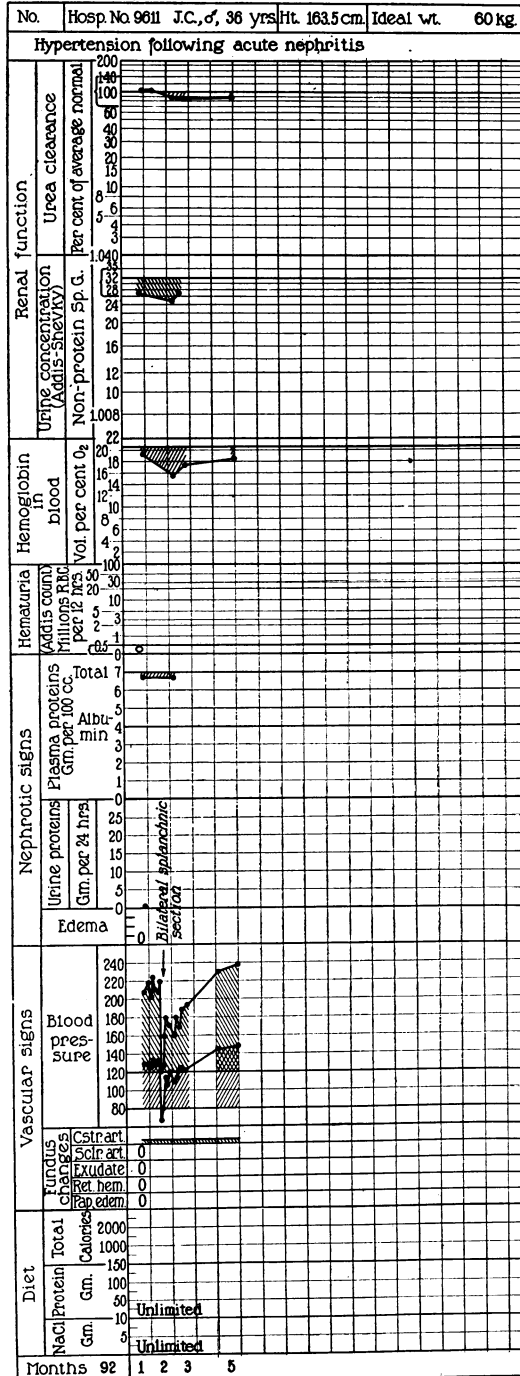


CHART 2.—Effects of splanchnic nerve resection. The blood pressure, reduced immediately after operation, has returned to its preoperative level. This has been our experience in nine cases subjected to this operation.

the erect posture, and it may be that relaxation of the abdomen is a factor in the lowering of the blood pressure. The loss of sweating of the skin of the trunk from the xiphoid or costal margin to the symphysis pubis has not been noticed by patients. The difficulty in evacuating bladder and bowel due to the loss of function of the abdominal muscles has disappeared, as a rule, within 48 or 72 hours. The supposed danger of failure of kidney function due to the fall in blood pressure was not anticipated by us and has not been realized. The blood flow through the kidney is maintained satisfactorily with a lowered blood pressure, and Doctor Page's postoperative studies show that the urea clearance and the ability to concentrate urine are practically unaffected by operation.

The serious danger in the operation is the occurrence of a lesion of the cord giving rise to paresis or paralysis of the lower extremities, bladder and rectum. The nature of the lesion in our case and its cause remain for the moment undetermined. That the lesion could have been due to cord compression the result of a blood clot in the wound seems doubtful; that it was not due to operative trauma of the cord seems proven by our careful examination of the cord; that it was not due to operative interference with the blood supply of the cord also seems clear. The possible occurrence of this complication seems to us a very strong objection to the procedure.

Our experience with the operation of splanchnic nerve resection combined with removal of the lower thoracic sympathetic ganglia can be stated very briefly. The operation in one or two stages has been performed thus far on nine patients and in all, except one instance, was carried out on both sides. In the selection of patients for this operation, seven of the nine cases had mild benign hypertension and two had malignant hypertension; the majority, therefore, were those in whom a favorable result might be anticipated. The same prolonged, careful and comprehensive observations have been made before and after operation as in the patients subjected to anterior root section. The results in the nine cases have been disappointing. In all, the blood pressure, reduced as a result of the operation, promptly rose to its preoperative level and for periods of six months to one year either has continued at this level or has become more elevated (Chart 2). The results from the viewpoint of the relief of subjective symptoms also have been minimal. So far as our experience goes, therefore, this procedure has failed to give results comparable with those of anterior root section; it is, however, realized that the number of cases thus far subjected to this procedure is too small from which to draw definite conclusions.

