The CENTRAL AFRICAN JOURNAL OF MEDICINE

Vol. 4. No. 7. JULY, 1958.

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PUBLISHED MONTHLY, ANNUAL SUBSCRIPTION £2 2s. 0d.
Registered at the General Post Office as a Newspaper.

The Neurosurgical Control of Pain

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Pain is a warning of danger and *ipso facto* performs one of the primary functions of the nervous system. For this reason destruction of the recording mechanism is to be viewed with concern and a very careful assessment must be made of the balance sheet weighing up the benefits to be obtained from control of the pain against other disadvantages which may result. For example, one would hesitate to cut the posterior root of L. 5 because the resulting anaesthesia would almost certainly allow some trophic ulceration of the foot, while a much less serious view would be taken of the posterior roots of the intercostal nerves, since the resulting anaesthesia carries with it no such risk.

On the other hand, pain can be an enemy as well as a friend. Having once made the patient aware of its danger, the pain may continue to respond strongly to the noxious stimulus, and it is this continuous pain that eats away at the patient's psychological and emotional reserves, prevents sleep and takes a stranglehold of his every moment and movement. It is in these cases of continuous unremitting pain that relief is most important; and when simple measures fail, surgical means may provide the patient with a relief that will enable him to remain comfortable without recourse to drugs.

Pain consists of two components. In the first place there is the organic one of reception of the pain and its onward transmission to the brain. Section of the appropriate pain pathway at any point along its course to the brain will result in loss of pain sensation in the appropriate area.

On the other hand, there is the psychological element of appreciation of the pain and of its significance. This latter factor is well illustrated in the classical case of disseminated sclerosis, in which euphoria and a total lack of appreciation of the implications of the disabilities allow the patient to remain relatively happy, even to the end. In the same way, lack of appreciation of the import of pain, while not lessening the pain, lessens the patient's reaction to it and his suffering in consequence.

Let us turn now for a moment to a review of the paths by which pain impulses pass to the brain. If a nerve ending in the skin is irritated by a noxious stimulus, some small fibres which are believed to transmit painful sensations become activated (Illustration I). The impulse passes centrally along the nerve to the posterior root, through which it enters the spinal cord. Here it makes an early synapse in Lissauer's tract and a neurone of the second order then passes across the cord to the other side, where it enters the lateral spinothalamic tract and turns centrally towards the brain. This decussation to the other side takes place at almost the same level as the nerve fibre enters the cord and there is very little segmental overlap.

The fibres pass centrally in the ventrolateral portion of the spinal cord and then, as the decussation of the pyramids is reached, the fibres are pushed laterally so that in the lower medulla they lie right at the side of the cord. Here they are called the spinal lemniscus and are joined by fibres from the descending tract of the fifth nerve, known as the trigeminal lemniscus, from the other side. As the pyramidal fibres come to lie ventrally in the pons, the pain fibres are pushed dorsally and come to lie just lateral to the medial lemniscus. From here they course on to reach the posterior ventrolateral nucleus of the thalamus. At this point tertiary fibres relay the impulses to the postcentral gyrus or sensory cortex. The further route of such pain impulses is unknown, but presumably relays back to the thalamus, as well as to the frontal lobe, must exist. Visceral fibres accompany the sympathetic fibres and enter the dorsal or cranial nerve roots in the same way as the peripheral fibres. Although there are sensory end organs specifically related to pain, normal sensations may produce pain under particular circumstances. For example, a touch may cause pain in a patient with trigeminal neuralgia. In some way the circuits of touch and pain must thus overlap so that one facilitates the other and thereby lowers the pain threshold.

Operations directed towards the relief of intractable pain therefore can be of three types:

(1) Direct section of the pain fibres.

(2) Destruction of the patient's appreciation of the significance of pain.

(3) Destruction of facilitatory mechanisms.

