ON THE AVOIDANCE OF SHOCK IN MAJOR AMPUTATIONS BY COCAINIZATION OF LARGE NERVE-TRUNKS PRELIMINARY TO THEIR DIVISION.

WITH OBSERVATIONS ON BLOOD-PRESSURE CHANGES IN SURGICAL CASES.¹

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(1) By common usage the term "shock" has come to represent a peculiar state of depression of the normal activities of the central nervous system. Such a condition is ordinarily brought about by traumatism, of one sort or another, to peripheral afferent nerves. In order to produce shock, the impulses resulting from this traumatism must have acted reflexly upon the vasomotor mechanism in the medulla in such a way as to occasion a marked fall in blood-pressure. This diminution of arterial tension is the most characteristic symptom of shock.

(2) Under ordinary circumstances injuries of only moderate severity to peripheral nerves cause a rise in blood-pressure. If, on the other hand, these injuries are extensive or frequently repeated, or if they are complicated by certain primary or secondary anaemias, they are commonly productive of a fall in blood-pressure, indicating a state of shock.

Shock consequently need not be occasioned even in most extensive surgical procedures on the extremities, provided due regard is given to perfect hæmostasis. In operations of considerable magnitude, however, during which the division of many large nerve-trunks becomes necessary, or in operating upon such

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traumatic cases as have been already complicated by extensive injury to peripheral sensory nerves, so-called operative shock is rarely avoided.

When, therefore, any condition is existent which predisposes to shock, such as loss of blood, prolonged anaesthesia, etc., or when a certain degree of shock is already present before operation, especial risk is attendant upon the division of important sensory nerve-trunks.

(3) Cocaine injected into a nerve-trunk effectually blocks the transmission of all centripetal or sensory impulses. Cocainization, therefore, of main trunks of nerves central to the proposed site of their division in a major amputation, prevents the conduction of those impulses resulting from the traumatic insult which otherwise, by acting reflexly through the medullary centres, might become the chief factors in the production of shock.

Three years ago, during the progress of an interscapulo-thoracic amputation for a metastatic sarcoma of the shoulder and before the principles laid down in the foregoing introductory paragraphs were sufficiently appreciated, it was the writer's misfortune to have occasioned a profound and almost fatal condition of shock by the division of the brachial plexus of nerves. This case and a subsequent one of ablation of the entire upper extremity, in which precautions of anaesthetization of the plexus before its division were observed, illustrate so well from the clinical side the principles which will be emphasized in this communication that they will be briefly summarized.


Miss A., forty-one years of age, entered the hospital, December 22, 1899. A pigmented cutaneous mole had been removed from the left forearm two years before her admission. In May, 1899, following an injury to her left shoulder, a secondary growth appeared in the axilla, which increased slowly in size up to the past few weeks. This has enlarged very rapidly of late, and a mass of glands has appeared above the clavicle.
Fig. 1.—Case I. Showing axillary tumor and oedematous extremity before operation.
FIG. 2.—Case I. Twelve days after operation.
During this period of rapid growth of the axillary tumor the pain in the arm has become so severe that large doses of mor-
phine have been necessary to control it. The patient has lost greatly in strength and weight from pain and sleeplessness. The
pain evidently is occasioned by pressure on the brachial plexus,
and is referred over its entire sensory distribution from shoulder
to finger-tips.

Physical examination showed a large, fleshy woman, appar-
ently suffering acutely, holding her left arm abducted forty-five
degrees from her side in order to avoid pressure against a large
axillary tumor the size of her head (Fig. 1). This growth ex-
tended from the clavicle almost to the nipple and from the para-
sternal line to the outer border of the scapula. The tumor seemed
to be attached to the chest wall, and attempts to move the arm
or the growth caused severe radiating pains. It imparted a sen-
sation of pseudofluctuation, and the skin which was thinned over
it was covered with dilated venules. The entire arm was ßedema-
tous and the hand slightly cyanosed. The tumor measured
sixty-seven centimetres in its partially exposed circumference.
The metastatic growth above the clavicle, the size of a hen's egg,
was firmly adherent to the neighboring structures and caused pain
when it was handled. The case seemed most unpromising, but
was undertaken in the hope of relieving the patient's suffering
by division of the brachial plexus should it be found impossible
to do a complete operation.