DISCUSSION.—DR. GEORGE W. CRILE (Cleveland, Ohio).—This paper is distinctly a Heuer type of paper, careful and logical. For my part may I present a slightly different approach.

Let us take a view of the background, the possible source or genesis of hypertension. Figure 1 shows the adrenal gland and the sympathetic system in an alligator of about the same weight as a full grown lion or tiger. It

has no sympathetic complex whatever. Sympathin is a product of the sympathetic nervous system, which was discovered by T. R. Elliott, and has been found to function like adrenalin; that is, it instantaneously speeds oxidation, its effects spreading over the whole sympathetic system. If that be true,

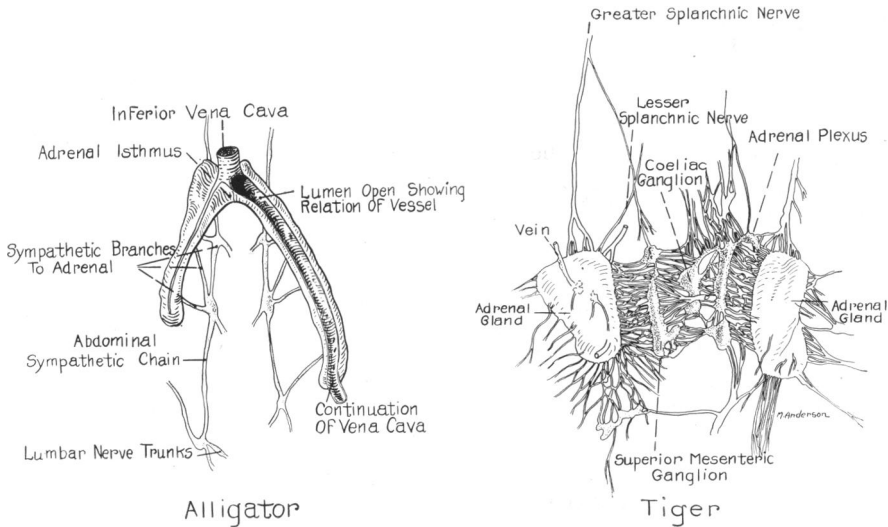


FIG. 1.—Adrenal sympathetic system of alligator. FIG. 2.—Adrenal sympathetic system of tiger.

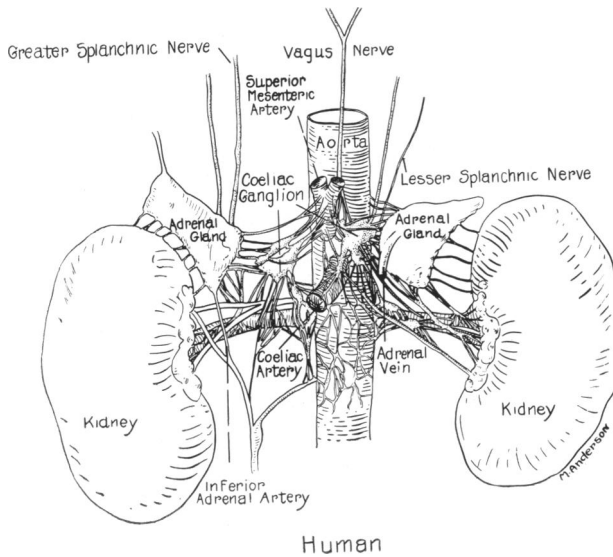


FIG. 3.—Human sympathetic system.

then those animals requiring great outbursts of activity should, in contradistinction to this slow and lazy alligator, have a great complex here. This contrast is exhibited in Figure 2, which shows the adrenal sympathetic system in a tiger of approximately the same weight as that of the alligator whose lack of a sympathetic complex we have just shown. Look at the enormous

development of the sympathetic complex, the numbers of unnamed ganglia present, like a cluster of grapes, and the size of the complex itself. Eighty-one fibers enter the adrenal gland in this powerful animal which shows the greatest power in its immediate outbursts of energy.