I.—Operations for the Destruction of the Pain Transmission Fibres

(a) *Peripheral Nerve Section.*

A total section of a peripheral nerve is not very satisfactory, since it involves not only destruction of pain fibres, but also of other sensations as well as motor fibres. It can, however, be used in the thoraco-lumbar region where a nerve is already involved in scar tissue and a neuroma has formed and where the loss of the motor component is relatively unimportant; it

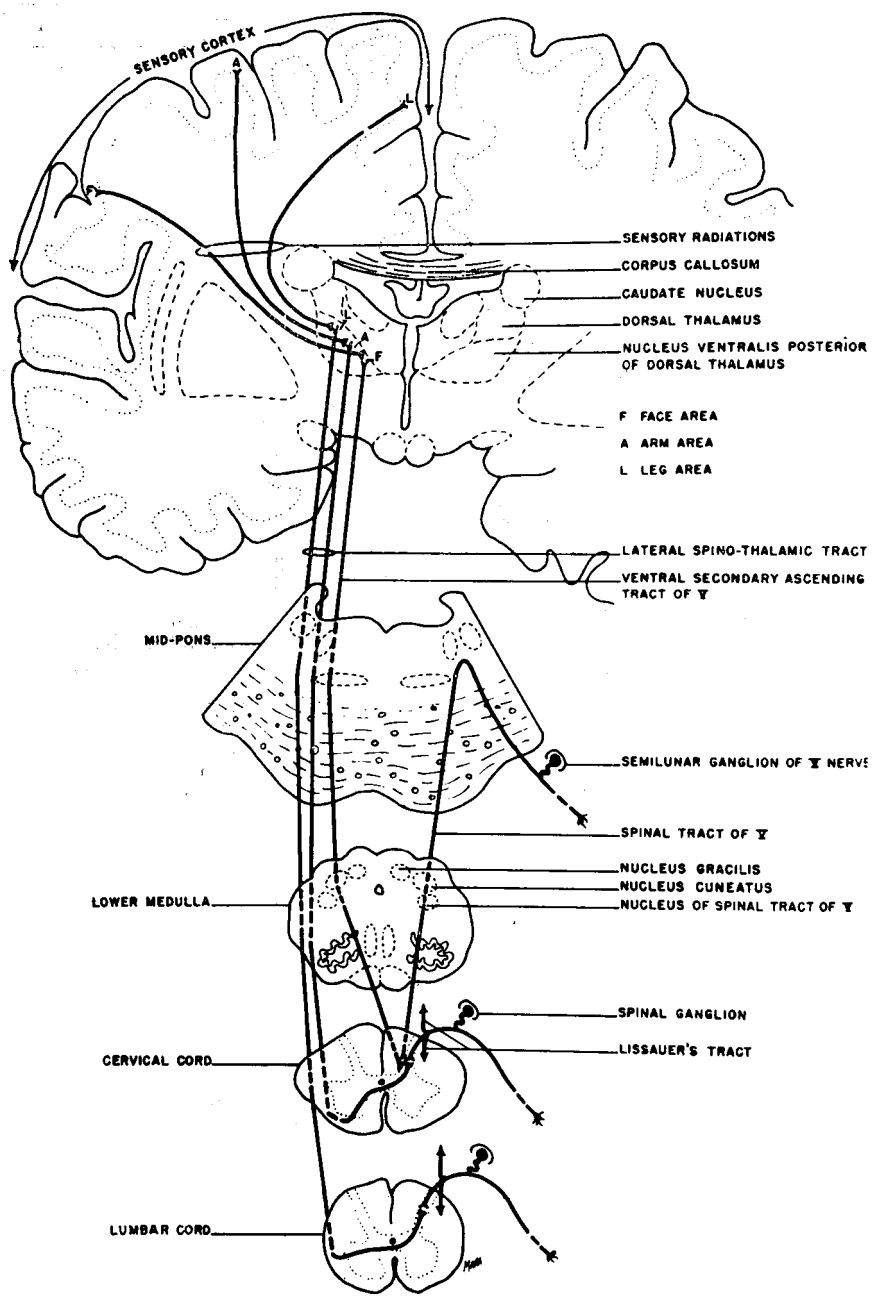

Illustration I.—A diagram illustrating the projection of impulses set up by painful (or temperature) stimuli on the surface of the face and the body to the dorsal thalamus and to sensory cortex. The projection pattern is shown on the thalamus and the cortex.

cannot be used in the limbs, except for the sensory branches of mixed peripheral nerves, as, for example, a digital nerve neuroma in the hand, or in Morton's metatarsalgia.

(b) *Posterior Root Section.*

Posterior root section has a great advantage over the former procedure because it enables the sensory fibres to be sectioned without involvement of the motor. On the other hand, of course, all the fibres of touch are thereby destroyed and an area of anaesthesia results. This is of no consequence in the trunk, but cannot be used in dermatones supplying the hands or feet.

