THE TREATMENT OF PAINFUL PHANTOM LIMB BY REMOVAL OF POST-CENTRAL CORTEX

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The phenomenon of phantom limb was probably first recognized and has very likely been seen most frequently by military surgeons. Ambroise Paré recorded the condition clearly in 1551 when discussing amputations in La maniere de traicter les playes faites tât par hacquebutes, et cetera. But it was not until 1871 that Weir Mitchell published his article "Phantom limbs" in Lippincott's Magazine of Popular Literature and Science and gave us this perfect term which has since had universal usage. He wrote:

A person in this condition is haunted, as it were, by a constant or inconstant fractional phantom of so much of himself as has been lopped away—an unseen ghost of the lost part, and sometimes a presence made sorely inconvenient by the fact that while but faintly felt at times, it is at others acutely called to his attention by the pains or irritations which it appears to suffer from a blow on the stump or a change in the weather.

In the following year he published his book Injuries of nerves and made further observations after studying 90 patients. He not only gave us the details of the various phenomena which the patient experiences in the absent member, but he made very important observations which can be used to explain the sensory ghost and its misbehaviour. He noted:

If we paradase the track of the nerves in or above the stump, we may cause the lost fingers and thumb to seem to be flexed or extended, and, what is most remarkable, parts of which the man is conscious, but which he has not tried to stir for years, may thus be made to appear to move to his utter amazement. . . . In a case of amputation at the shoulder joint, in which all consciousness of the limb had long since vanished, I suddenly paradased the brachial plexus, when the patient said at once, 'My hand is there again. It is bent all up and hurts me.' It is of course impossible that the motor nerves stimulated should convey any impression centrally, and we must therefore conclude that irritation of sensory trunks may occasion impressions of muscular motion in the sensorium.

The phenomena of the phantom vary in nature and in incidence. Weir Mitchell found that 95 per cent of patients experience phantom limb after amputation, Pitres 97 per cent, Leriche 98 per cent and Foerster 100 per cent. Riddoch noted that pain was referred to the phantom in half of all amputated limbs, but Foerster claimed that pain was experienced in every instance. In our patients it has been almost literally true, as Foerster observed, that pain was felt in every phantom, but it was disabling in very few.

* Read before the eleventh annual meeting of The Harvey Cushing Society, New York City, May 20, 1942.
† Loc. cit. l. 59a. "Car les patientz long temps apres l'amputation faicte dixent encore sentir douleur és parties mortes & amputées: & de ce se plaignent fort, chose digne d'admirabilité, & quasi incrible à gêze, qui de ce n'ont expérizée. Parquoy se faizt donner garde, que tel sentiment ne nous retardez à faire le debouir de la parfaicte curation: comme quelque fois l'ay reu couper en membre à deux ou à trois fois: pour s'etre arrezé audict sentiment faux & menteur."
The sensations occur much more frequently in the hand than in the foot. They may appear immediately or, more frequently, not until two or three weeks after the operation, although occasionally as long as a year or more may pass before the syndrome develops. Usually only the distal part of the amputated limb is felt, such as the hand or foot, although the whole arm or leg has been removed. In the course of time the phantom recedes and ultimately comes to be attached to the stump. It may move voluntarily or involuntarily; it may be in a constantly cramped state of painful contraction. Frequently it assumes the position of the limb at the time of the amputation. Wounds and parts of the limb previously painful are experienced in the phantom as they were beforehand.

The unpleasant sensations may include undue warmth, itching, or simply the distress due to overconsciousness of the painless phantom. These discomforts may be intermittent but if severe are usually continuous. They are then described as a dull ache or as burning, throbbing, piercing, cramping, sticking, cutting pains. Many patients suffer a deep, agonizing torture due to the sensation of the limb being very tightly compressed, which may be so severe that the victims are willing to undergo any kind of treatment. It has not been unusual for a dozen or more operations, principally amputation of terminal nerve stumps, to have been performed on one patient. Many ultimately have become morphine addicts.

The treatment of the painful phantom has been such an unsatisfactory and disappointing experience that there are very few detailed reports in the literature. Most discussions concern generalities rather than specific records, which is natural, since failure has been the common story. Foerster recorded some of his experiences in 1931 in his paper “Division of the anterolateral tract in man.” Two patients with painful phantom fingers whom he treated by high cervical chordotomy and one with a painful phantom foot by upper thoracic chordotomy had only very temporary relief of pain in the phantom. In 1935 he reported five more cases. Two of these had phantom hands and division of all cervical and upper thoracic posterior roots on the side involved gave only transitory relief. Another patient whose arm was amputated at the shoulder was relieved for “eight years” by division of the anterior and posterior roots C-4 through Th-5; “permanent” relief was obtained by another man with a phantom lower limb after dividing the anterior and posterior roots Th-10 through S-5. In a final patient with amputation at the shoulder the posterior roots C-4 through Th-4 were divided and the cervical sympathetic chain was removed including the middle cervical through the second thoracic ganglia. He remained free from pain for many years. Foerster remarked that the combination of posterior root division with removal of the sympathetic trunk was effective in several other cases but did not give details.