Figure 3 shows the human adrenal sympathetic complex. When we denervated the adrenal glands, we could cure hyperthyroidism and neurocirculatory asthenia. We could abate essential hypertension in some cases but in many cases we failed to do so and so we were dissatisfied. As the results of our clinical experience and our findings in animals during the last six months, we have concluded that there are at least two separate functions of this great energy system. One is that of driving—speeding the oxidation in the animal. That is clear enough. The other is a drive on the circulation,

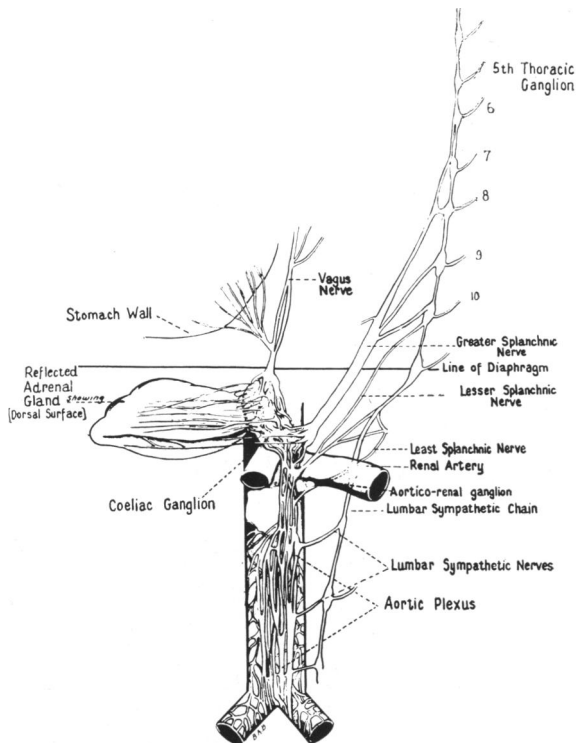


FIG. 4.—Sympathetic nerves on surface of aorta.

to carry an increased supply of oxygen through the blood stream. And to accomplish this we have a concentration of lines of communication on the aorta, some actually entering into its walls. There are similar communications with the whole arterial tree, the capillaries alone, according to Crowe, amounting in length to about 150 miles. We therefore changed our point of view, and in the treatment of hypertension attacked only the lines of communication of this energy system with the arterial tree.

Figure 4 shows the denervation of the aorta, from the bifurcation to the crus of the diaphragm. We also break up the coeliac plexus and take out the coeliac ganglia. This is a complete denervation, so far as the artery is concerned and that is all we need to think about in essential hypertension. One can see how inadequate it is just to denervate the adrenals and divide the

splanchnic nerves. Our attack should be solely upon the energy that causes the contraction of this great arterial tree.

A universal Raynaud's disease is probably what essential hypertension is. If that is true, then this procedure should produce an immediate effect, an immediate fall of the blood pressure. As the result of this operation, there is a more definite immediate fall in the blood pressure, especially in the diastolic pressure, and the hypertension is more definitely relieved. For the final end-results we must await the confirmation of time.

DR. ALFRED ADSON (Rochester, Minn.).—I do not think there is a great deal to add after Doctor Heuer has given his thorough discussion and Doctor Crile his contribution to the subject. However, my interest in the subject has been carried along for a number of years; perhaps I might add one or two points relative to the selection of patients for sympathectomy and relative to the choice of operation.

I wish that it were possible always to prognosticate definitely, preoperatively, which patients are suitable for, and which are going to respond to, extensive sympathectomy. All of us who have been carrying out these operations, I am sure, have had this experience: we have advised operation and have performed it upon a patient whom we though should respond favorably, only to be disappointed and see the pressure rise and the symptoms return at a later date. Equally true, we have accepted a patient for operation rather reluctantly because of marked retinitis and changes resulting from high pressure and have found, to our surprise, that the patient made remarkable improvement following operation.

I want to emphasize what Doctor Heuer called attention to, and that is the preoperative studies, because it is very evident that if there has been irreparable damage to the heart, kidneys, retinae and cerebral vessels, little is to be expected from operative interference.

I had observed early in the series that whenever a patient's blood pressure dropped, as Doctor Crile illustrated on his chart, following thorough anesthesia before operation, that patient was the one who responded most favorably and received the best results. Doctor Allen, who has taken Dr. George Brown's place in the section on vascular disease, took the cue and has carried out a number of studies, such as Doctor Heuer has referred to, with reference to the drop in pressure during rest and under the influence of barbiturates; but Doctor Allen carried it one step farther. He had these patients anesthetized with a barbiturate, such as pentothal sodium, or an amylal, and frequently found that the systolic blood pressure would drop to 130 or 120 Mm. of mercury and even as low as 100. During the ten minutes of anesthesia the diastolic pressures also fell to less than 100 Mm. of mercury.