The posterior root may be sectioned surgically or by the use of alcohol or phenol or silver nitrate.

Maher (1957) has written about the use of phenol and silver nitrate. He dissolves a small quantity of phenol in glycerine or myodil and makes the injection into the epidural, subdural and arachnoidal layers, the patient lying on the appropriate side with the head slightly elevated so that the heavier material will flow caudally. He reports this method as being very satisfactory. Of 106 patients so treated, 69 were relieved (65 per cent.). I have used alcohol in the reverse way—that is to say, the patient lies on his side and the alcohol flows upwards in the subarachnoid space to reach the nerve root. The motor fibres are apparently unaffected.

SELECTIVE OPERATIONS ON PAIN FIBRES

Once the pain fibres enter the spinal cord it becomes possible to make a selective section of these, because there is then a sorting-out of fibres into their different groups on a functional basis. Thus the pain fibres come to lie, as we have seen, in the ventrolateral quadrant of the spinal cord. A chordotomy or lateral spinothalmic tractotomy is the operation of cutting these pain fibres within the spinal cord, and it is generally performed at one of two levels, either in the high thoracic or cervical regions. When pain involves the lower limbs and the abdominal region up to as far as, let us say, T. 7 and 8, it is possible to relieve this pain by making a cut in the thoracic region round about T. 3 or 4. Because the pain fibres cross the mid line from the other side, incoming fibres from higher levels tend to lie more medially in the ascending tracts. Therefore, if a section is

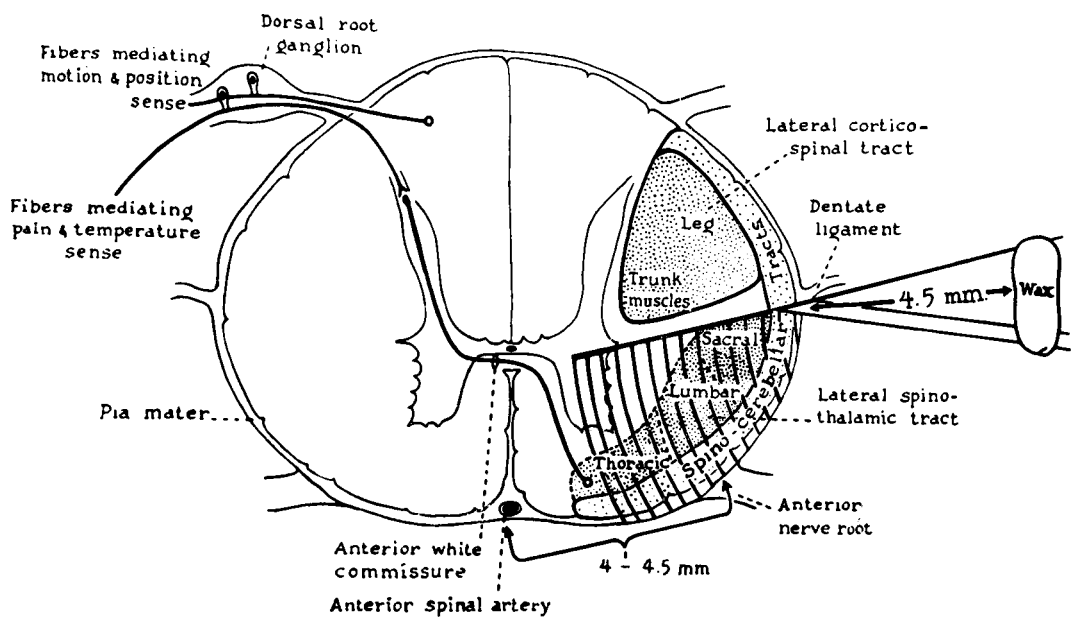

Illustration II.—Upper dorsal anterolateral cordotomy.