No one else has reported the results of combined operations of these types but Leriche used sympathetic interruption, surgical or by infiltration anaesthesia, with some success. The effects lasted for a period of only weeks.
or months. Livingston also has had satisfactory results following sympathetic novocaine block.

To present the clinical problem with the vicissitudes of management the following case is brought forward from the records of the late Dr. A. J. McLean.

In September 1932 a man aged 40 developed pain in a phantom arm two weeks after amputation at the shoulder. Three months later the right brachial plexus was explored without relief. Novocaine block of the sympathetic chain was not helpful. In July, and again in August 1932, posterior roots were divided which ultimately included C-5 through Th-3. There was still no relief from pain, and his condition became so unbearable that he was violent at times. In November 1933 while walking in his room his phantom right arm, which was usually felt semiflexed over his abdomen, was pulled outward from his body by great force, raised above his head, and snapped off at the shoulder joint. Then he lost consciousness. His wife saw him half flex the hips and turn his head strongly to the left; after a short period of gasping breath and tonic extension there were clonic motions of the arm and both legs. Following the convolution the phantom arm was present as before, but the pain had cleared remarkably and he required only very little morphia for a long time. Later the phantom felt as if it were on fire and tied up tight in a straightjacket against his body, utterly incapable of movement. A burning sensation was present all the time in the palm of the hand, wrist and arm. Sharp, excruciating, cutting flashes of pain, lasting for one or two seconds, occurred about every hour throughout the day. These affected the little finger, hypothenar eminence, and the tips of the ring, middle, and index fingers. In January 1934 he was first seen by Dr. McLean who did a chordotomy at the level of C-2 on the left. The painful phantom disappeared for a day only to return.

This case is of particular interest, not because of the therapeutic result but because of the convolution after which the pain in his phantom disappeared. This suggests a temporary interruption of cortical function leading to relief from pain. A similar extraordinary disappearance of a painful phantom was observed after convulsions in another patient in whom a permanent interruption of cortical function was carried out surgically some time later.

Explanations for the phenomena have been proposed by almost everyone who has dealt with this baffling problem. Paré, who made the first suggestion, considered the retracting divided nerves responsible.* Mitchell re-produced the phantom phenomena by electrical stimulation of the nerve stumps, thus emphasizing a peripheral mechanism as the cause. His observations were complemented by Pitres who injected cocaine into the region of the neuromas, thereby stopping the disturbing sensations. More evidence was added by Souques and Poisot who injected cocaine around the terminal scar, causing a constant disappearance of all hallucinations which could not be reproduced by electrical stimulation during the period of anaesthesia. They reported this method for treating the discomforts as well as for inhibiting the involuntary movements of the stump. Thus considerable evidence was accumulated over a period of three and a half centuries which

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* Loc. cit. ll. 66b–67a. "D’avantage, long temps apres l’amputation faite, les patientz disent encore avoir la partie qui a esté amputée (côme s’ay dit) ce qui vient, comme il me semble, à cause que les nerfs se retirent vers leur origine, & en se retirant font grande douleur, & presque semblable aux retractiōs qui se fôt aux spasmes."
The participation of higher centres was recorded by Head and Holmes in 1911. While studying the sensory disturbances which followed cerebral lesions they made the following observation:

One of our patients had lost his left leg some time before the appearance of the cerebral lesion which destroyed the power of recognizing posture. After the amputation, as in so many similar cases, he experienced movements in a phantom foot and leg. But these ceased immediately on the occurrence of the cerebral lesion; the stroke which abolished all recognition of posture destroyed at the same time the phantom limb.

The part which the autonomic system plays has been emphasized by Leriche and Livingston through relief of pain, although temporary, which has followed interruption of the sympathetic nerves. There were also not a few supporters of a purely psychological explanation. Pick was probably the first of these, and since him others have gone so far as to maintain that the phantom and the associated pain were “a state of mind” without organic basis. Thus the origin and perpetuity of phantom limb have been attributed to all parts of the individual from the skin to the psyche.