Operation, December 26, 1899. Ether anaesthesia. An in-
cision, starting just below the mastoid process, was carried down-
ward across the clavicle and along the inner margin of the breast.
The clavicle was exposed and divided with a Gigli saw. The
axillary artery and then the vein were ligated and divided. The
tumor with the breast, pectoral muscles and arm were then turned
outward and the growth fortunately found to be unattached to
the thorax. The operation up to this point was without incident;
practically no blood had been lost, and the only remaining step
was the completion of the scapular part of the amputation.

As the tumor with the breast, arm, and clavicle dropped away
from the chest wall, the brachial plexus was exposed and the
nerve-trunks under some tension were divided with a few strokes
of the knife. It was necessary to pick up with clamps the central
bleeding ends of a few of these nerve-trunks. Immediately the
patient's pulse jumped from 110, which represented its "ether level," to 150, where it remained until the shoulder amputation was completed.

The mass of glands in the neck had been freely exposed by the high incision and was readily enucleated. Several large branches of the plexus, however, were spread out over this growth, and a secondary division of this portion of the plexus consequently was necessitated. When this was done, the patient's radial pulse immediately became impalpable (see accompanying chart, Fig. 4). It continued thready and almost imperceptible during the remainder of the operation, which was rapidly completed, and for almost twenty-four hours afterwards. During this postoperative period the patient's general condition closely resembled that seen in cases of shock such as accompany serious traumatic crushes of an extremity.

The patient finally made a complete recovery. The wound healed by primary union throughout (Fig. 2). The size of the tumor in comparison with the arm is shown in the photograph (Fig. 3). It was a round-celled sarcoma.

It doubtless has come within the experience of most operators to see patients brought into a profound condition of shock before the termination of major amputations of this nature. It is, however, unusual to be able so definitely to attribute to one particular step the exact occasion of the upset to the vasomotor and cardiac mechanism. For some years it has been our custom to have the anæsthetist plot a so-called "ether chart," which records the variations in pulse-rate during the period of narcosis. Such charts were, I believe, first introduced by Dr. Codman for use in the Massachusetts General Hospital, and very valuable data as to the patient's condition may be obtained therefrom. The pulse-rate, however, thus graphically represented during an operation, may give no real indication of the degree of actual or impending shock for the true estimation of which observations upon the blood-pressure are necessary. It must be borne in mind that a pronounced rise or fall in arterial tension may be unassociated with any change in pulse-rate. However, a persistent increase in the rapidity of the pulse in cases in which loss of blood has been
FIG. 3.—Case I. Showing size of tumor mass in comparison with òedematous arm.
slight may be taken as in a measure indicative of a corresponding fall in blood-pressure, and so representative of the degree of shock. The accompanying chart (Fig. 4) represents the pulse-rate as plotted during the operation upon this particular case, and shows by the marked alteration in its rapidity the reflex effect upon the neurovascular mechanism which was produced by the division of the brachial plexus in each instance as described.

The following case, one of similar nature and in which the same operative procedure was carried out, illustrates how the disturbing effects of nerve section observed in Case I might have been avoided.

**Case II.**—(Surgical Number 9828.) *Large Sarcoma of Upper End of Humerus with Pathological Fracture. Interscapulo-thoracic Amputation. Cocainization of Brachial Plexus and without Production of Shock.*

J. E., thirty-two years of age, entered the hospital, January 11, 1900. The patient had had pain of supposed “rheumatic”
nature in the left shoulder for four years. Following an injury, which occurred six months before his admission to the hospital and which was associated with severe contusion of the shoulder, the pain increased, and a short time later the present tumor began to be evident. During the past two or three months the growth has increased rapidly in size (Figs. 5 and 6).

The patient was in good physical condition in spite of his suffering, which was considerable and had been constant for four months. The character of the tumor is better shown by the photographs than by a description. A pathological fracture was present in the centre of the growth, and the slightest motion of the arm was forbidden. The entire arm was oedematous and cyanotic, and neurotrophic disturbances were evident in the fingers and hand. The tumor measured sixty-six centimetres in circumference.

Operation, January 2, 1900. Ether anaesthesia. The entire left half of the shoulder-girdle with the arm was removed in the usual way. On account of the inaccessibility of the subclavian vessels from the encroachment of the tumor upon the operative field, it was easier to divide the vein before the artery. This was done, though it was doubtless an error in judgment and a procedure which occasioned the loss of considerable blood into the extremity. Nevertheless, after preliminary cocainization of the brachial plexus, the bundle of nerves was severed; the extremity with clavicle and scapula was removed, the dry wound closed without drainage, and no shock resulted from the operation. The patient was up the following day; began rapidly to gain in weight; the wound healed by primary union (Fig. 7). He was discharged on the fourteenth day, and has since been actively engaged in his former occupation of farming. Fig. 8 shows a section of the tumor in illustration of the extensive destruction of the humerus. The tumor proved to be a medullary sarcoma.