B (*Lower*). Schematic drawing of anterolateral cordotomy at T2 cord segment. The anatomical relationships are believed to be correct. (From Kahn and Rand: *J. Neurosurg.*, 9: 616, 1952. Courtesy, Charles C. Thomas, Publisher.)

being made at any given level, deeper cuts have to be made to bring the sensory level as near to the section level as possible. Under general or local anaesthesia, the laminae are removed from one or two vertebrae or, if preferred, a hemilaminectomy is performed. The dura is then incised and the arachnoid likewise. It is usually necessary to cut one or two of the posterior roots in the immediate neighbourhood, because this allows greater mobility of the spinal cord. The dentate ligament is freed from the duramater and is grasped firmly in a small forceps and is used to rotate the cord so that the anterior surface may be seen (Illustration II). An incision is made directly into the cord just below the dentate ligament about 4 mm. in depth in the thoracic region for good levels. The knife blade is swung downwards and emerges from the cord just medially to the point of exit of the motor roots. There is a theoretical danger of cutting the anterior spinal artery, as this cannot always be visualised, and there is always the possibility that some weakness may result from a cut made too far dorsally, which involves the pyramidal tracts.

If the operation is done bilaterally, as it may occasionally have to be, it is liable in a certain percentage of cases to be followed by incontinence of urine and impotence in the male, presumably due to bilateral involvement of the sympathetic pathways. Radicular pain usually occurs for about one month in the operation site, but this almost invariably disappears without further trouble.

Mrs. H., of Umtali, was referred because of severe radicular pain. She had developed an herniated intervertebral disc following a twist, and after a period of conservative treatment had come to surgery, a large disc being removed from the L. 5 S. 1 space on the right side. She suffered the misfortune of a wound infection, which continued to flare up and discharge intermittently for almost a year following her operation. This finally healed, but fibrosis appeared round the nerve root causing severe pain in the back and leg so that she could scarcely move without making it worse. Thoracic chordotomy was performed at T. 4, a 4 mm. cut being made on the left side. This produced anaesthesia to pain at T. 8/9 and she is now completely mobile. She is now able to do her housework and drive about in a car without difficulty. It is unfortunate, however, that she has again suffered a slight wound infection, probably due to a reaction to catgut, and has still some radicular pain at the site of the operation. However, this is steadily subsiding and she is making excellent progress.

Cervical chordotomy is probably no more dangerous than thoracic chordotomy, except that the penalties for failure are greater, since the arms may be involved as well as the legs. However, there is more space in the spinal canal at this level and the cord itself is larger and more easily manipulated, although one is perhaps slightly more concerned owing to the proximity of the medulla oblongata. Nevertheless, a good deep cut of 5 mm. carried medially and then downwards can produce good levels of analgesia in the arm.

Mr. L.M. was referred by the Medical Service of the 4th Division of Bellevue Hospital, New York City, in September, 1954. He was suffering from diffuse carcinomatosis with pain in the left shoulder and arm, particularly down the medial aspect. Under general anaesthesia a right cervical chordotomy was performed and a 5 mm. cut made in the spinal cord between the levels C. 1 and C. 2. This produced a satisfactory analgesia from the level C. 6 downwards on the left side and the patient was free of pain. Some two months later he was again seen because he had now developed radicular pain in the right side at T. 5 and 6. On two separate occasions thoracic puncture was done at these levels and one c.c. of absolute alcohol introduced into the subarachnoid space. Temporary relief only was obtained for about two weeks. The pain subsequently progressed into his right arm, and chordotomy on the other side was performed, this time the section being made between C. 2 and C. 3. This again resulted in a loss of pain, but he developed a slight weakness of the arm, and for a short while there was some difficulty with bladder control. This latter, however, cleared up. He survived only a further three months, but at least his survival was made relatively comfortable by this procedure.

We have now entered the skull, and at this point, as we follow the pain fibres upwards, we find that they are joined by a portion of the V nerve (Illustration I), namely, the descending or spinal tract of the Vth, so let us turn our attention for one moment to that most distressing complaint, trigeminal neuralgia.

Trigeminal neuralgia is, generally speaking, a disease of older people and it consists of lightning pains in one or more of the divisions of the trigeminal nerve. There are usually one or more trigger points on the face from which these painful impulses seem to originate, and thus would seem to be an example of facilitation, since even a light touch may be adequate to stimulate pain. These pains may be so severe as to render the patient suicidal. Sometimes the pain is restricted to small areas such as the supra or infra orbital nerves, or to the mental nerve, and these are easily accessible and can be injected with alcohol with relief. Otherwise one or more of the divisions may be involved. Fortunately it is rare for the ophthalmic division to be involved alone. Most cases consist of the maxillary division, the mandibular division or these two combined. Under these circumstances it may be possible to inject the nerve and ganglion with alcohol through the foramen ovale, and if this is carefully done the third division

can be completely anaesthetised, the second partly and the first can be allowed to escape. If the injection is done more superficially at the foramen ovale, the third division alone can be completely anaesthetised.