In comparing the preoperative and postoperative changes, Doctor Allen found that preoperative drops in pressure corresponded to the postoperative pressures. It appears that the anesthesia test is one that may help in selecting suitable cases. Even though there are no evidences of irreparable damage in the kidneys or heart, there may be present a fixed change in the arterial wall which will not allow vasodilatation. Therefore negative renal function and blood tests are not necessarily assurances that the patient will respond to extensive sympathectomy.

The object of the operation, as Doctor Heuer has told us, has been to denervate a large vascular area, below the diaphragm, and to thoroughly denervate the suprarenal gland high, at the source of its innervation. Perhaps the most radical and most effective operation is extensive rhizotomy, because then the sympathetic fibers are divided as they leave the spinal cord. The

operation Doctor Peet has been performing is a much simpler and less extensive procedure. It does not include the rami to the upper two lumbar ganglia and only occasionally the rami from the twelfth dorsal root.

We have had two cases such as Doctor Heuer referred to; that is, transverse myelitis which developed following extensive rhizotomy. This led to the development of the subdiaphragmatic procedure, since the supradiaphragmatic operation did not include as many sympathetic fibers as I wanted to divide.

In developing the subdiaphragmatic procedure, it occurred to me that if it were possible to resect all three splanchnic nerves, major, minor and lesser, on both sides, and if it were possible to take out the first and second lumbar ganglia, I would then interrupt all of the sympathetic fibers carrying vasoconstrictive impulses to vessels below the diaphragm, just as is accomplished in rhizotomy. Therefore, I have discontinued rhizotomy and have employed the subdiaphragmatic operation. To date, we have carried out the procedure on 25 patients, operating first on one side, and ten days later on the opposite side.

In view of the experiences that other men have had with the suprarenal gland, and in the light of Doctor Crile's work on denervation, I included biopsy of the suprarenal gland in the first case, but in the others I included half of each suprarenal gland. I am not sure that this is necessary.

In our group of cases in which rhizotomy has been performed, I should say the results are poorer than those that Doctor Heuer has reported. This may be attributable to the fact that in our early experience we had no guide for accepting cases except trial and error. The group of cases in which rhizotomy was performed numbered 27, with two deaths. One patient died from a suprarenal tumor; one from meningitis. Thirteen patients obtained satisfactory results. In the series in which the subdiaphragmatic operation was performed, there were 25 cases with no postoperative deaths, nor has there been a death since operation. The first patient was operated upon in February, 1935. Three patients in this group have not responded well, since the pressures have returned to preoperative levels, while the pressures of others have dropped so low that it has been necessary to apply an abdominal binder.

I believe the subdiaphragmatic operation is just as effective in interrupting vasoconstrictor impulses as is rhizotomy, and it is possible that the operation may be more effective in that we are interrupting postganglionic rami instead of preganglionic fibers.

DR. DALLAS B. PHEMISTER (Chicago, Ill.).—In general, the excision of normal structures, with obliteration of normal physiologic processes, should not cure disease as does excision of pathologic tissue obliterating a pathologico-physiologic process. We do not know but that the nerves excised or divided in these operations may be normal, and that is what makes it so difficult to determine what the effect is going to be upon the pathologic physiology.

I thought you might be interested in some experiments that Dr. Kieth Grimson has carried out with me, in which normal dogs were operated upon: excising the entire thoracolumbar chain on both sides, and then studying the blood pressure at frequent intervals by the arterial puncture technic, over long periods of time. After the first operation, *i.e.*, excision of the thoracic chain on the right side, a fall in blood pressure occurred; excision of the left side was then undertaken, followed by excision of the abdominal portion at one operation. The blood pressure remained low for a variable number of

days, ranging from 75 to 150; climbed gradually, and in 150 to 250 days, as a rule, was back to normal. In 430 days the pressure was practically the same as it was before the operation.

Autopsies have been performed upon some of these dogs, and there have been no evidences of restoration of the sympathetic chain. It is difficult to know whether there are fibers that have grown in and reestablished connections that cannot be identified grossly.

The same operation that Doctor Heuer has performed upon a patient, and also the Peet operation, was carried out upon dogs. In those cases, in both instances, there was a very rapid return of the blood pressure to normal. Four other dogs, operated upon by the method of Doctor Heuer, had a return of their blood pressure level in from 10 to 30 days.

These findings might be regarded as a discordant note in the surgical treatment of essential hypertension, but again I want to emphasize that the results obtained from surgery upon a normal dog are not comparable with results obtained, from the same operation, upon a sick patient.