However much alike, as in these two cases, individual conditions may seem to be, it is impossible to say that the same physiological response on the part of the central nervous system would follow in each instance a given insult to peripheral sensory nerves. As will be emphasized hereafter, the same afferent impulses may, under certain circumstances, determine reflexly a rise in blood-pressure from augmentation
Fig. 5.—Case II. Tumor and oedematous extremity before operation.
Fig. 6.—Case II. Posterior view.
Fig. 7.—Case II. Ten days after operation.
Fig. 8.—Case II. Photograph of section of very soft, diffuent tumor, receiving large amount of hæmorrhage into it and organizing blood-clot, accounting for rapid growth. Very little new bone formation.
of vasoconstrictor action, which under other indefinable circumstances might determine a fall, from diminution of the same. These two patients, however, presenting as they did such close similarity in clinical condition, and subjected as they were to an operative procedure of such close correspondence, may, for the sake at least of pointing a moral, be considered to have stood upon the same physiological level.

It can be seen by consulting the "ether chart" (Fig. 9) kept during the operation on this second case that at the moment of cocainization and subsequent division of the plexus there was an associated retardation in pulse-rate from 120 to 102 beats per minute. The slight increase in cardiac activity which preceded this division for ten or fifteen minutes doubtless was due to the dragging upon the nerve-trunks brought about by the weight of the hanging extremity and shoulder. Such an acceleration of cardiac rhythm accompanying a reflex pressor effect is the normal response to such a stretching of peripheral mixed nerves. On repeating this operation on animals, I have seen this early pressor effect
followed, after crushing the plexus with forceps and dividing it, by a marked fall in blood-pressure, recovery from which might or might not take place, depending on the previous condition of the animal.

Although an interscapulo-thoracic amputation may be regarded as an operation of considerable magnitude, it should be a comparatively bloodless performance, and the wide experience at this hospital with an operative procedure of possibly greater extent, carried on in a neighboring situation and one which demands a greater amount of time for its performance, namely, the complete Halsted operation for carcinoma of the breast, has shown that a condition of shock rarely supervenes, provided that principles of absolute haemostasis have been carefully observed. In illustration of this and for comparison with the ether charts which accompany the first two cases, a representative chart of the type of those which are plotted during this extensive operation is here reproduced (Fig. 15). In this procedure the chest wall is completely bared of both pectoral muscles; the entire axillary contents are removed, leaving exposed the axillary artery, vein, and brachial plexus; the contents of the supraclavicular triangle furthermore are often removed, laying bare the vessels and brachial plexus a second time in the neck. Although this is one of the most extensive operations of the present day surgery, provided there is no loss of blood, shock need rarely, if ever, be occasioned. This is undoubtedly due not only to the perfect control of haemorrhage, but to the fact that no large or important sensory nerve-trunks are divided or injured. In operative cases, however, in which it becomes necessary to divide large bundles of nerves, precautions other than the avoidance of the loss of blood seem to be demanded.

Dr. George Crile, in his recent admirable monograph ("Problems Relating to Surgical Operations," Philadelphia, 1901, p. 157), has once more laid emphasis upon the physiological blocking effect of cocaine when injected into peripheral nerves, and much of the credit of the considerable employment of such a procedure in the prevention of shock has been the
result of his interesting experimental work. The same principle of "blocking" nerve-trunks has been utilized for a long time as a means of producing anaesthesia over proposed operative fields by thus throwing out of function the sensory nerves radiating from it. I would suggest that this be called "regional anaesthesia" in contradistinction to "local anaesthesia." Thus, operations for hernia, amputations of an extremity and the like, may be painlessly performed. Dr. Crile reports a case of interscapulo-thoracic amputation in which cocainization of the brachial plexus sufficed for the accomplishment of the operation. In this way risks of general narcosis were avoided as well as any likelihood of shock, and the blocking subserved the double function of giving an analgesic field for operation and of preventing central disturbances from inflowing impulses.

Unfortunately, in this particular procedure the skin incision must pass through non-anaesthetized territories supplied by cutaneous nerves of thoracic segments. These areas necessarily must be individually cocainized,—a difficult performance, and one requiring an accurate knowledge of segmental distribution. Similarly, cocainization of the sciatic nerve to produce "regional anaesthesia" for amputation of the leg below the knee does not in itself suffice for a painless operation. In the two instances in which I have so operated, care has been taken to anaesthetize locally, along the line of proposed incision, the territory supplied by the long saphenous nerve. It is worthy of note, also, that this nerve supplies the periosteum over the inner surface of the tibia which must also be cocainized. These two operations were performed for gangrene of the extremity in old people in whom general narcosis seemed to be contraindicated.