Mr. W. v. O. was referred by Dr. Martin, of Rusape. Some ten years ago the patient had suffered an injury to the left side of his face. He was hit on the head by a heavy object and a small scar and tender spot resulted over the zygoma. For the past two years he had been suffering from repeated attacks of pain which seemed very typical of trigeminal neuralgia, and there were two trigger points, one in the left zygoma and one on the lower jaw. The patient had been treated with numerous drugs without effect and was referred for alcohol injection. In December, 1956, on three occasions alcohol was injected into the area around the mandibular nerve at its point of emergence from the foramen ovale, but on no occasion was a direct perforation of the nerve obtained.

Nonetheless an area of anaesthesia was produced over the left lower face and jaw up into the temporal region. The pain remained absent for five months, when it returned as severely as before, but the trigger point seemed mainly located over the left zygoma. Under local anaesthesia, Dr. Martin sectioned the temporal branch of the mandibular nerve with the production of anaesthesia over the left temple and relief from pain in that region. Pain, however, persisted in the left lower jaw. The mandibular nerve was again injected at its point of emergence from the foramen ovale about one week following the resection of the nerve. Again a good area of anaesthesia was obtained over the left lower face and jaw, and the patient is again pain-free. It is to be hoped that the anaesthesia will hold for a longer period on this second occasion.

If, for some reason, injection does not produce the desired relief from pain, the nerve can be cut surgically through the temporal fossa by exposing the ganglion, and thus the fibres of the ophthalmic division, being directly visualised, can be allowed to escape and the eye is thus protected. Paraesthesias occur after this in a small percentage of cases. Recently Taarnhoj (1952) has suggested that section of the nerve is not necessary, but that decompression of the ganglion, by removing its dural layers, will be adequate. The rationale of this operation is that compression of the ganglion by the surrounding fibrous dura mater causes pain by constricting the nerve and therefore decompression of the ganglion will relieve it.

Mrs. E. S. was seen on the Neurosurgical Service of the Fourth Division of the Bellevue Hospital on the 1st July, 1954. She complained of severe pains on the right of her face, involving all three divisions of the trigeminal nerve. It was a typical "tic dolorueux" and all forms of conservative therapy had been tried without success. On the 12th July, 1954, the gasserian ganglion was decompressed by an intradural and extradural subtemporal approach, Meckel's cave being incised throughout its length and the superior petrosal sinus being divided. After the operation there was numbness for approximately one month in all three divisions, presumably owing to trauma to the nerve at the time of operation. Subsequently sensation became normal and there was no recurrence of pain. When seen 11 months later, she was still free of pain. Several series have been reported to evaluate this procedure, but so far insufficient numbers of cases have been done to make a true assessment.

Love (1955) had done 29 cases, and in only two was section of the nerve necessary later.

Sometimes section of the gasserian ganglion is insufficient to control pain which presumably arises above the ganglion. Under these circumstances, section of the posterior root may be made through the posterior fossa, the nerve being sectioned as it enters the pons—the motor root being spared. This operation was popular with the late Walter Dandy, after whom it is named. Some authors maintain that if only three-quarters or two-thirds of the fibres entering the pons are sectioned instead of the entire root, pain is abolished while sensation remains sufficiently intact for the cornea to escape damage.

As the sensory fibres of the Vth nerve enter the pons, the fibres conveying touch and proprioception pass to the main nucleus of the Vth nerve, while those conveying pain turn caudally and run down through the fourth ventricle to the upper part of the spinal cord, forming the spinal tract of the Vth. There is thus an anatomical separation of pain from touch and proprioception in this nerve.