Much psychological discussion has been offered to explain phantoms, but before blaming all on the state of mind of the unfortunate sufferer the simple physiological facts should be exhausted. At this point the decisive observations of Weir Mitchell, Pitres, Souques and Poisot, Head and Holmes, Leriche, and Livingston should not be forgotten, for they demonstrated clearly an organic basis which will explain the pathogenesis of phantom limb—peripheral nerve stimulation reaching consciousness. The vagaries of individual phantoms are beyond immediate analysis. It would be pure speculation to give a reason why a phantom hand gradually finds its way to the height of the amputation, even to the axilla. It is impossible to say why one patient experienced a rough skin on the dorsum of his phantom hand and smooth skin on the palmar side, or why another spoke of his phantom as having a yellow colour. It is also difficult to explain why, although phantoms are experienced universally, not all are painful, and if so, why the pain varies so much in degree and time, even allowing for the inherent differences of the brains in which the peripheral stimuli register. The bizarre nature of the discomforts is also a bit of a mystery but is probably due to the unregulated conglomerate stimuli which assemble in the stump.
before marching to consciousness. The various positions which the limb assumes are also not easily explained, a number retaining the posture of the limb at the time of amputation when this has taken place with violence as in warfare or in accidents. The position most frequently described for a phantom upper limb—abduction of the upper arm, flexion and pronation of the forearm, and flexion of the hand and fingers (Fig. 1)—is one which can be reproduced by massive electrical or mechanical stimulation of any one of the large nerve trunks of the arm. Not only do the muscles innervated by the nerve stimulated, be it median, radial, or ulnar, contract, but the entire extremity is moved reflexly so that the upper arm is abducted, the forearm pronated and flexed, and the hand and fingers powerfully flexed. The same reflex movement has been observed immediately after gunshot wounds of large nerve trunks of the arm and has been so forceful as to have remained etched in the memory of the subject. The vividness of the phantom has been explained by Foerster\textsuperscript{2} as due to a cortical engraving which was made by the strength of the impulses originating at the time of the amputation or trauma. This engraving then is more readily receptive to subsequent unorganized peripheral stimuli and is prepared to interpret them as previously experienced.

To emphasize the importance of the cerebral cortex, especially the post-central area, in the pathogenesis of the phantom and to demonstrate a method of treatment by extirpation of the proper part of this area, the following case is presented, an interval of more than two years having elapsed since operation.

A man aged 40 caught his right hand in a circular saw which amputated the terminal phalanx of the middle finger and the terminal and half of the middle phalanx of the ring finger. He had not realized these had been cut off until someone saw his hand. Immediately after operation he was conscious of the presence of the amputated fingers. These phantoms were extremely painful, felt raw, itched, ached, and were so sore he wanted to take hold of them. The fingers became flexed powerfully and this pain was “killing.” On 13 August 1940 he suddenly became unconscious and partially paralyzed on the right side. He recovered considerable function of the limbs and there was very little if any sensory deficit. There was no alteration of the phantom fingers or pain. However, he had a few convulsions after each of which the pain in the phantom disappeared for a day but recurred with its previous severity and persistence. Because of his incapacitating, unbearable pain it was decided to remove the sensory cortex corresponding to the parts amputated. This was done on 10 December 1941 under local anaesthesia. The left post-central cortex was stimulated and after determining the area corresponding to the middle and ring fingers for the right hand this was excised by subpial resection. The piece of cortex (Fig. 2) removed measured 15 by 10 by 8 mm. There was an immediate disappearance of the phantom fingers and the pain which have not recurred two years after the operation.

Thus from analysis of the clinical experiments offered by surgical therapy the unmistakable conclusion is reached that stimuli originate at the periphery in the stump with its amputated nerves which transmit these impulses by all possible pathways to registration in consciousness. Inactivation of these stimuli by novocaine block at the site of origin or by mechanical interruptions along the pathways through which they are transmitted, various
and multiple though they be, have stopped the phenomenon at the lowest level. Perception at the highest level has been altered by hypnosis. Elimination of an intermediate level in this chain of sensory stations, the post-central cerebral cortex, has also silenced the ghost. Interruption of the single peripheral pathways, the lowest level, has been tedious and usually without effect because when one road was cut the impulses detoured by way of another, and if that also were blocked, still other bypaths were found. Attack on the absolute periphery of this phantom system is only temporarily effec-

![Fig. 2. Microphotograph of the section of post-central cortex removed at operation. Nissl technique (X16).](image)

tive because excision of a neurofibroma leaves us with a pathophysiological state similar to that which followed amputation of the limb, and stimuli will start immediately or very soon at the end of the newly amputated nerve. These will become more vigorous as time allows the end of the nerve to develop another neurofibroma, the inevitable pathological process which occurs at the end of a nerve whether it is cut or injected with alcohol, formalin, or other fixatives. There is thus no permanent inhibition of the phenomenon by attack at the periphery, including interruption of the nerve anywhere in its entire extent. Because of the very numerous peripheral pathways which would have to be interrupted (anterior roots, posterior roots and sympathetic chain) it seemed preferable to eliminate the intermediate level in the sensory sequence leading to consciousness, and the post-central cortex corresponding to the phantom limb was removed. Since this stopped the phan-
tom, one may say without hesitation that for the existence of a phantom limb there must be a divided peripheral nerve stump and a sensory cortex which had been adequately mature at the time of amputation to have experienced a consciousness of the living behavior of the amputated limb.*

SUMMARY

Phantom limb is a disorder which has an organic basis—a divided peripheral nerve from which stimuli originate and are transmitted through higher levels to conscious registration. The painful phantom can be stopped by interruption of the sensory chain leading to consciousness. Since the peripheral (lower level) pathways are multiple it is simpler to interrupt the chain at the intermediate level by removal of the corresponding part of the post-central cortex. This has been effective in a patient whose operation was done more than two years ago.

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* Phantom limbs are not found in patients who have had a congenital amputation or in those who have undergone amputation in infancy.