Such operations under local or regional anaesthesia are at best more difficult than corresponding ones carried out under general narcosis, and few operators seem able or will take the time to perform them satisfactorily. The blocking of nerves before division during operations under complete anaesthesia, however, is another matter, and is only related,
through the physiological principle involved, to these operative procedures under regional anaesthesia in which the sensory nerves supplying the operative field have been cocainized.  

It will be recognized immediately by operators that the surgical principles here upheld preclude the possibility of employing the time-honored methods of amputating, which, it must be confessed, are more or less a relic of the spectacular days of surgery. Operations of the sort described above are undoubtedly carried out with far greater security by the method of dry, painstaking dissection, which is now employed in most surgical clinics for practically all major amputations. The tourniquet and long amputating-knives are practically relegated to disuse. The peripheral vasodilatation which follows the removal of a tourniquet occasions the loss of blood, and usually necessitates drainage. The use of pins and other appliances for the purpose of skewering the vessels in high amputations only adds difficulties to what otherwise is a comparatively simple procedure of dissection. On the two occasions in which I have amputated at the hip with primary ligation of the external iliac vessel, with careful observance

1 The physiological principle involved in this discussion covers only the blocking effects of cocainization of peripheral sensory neurones for purposes of "regionary anesthesia," or for the avoidance of shock during general narcosis. Cocainization of the spinal cord by a subarachnoid lumbar injection, with blocking, possibly, of a higher order of neurones, is quite another thing. Here a different physiological effect comes into play in consequence of the throwing out of action in the majority of cases of the vasomotor fibres passing from the upper thoracic segments to control the splanchnic system. As a result, there is a flooding of this territory. Shock consequently, in so far as it is an expression of low blood-pressure, is almost without exception produced, not avoided. This I believe to be the real source of danger in "rhachicocainization," and not the toxic effects of the drug itself. In my estimation, it is a performance invariably attended by considerable risk on account of this associated fall in blood-pressure. Unfortunately, the enthusiasm which followed Bier's original proposition swept many an operator along with it, a result which the originator himself deeply regrets. ("Weitere Mitteilungen über Rückenmarksanästhesie." Verhandlungen der deutschen Gesellschaft für Chirurgie, Band I, S. 171, 1901.)
Fig. 10.—Ten days after amputation of thigh by dissecting method, showing configuration of innominate bone covered by little more than skin flap.
of complete hæmostasis during the dissection and with cocainization of the anterior crural and sciatic nerves before their division, there was no indication of even a temporary reflex effect upon the blood-pressure or cardioregulatory centres. No drainage, of course, is required in case such a method is employed. One of these amputations was carried out on a greatly prostrated young man suffering from a recurrent sarcoma of the thigh, an amputation of the leg lower down having been performed a short time before. In this case the amputation was of necessity made very close to the innominate bone, so that practically nothing was left to cover the wound but a flap of skin saved from the gluteal region (Fig. 10).

Should the tourniquet be used in amputations, I believe that its application distal to the site of amputation has more rationale than the usual proximal method of employing it. It may thus be applied as an Esmarch bandage either after the ligation of the main arterial vessel or before beginning the operation, its purpose being to prevent the loss of blood into the extremity. Such a filling up with blood otherwise not only follows the ligation of the chief venous radicle, but also the division of nerves to the member, since their section causes a flushing of the territory from local vasomotor paralysis. This flushing, however, occurs distal to the site of operation not in the stump itself, as when the tourniquet is applied proximally. The carrying of such an Esmarch bandage over the area occupied by a new growth of course should be avoided under any circumstances.