Trigeminal tractotomy was introduced by Sjoquist (1938) in 1937 in an effort to avoid the anaesthesia of the cornea, which followed section of the sensory root. At first he made his section into the medulla just below the vagus nerve. However, this incision tended to produce ataxia, and subsequent authors have tended to cut lower down in the medulla. Raney (1950) demonstrated that total analgesia could be produced by making the section into the medulla just above the first cervical nerve root. McKenzie (1952) has performed the operation in 41 cases by making the incision 5 mm. below the obex. Analgesia remains complete in 25 sides and incomplete in 18. In one case there was a severe return of pain which necessitated a section of the sensory root. McKenzie estimated that he would offer a patient a 75 per cent. chance of complete relief from pain with this operation. Kahn (1955) performs the operation between 2 and 5 mm. above the first cervical nerve root and makes a 5½ mm. cut just at the point that the fibres of the accessory nerve emerge.

Medullary tractotomy would therefore appear to have a very good place in the surgery for the

relief of trigeminal neuralgia and its potentialities have probably not been fully explored by neurosurgeons as yet. Needless to say, if the pain can be relieved by an operation away from the medulla, most prefer to do so. Recently the operation of mesencephalic tractotomy has been introduced with section of the pain fibres in the mid-brain. The potentialities of this operation have not been fully explored, but some authors report the development of severe thalamic pain subsequently, for which there is, as yet, no treatment.

The next point at which the afferent pain fibres could possibly be attacked are in the nuclei of the thalamus. The thalamus has not been explored from the stereotaxic point of view as yet, though clearly it will not be long before it comes under attack. It should not be difficult, using modern stereotaxic techniques, to place a needle into the appropriate nucleus of the thalamus and cauterise this area, thereby rendering the opposite half of the body anaesthetic.

Resection of the sensory cortex has been practised on occasions. This has a certain disadvantage, partly in relation to the close proximity of the motor strip and also because it involves other moieties of sensation. It has been used, however, in some of the very intractable causalgias and phantom limb pains with success.

We have now seen how it is possible to attack the afferent pain fibres at all levels, from the periphery to the cerebral cortex, and have seen some of the conditions for which such operations may provide relief.

Let us now consider some procedures related to the destruction of the patient's appreciation of the significance of pain. Meyer and Beck (1945) found that a unilateral lobotomy occasionally resulted in considerable clinal effect in abolishing anxiety, but whereas this was often slight and transient, it has also been found that the effects of chronic pain may be greatly alleviated by unilateral leucotomy, especially when the pain is coupled with anxiety, fear and depression. The patient is perfectly prepared to acknowledge that pain is still present, but may no longer complain of it spontaneously or appear to be particularly upset by it. It seems most likely that this is due to relief from anxiety. Various authors have examined the brains of patients submitted to such procedures, and it has been found that a section of the ventromedial quadrant is the most efficacious in alleviating this anxiety, and it would seem that localised cuts in this region are the most important so that a total lobotomy need not be performed. Apart from this freedom from anxiety, personality changes appear to be minimal. On the other hand, of course, it must be remembered that this is an operation which tends to change the personality, though it be only slightly, and therefore must at all times be performed as a last resort.

Lexel (personal communication) has been performing lobotomy, using the stereotaxic instrument of his own design, both for chronic anxiety as well as for painful conditions. He reports success with this instrument, the advantage of which of course is that the cerebral cortex is not disturbed as is necessary in a standard lobotomy, and strictly localised lesions can be placed. At all times, however, in these procedures we are up against the possibility of getting a more severe change than is wished for, and for this reason their scope is strictly limited. In some centres, particularly in France, the operation of unilateral lobotomy has been performed under local anaesthesia. A small electrode is passed into the ventromedial quadrant and small areas of brain are cauterised. This procedure is persisted with until the patient's reaction to pain is considered sufficiently improved, and at the same time, should undesirable symptoms make their appearance, the procedure can be stopped before irrevocable damage has been done.

We will now turn to the final group of operations, namely, those designed to destroy the facilitatory mechanisms. Here, for a moment, I would like to branch off on to the subject of phantom limb pain, which is a fascinating one and which formed a tremendous problem in the years immediately following the war. A phantom limb is felt by most amputees at some time or other, but is not usually unpleasant. On the other hand, a phantom limb pain occurring in an amputation stump is usually of a burning, twisting and disagreeable nature, in which not only may pain be experienced, but the phantom limb may be felt twisted into various unpleasant positions, often grossly unnatural. Five per cent. of amputees suffer from it at some time. The mechanism in many of these cases is as follows:—