To major amputations for traumatic injuries of the extremities do these principles apply in degree almost greater than in pathological cases. Here a state of shock may already be present, and the attendant ordinarily is advised to wait for some hours, during which time a readjustment of conditions is expected to take place and the severity of shock to diminish. As a matter of fact, the very conditions are present which tend to perpetuate or to increase the already existent degree of shock. Such an increase is brought about by a continuation of afferent sensory impulses. The tourni-
quet itself, which has been applied at the time of the accident, although controlling the loss of blood, constantly adds, from pain, an increment to the shock of the original injury. The dragging of the helpless or mangled limb on the great sensory nerve-trunks, which are rarely severed, gives impulses of pain with every movement of the often restless patient,—impulses which in such a state cause reflexly a further lowering of blood-pressure. Strychnine, intravenous infusion, even though there may have been but slight loss of blood, and delay, are the usual measures advocated for such states. I believe they are, if not actually harmful, certainly not helpful. The real indication is to rid the patient of the centripetal impulses, originating in the crushed member, by cocainization and division of the large nerves, so often exposed in a mangled limb, by ligation of vessels if necessary, and the earliest possible removal of the painful tourniquet. Under proper management, with possible strapping of the abdomen to hold up the blood-pressure, with morphine in small amounts to control restlessness, and with a proper avoidance of those conditions which during the operation would increase shock, I believe that it is no heresy to advocate ether anaesthesia (never chloroform) and early operation for most cases of severe traumatism of the extremities.²

²I am rather inclined to believe that the reason why delay has come to be so universally advocated in severe cases of traumatic shock is because in the course of some hours time itself will pick out those cases which are favorable ones for operation. The border cases and the unfavorable ones grow worse from the start, and finally are abandoned as unfit for interference. Thus the results in case of delay must of necessity from a statistical stand-point be much the better. It is very much the same thing as waiting for the effects of so-called shock to pass away in cases of intestinal perforation. Here, also, delay suffices to select those cases favorable for operation. Those which progressively go down hill and do not rally are finally regarded as unfit for operation. It is the border-line case which early intervention, carried out under proper principles, may succeed in saving. I have recently seen a case of typhoid perforation in collapse improve on the operating-table during a cocaine operation, the patient's arterial tension measuring considerably higher after the closure of the wound than before the operation, no stimulants whatever having been used. Similarly in the border-line cases of trau-
Unfortunately, at the time when these two cases which I have cited were operated upon, observations upon blood-pressure, the estimation of which is much more important than the pulse-rate, could only be guessed at through the medium of a palpating finger on a peripheral artery. Although the importance of an educated touch is by no means to be belittled, it is nevertheless desirable on all important occasions to supplement tactile observation, where possible, by the data obtainable from some instrument of precision. The clinician is not satisfied, as of old, with an estimation of temperature gained by placing the hand on a patient's forehead nor by a guess at the pulse-rate, especially when comparative alterations from moment to moment are of value. That figures giving us accurate data concerning variations in arterial tension are even more desirable needs no comment. This is especially true if we wish to study intelligently the condition of shock in our traumatic and operative cases for the purpose of properly estimating its degree, its alterations, whether increasing or diminishing, the effect produced upon it by various steps of our operative procedures, and the true influence which the usually prescribed therapeutic measures have upon its course.

At the present time, happily, a simple and convenient "blood-pressure" apparatus has been introduced into the clinic, a form adapted from that described by Riva Rocci. By means of this apparatus, alterations in arterial tension may be taken during an operation with the shortest possible interval, and the figures representing millimetres of mercury immediately charted. Thus an operating surgeon may obtain, graphically represented, data concerning the patient's condition in almost exact correspondence with that which the physiologist gains.

matic shock I believe that the prompt removal of conditions tending towards its perpetuation will save cases swaying in the balance which otherwise must go to the ground. Should a general anaesthetic be required, ether should be selected. Chloroform, owing to the fall in blood-pressure which accompanies its administration even in normal states, is of course absolutely contraindicated.
during an experiment by having an animal's carotid in connection with a mercury manometer whose level is constantly being recorded on a revolving drum.

By means of information obtained by this apparatus in the operating-room during the past six months, on several occasions in critical cases, have we been able to anticipate and to avoid profound states of shock and collapse, and indeed, in some instances, I feel confident that it has been instrumental in saving lives.

A study of these cases in which comparative curves of pulse-rate and blood-pressure have been kept during operative procedures is being made by Dr. Briggs, who will report upon them later, with especial reference to the therapy of shock. Unfortunately, for purposes of comparison, no interscapulo-thoracic amputations of the sort described above have been performed since the inauguration of these blood-pressure records.

A few examples, however, from Dr. Briggs's collection will be reproduced here in illustration of the way in which the physiological effects of operative procedures on the pulse and blood-pressure may be plotted in some conformity with the more familiar charts made during laboratory experimentation. Of these illustrative charts three have been selected from the groups comprising the abdominal and cerebral cases. One or two reproductions of charts showing the blood-pressure responses in peripheral operations, with which group of cases this communication more particularly deals, are also given.

**Chart I.—(Fig. II.) Abdominal Group. Visceral exposure for tuberculous peritonitis.** Shows the depressor effect brought about during an intra-abdominal exploration by exposure and handling of the viscera. This fall in blood-pressure, which might have become perpetuated as a condition of shock, was rapidly recovered from, after a hurried closure of the wound, by the application of a tight abdominal binder, which gave support to the relaxed splanchnic vessels. In such cases the vascular relaxation is probably due to direct insult to the splanchnic...
end of the neurovascular mechanism and not to a reflex action such as peripheral injury occasions.

Note (1) Condition before beginning anaesthetic; rapid pulse, 150; low blood-pressure, 110. Note (2) Effects of evisceration. Note (3) Beginning of shock and fall in blood-pressure; cf. no especial change in pulse. Note (4) Result of application of tight abdominal binder.

Chart II.—(Fig. 12.) Cerebral Group. Gasserian ganglion operation. The chart illustrates the normal response in intra-
cranial cases when the brain is subjected to compression. This response is the exact counterpart of the experimental one here-tofore described as accompanying cerebral compression. (Johns Hopkins Bulletin, 1901, Vol. xii, p. 290.) The compression anaemia apparently stimulates directly the vasomotor centre, which in turn raises the blood-pressure by constriction of the splanchnic territory, in degree sufficient to overcome the anaemia. The pulse is slowly affected meanwhile by a similar stimulation of the vagus centre in the medulla. The fall in blood-pressure associated with clamping of the ganglion and with its extraction shows that this might be a dangerous procedure if blood-pressure were already low. In critical cases of ganglion extirpation, doubtless the structure should be cocainized before handling, as in the case of any sensory nerve.3

CHART III.—(Fig. 13.) Cerebral Group. Ganglion operation. Shows a rapidly fatal case of shock in an intracranial operation with paralysis of the vasomotor centre and consequent fall in blood-pressure. Here the normal response with rise in blood-pressure and slowing of pulse did not take place during the compression of the brain. Possibly this was due to extensive pathological alterations present in the blood-vessel walls. The rapid fall in blood-pressure even before there was any outspoken change in pulse-rate should have been an indication to immediately abandon the operation. Owing to the low blood-pressure the ganglion was removed with a minimum of bleeding in this case. The usual therapeutic measures to restore arterial tension proved futile.

3It is important to note that this rise in blood-pressure is the occasion of the troublesome bleeding so often encountered in ganglion operations. It was my practice formerly to administer chloroform in these and in all cases of cranial operation as has been advocated by Mr. Horsley. Our blood-pressure observations have sufficed to show its great danger. In the majority of instances there is a fall in blood-pressure associated with the administration of chloroform which accounts for the lessening of haemorrhage under this form of anaesthesia. Any further depression of blood-pressure from the operative procedure itself could easily and rapidly bring about a fatal condition of shock. Elevation of the head may oftentimes control the oozing in these cases. This posture is accompanied, however, with risk, which should be estimated and controlled by frequent observations on blood-pressure. The principle of cocainization of the ganglion before its manipulation and extraction has been carried out in my last cases.
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Fig. 12.—Chart II. Pulse-rate and blood-pressure curves taken during an operation for extirpation of the Gasserian ganglion; ether anaesthesia. Upper line represents blood-pressure; lower, pulse.

**Note (1)** Great excursions of blood-pressure during the paroxysms of the "neuralgia quinti major," unassociated with any change in pulse-rate. **Note (2)** The rise in blood-pressure from its "ether level" at 205 millimetres of Hg. to 230 millimetres during the elevation of the temporal lobe and associated compression of the brain.

**Note (3)** The corresponding retardation of pulse-rate from sixty-five to thirty beats per minute due to vagus stimulation. **Note (4)** The return of pulse-rate and blood-pressure to normal levels after the release of the brain from compression.
Chart IV.—(Fig. 14.) *Peripheral Group. Stretching sciatic nerve.* Shows the physiological response as a rise in blood-pressure consequent upon the handling of an important mixed peripheral nerve-trunk in a normal individual. Here an accelerator and pressor response are combined. In other instances there may be no increase in pulse-rate.

Chart V.—(Fig. 15.) *Peripheral Group. Complete breast operation.* Shows the absence of any appreciable effect on pulse-rate or blood-pressure other than the usual rise during the primary stage of ether anaesthesia. In such an operation there is no loss of blood, and no important sensory nerve-trunks are divided or handled. (Contrast pulse-rate with Figs. 4 and 9.)