The healthy limb is removed by amputation and the viable nerve endeavours to grow down to join the other end and re-establish continuity. There is, however, no other end for it to join to, and in consequence a fibrotic reaction takes place by a kind of end bulb forming over the free end of the nerve, consisting of axons and

fibrous tissue. This neuroma is excruciatingly tender to pressure and is probably responsible for these phantom limb pains in most cases. Removal of the neuroma is not always attended with success, since a new one may form almost immediately. It is a fairly common practice to attempt to bury the nerve-ending in muscle in the hope that it will be protected from the effects of trauma and pain will not result. This is not always uniformly successful. A great many operations have therefore been devised for this condition, perhaps the most successful being cervical chordototomy with a deep cut when the amputation stump is in the upper limb. On the other hand, this does not always appear to work, despite the development of an adequate level, and no explanation for this is forthcoming. Cervical sympathectomy has therefore been performed for some of these cases and occasionally this is attended by success. This would seem to be an example of facilitation rather than the development of alternative passages for the transmission of pain. As previously mentioned, resection of the sensory cortex has been performed in these cases, and where the limb is amputated high up this may not present much disability, or at least not as much disability as it would were the patient's hand intact. It occurs to me that I have never seen a patient who has suffered amputation for gangrene due to defective blood supply who has suffered from a phantom limb pain. It would seem likely that in these cases growth of the nerve ending into the peripheral tissue is inhibited by a lack of blood supply from the defective artery. It would seem, therefore, that if it were possible for us to completely denude a large section of the peripheral nerve of its blood supply, regeneration might not occur and this neuroma formation and phantom limb pain might be avoided.

An interesting and occasionally extremely effective treatment for phantom limb pain and the causalgias connected with it is percussion. The patient gets a small, light hammer, and with this and an applicator taps the neuroma lightly for 10 to 15 minutes several times per day. In some centres patients are recommended to bang their stumps against the wall. This seems not only to deaden the neuroma for a short while, but after the initial phase of acute pain is over the neuroma appears to become deadened for increasingly long periods. Of five cases treated by me in this fashion, one has obtained lasting relief two years after the commencement of the treatment; one obtained relief for approximately fifteen months, when pain re-appeared; while in three cases the treatment had to be abandoned during the course of the first two weeks owing to severe pain.

It is interesting to observe that posterior root section does not always work in these cases, besides which there are a number of great disadvantages. If one of the main nerves of the upper limb is involved, a rather large number of posterior roots have to be taken in order to render this area anaesthetic and this may involve other nerves which in some cases may be intact.

There are one or two other minor pain problems that it might prove profitable to discuss. Osteoarthritis of the spine in the cervical region may be responsible not only for a referred pain in the shoulder, but in a number of cases may produce a severe occipital headache, which is generally being referred to as occipital neuralgia. In these cases resection of the posterior root of C. 2 and C. 3 may be adequate to cut off all afferents from the greater occipital nerve with the production of an area of numbness on the back of the head, but with the relief of pain.

Much surgery has been performed for migraine to relieve intractable headaches, and the commonest operation has been cervical sympathectomy. This, however, appears to have been abandoned by most at the present time. There are, in addition, a number of other interesting but rather rare neuralgias of the cranial nerves. These include neuralgia of the nervous intermedius, greater superficial petrosal neuralgia, sphenopalatine neuralgia, vidian neuralgia, postherpetic trigeminal neuralgia, automonic facio neuralgia and others with which I do not propose to deal, but most of which can be relieved by section of the involved nerve.

In the diagnosis of pain conditions we are always faced with the difficulty that such pains may be of psychoneurotic rather than of organic origin, or that they may have such a large psychological component that a surgical operation would not only provide no relief, but would actually increase the disability. This is particularly so in the case of headache, for which there are so many diverse causes that it would be impossible to enumerate them all. Before a pain-relieving operation can be undertaken we must be reasonably sure that there is no real functional background to the problem, and in many cases we cannot always be certain of this. Bad results follow operations on atypical trigeminal

neuralgia just as they do on similar pains elsewhere. Only recently I was tempted to perform a posterior root section on a patient who complained of neck and face pain; fortunately I restrained myself and the patient was subsequently cured by psychotherapy. We must be on the look-out at all times for this problem.

Pain can be an enemy as well as a friend. and amidst the many unhappy cases that comprise much of neurosurgical work I find that a well-performed and successful pain-relieving operation, besides giving the patient tremendous relief, provides the surgeon with tremendous satisfaction.

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