In these three groups of cases—*abdominal, cerebral,* and *peripheral*—the blood-pressure alterations are occasioned, generally speaking, as follows: In the first group they are brought about largely by direct peripheral action on the splanchnic vascular system; in the second, by direct action on the vasomotor centre in the medulla; in the last, by reflex effect of peripheral sensory impulses acting through the medullary centres upon the vascular fields. Thus the reflex sensory vasomotor arc, so to speak, may be acted upon through any one of its component parts.

Physiological Notes.

An attempt has been made in the introductory paragraphs of this communication to summarize briefly the present conception of the term "traumatic shock," its method of production under ordinary circumstances, and the means by which in certain cases it may be avoided.

The experimental observations by Fischer, Goltz, Seabrook, Crile, and others have shown that the weakened or paralyzed condition of the vasomotor centre in the medulla, brought about reflexly by the mechanical injury to peripheral sensory neurones, plays the chief rôle in inaugurating a state of shock. The loss of control over the general arterial tone which results from this weakening of the centre results in a determination of blood in certain vascular fields. Of these
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Fig. 13.—Chart III. Pulse-rate and blood-pressure curves taken during a fatal case of ganglion extirpation; ether anesthesia. Note (1) The comparatively high blood-pressure and rapid pulse during the preparation of the patient and the early stage of anesthesia.

Note (2) The fall in pulse-rate to 100, which should probably have been "ether level. Note (3) The drop in blood-pressure and acceleration of pulse from slight loss of blood during opening of skull. Note (4) The immediate fall in blood-pressure and rise in pulse during elevation of temporal lobe, the opposite of the normal reaction.
the largest and most important is the great splanchnic territory, the flooding of which side-tracks, as it were, such an amount of blood that there results an anæmia of the brain and lungs, a weakened cardiac action, or the "empty pump" principle of Goltz, and a consequent great fall in blood-pressure.

As has been stated in the brief discussion of the two cases which, early in this paper, have been cited at some length, there are certain predisposing factors which are influential in favoring this reflex loss of vasomotor tone. It is, in the first place, a well recognized physiological fact that stimulation, of one sort or another, of a peripheral sensory nerve of an animal in normal condition occasions a rise of blood-pressure or so-called "pressor" response due to a reflex constriction of the smaller arteries of certain vascular territories. Such a pressor response is frequently seen in clinical cases, and we have had the opportunity of plotting many such curves in correspondence with the experimental observations such as Dr. Crile has carried out. A patient in an attack of biliary colic, for example, will have a rise of blood-pressure from its normal level, corresponding possibly to 120 millimetres of mercury, to a level of 200 millimetres or over. A corresponding response occurs, as I have many times observed it experimentally, when there is a forcible injection of fluid into, and so as to distend, the biliary passage of an animal under anaesthesia. Similarly an attack of pain, such as is experienced in a paroxysm of trigeminal neuralgia, will raise the blood-pressure to inordinate heights. The increase in arterial tension under these circumstances may be unassociated with alteration in pulse-rate. Certain simple operative procedures as well, such as dilating the sphincter or stretching the sciatic nerve, as has been already instanced (Fig. 14), will call forth a pressor response.4

4 When one sees recorded the pressor effects, which often occur in operative cases under anaesthesia, with a rise of arterial tension to double or more its normal level, it becomes a matter of astonishment that rupture of blood-vessels does not more often occur, especially in the feebly supported vessels of the central nervous system, and in patients who show evidence of alteration in the arterial walls. It is not improbable that the
COCAINIZATION OF NERVE-TRUNKS.

FIG. 14.—Chart IV. Pulse-rate and blood-pressure curves taken during the operation of stretching the sciatic nerve for sciatic neuritis; ether anesthesia. Upper line, blood-pressure; lower line, pulse-rate.

Note (1) Rise during primary stage of anaesthesia and "ether level" of pulse, 95 to 100, and blood-pressure, 170 to 175. Note (2) The pressor effect (to 238 millimetres of Hg.) and accelerator response, 140 to 145, due to stretching the nerve for a period of ten minutes. Note (3) The return to "ether level" on releasing the nerve.
From the experimental side many observations have been made to determine the conditions which favor the calling out of the depressor rather than the normal pressor response to a given stimulus. The loss of blood or a coexistent primary anæmia, the exhaustion of an extensive operation or of prolonged anæsthetization, the repeated calling out of pressor responses from painful stimuli with consequent fatigue of the vasoconstrictor mechanism, and a great variety of other conditions might be mentioned in illustration; conditions which have long been recognized as prejudicial to the safe-conduct of certain operations.

Comparatively recent observations, chiefly those coming from Howell's laboratory, have been largely instrumental in establishing the view that in each bundle of mixed peripheral nerves there exist definite centripetal ("pressor") fibres, stimulation of which calls forth by reflex action a vasoconstrictor response, and others equally definite, which on the other hand produce when stimulated a depressor effect from reflex vasodilatation with consequent fall in blood-pressure. In the neck of the rabbit, as is well known from the classical experiments made in Ludwig's laboratory, afferent fibres subserving in a certain measures these different functions run apart and may be individually stimulated. One of these nerves has become known in consequence as "the depressor nerve," and must not be confused with the depressor fibres supposed to be present in other mixed nerves. Under ordinary circumstances, however, in the neck as well as in the nerves of the extremities, both pressor and depressor fibres run together in the same trunk and due to the fact that the former under normal conditions respond more readily and effectually to most forms of stimulation, a rise in blood-pressure is usually produced. Of these two sets of fibres, those having a pressor action seem to be the first to suffer from injury or over-stimulation, and when,

cases of sudden death, which on rare occasions have followed such simple procedures as stretching the sphincter ani for fistula, may be attributable to such an occurrence. Cases furthermore of anæsthesia apoplexy are by no means rare.
in consequence, they have become exhausted, the same irritation to the mixed nerve which previously would have called forth a vasoconstrictor action then elicits a fall in blood-pressure from stimulation of the still active depressor fibres.

**Fig. 15.—Chart V.** Pulse-rate and blood-pressure curves taken during the Halsted operation for carcinoma of the breast. Heavy line, blood-pressure; light line, pulse.

*Note (1)* Slight deviation from normal levels except during primary stage of anaesthetization.
Howell, for instance, has shown, when such a mixed nerve has been subjected to the effects of cold applied locally in its course, that it no longer calls forth pressor responses to peripheral stimulation, but that depressor effects may still be evoked. He and his pupils (Howell, Budgett, and Leonard, Journal of Physiology, 1894, Vol. xvi, p. 298) demonstrated, furthermore, in illustration of the fact that these two sets of fibres are functional entities, that after division of a peripheral mixed nerve those fibres calling forth reflexly a vasodilator response regenerate more rapidly than do those producing on stimulation a vasoconstrictor action.

Hunt subsequently, working in the same laboratory, has further elaborated these studies, and has brought out the fact that in a fresh animal the depressor fibres may apparently be stimulated in excess of those subserving a pressor function by the action of weak electric currents. Strong currents, on the other hand, would produce the usual rise in blood-pressure from vasoconstrictor action. He has shown, also, in agreement with Kleen, that the mechanical bruising of muscles is apt to lead to a depressor effect. In confirmation of the observations of Latschenberger and Deahna (Latschenberger and Deahna, "Beiträge zur Lehre von der refectorischen Erregung der Gefässmuskeln," Pflüger's Archiv, 1876, Band xii, p. 157) and others, Hunt's experiments demonstrate that on the repetition of a particular stimulus or injury, each of which, singly, would cause a rise in blood-pressure, a point is reached at which a pressor effect no longer occurs, but at which the same stimulus calls out a depressor response with fall in blood-pressure.

It must be confessed that there is no present uniformity of opinion among physiologists as to the nature of the depressor response. Conclusive proof even of the presence of depressor fibres, in the sense of Latschenberger and Deahna, is yet forthcoming. It is believed by some investigators that

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8 The fall of blood-pressure resulting from the stimulation of afferent nerves. Journal of Physiology, 1895, Vol. xviii, p. 381.
the fall in blood-pressure is due to alterations in the centre itself rather than the result of a reflex dilator action of specific afferent fibres. Whatever the mechanism of the response may be, however, the fact of its occurrence is sufficient for practical requirements; and, although the matter may have been presented here in an amateurish fashion, it needs but a glance to appreciate the importance to the operating surgeon of these laboratory observations. Their relation also to the clinical notes, which have been given in the first part of this paper, demands no written interpretation.

The facts remain that injuries of most diverse nature to peripheral nerves may, especially in some physical states, produce reflexly a fall in blood-pressure; that this loss of vascular tone, when it endures, is the most characteristic feature of shock, the symptom-complex of which is largely due to this one factor; that local anaesthetization of a nerve-trunk will block the transmission of the centripetal impulses which otherwise might bring about this reflex loss of vascular tone.