1951

The phantom limb

THE PHANTOM LIMB

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March 15, 1951

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In May 1945 I first began to inquire of various physicians and surgeons about the phenomenon of the "phantom limb" after loss of an extremity. The explanations were often uncertain or vague. Thus, I was prompted to choose this occurrence as a subject for a review of the literature and report of my findings.

I propose to present the descriptions of the syndrome and etiological mechanisms; and to discuss the pathologic anatomy and therapy employed in those cases where the patients seek relief.

Much of the cause is still vague and as yet no circumscribed explanation is available. The understanding of the phantom is beset by complicating features: the information obtained is subjective and there is a lack of objectively recognizable features; those individuals who perceive pain often use the same descriptive terms as those persons who merely feel the presence of the absent part; and finally therapy when sought encompasses a wide variety of surgical procedures which are in most cases only temporarily effective, introducing an element of suggestibility.

HISTORY

Silas Weir Mitchell, a founder and spiritual leader of American Neurology (7) was the first observer of the phantom limb phenomenon (45) though Ambrose Paré alluded to it in the sixteenth century.

In 1872, Mitchell wrote:

> "Nearly every man who loses a limb carries about with him a constant or inconstant phantom of the missing member, a sensory ghost of that much of himself and sometimes a most inconvenient presence faintly felt at times, but ready to be called up to his perception by a blow, a touch, or a change of wind."

CONCEPTS

Gallinek (16) described the phantom as an hallucination occurring in persons with a perfectly clear mind; while Pisetsky (36) called it an illusion, a perverted perception, which represents the persistence in the consciousness that a limb which has been severed is still present. That often the vivid quality of the sensory illusion caused the patient to be more aware of the phantom limb than of the normal one (29) is aptly shown by Mitchell's patient (30) who said,

> "If I should say that I am more sure of the leg which ain't than the one which are, I guess I should be about correct."

INCIDENCE

Henderson and Smyth (21) after observation of 300 major and minor amputations concluded that the phantom limb was a natural and almost universal sequel to amputation and this has been generally accepted by other observers (4, 30, 42, 45) with the single exception of Gallinek (17) who stipulated that suddenness plays a part since the phantom was absent in slowly progressing losses such as freezing or tuberculosis of joints. However, the phenomenon has been reported as absent in congenital absence of limbs, congenital amputations, and injuries of early childhood that result in a missing extremity (2, 4, 16).

DESCRIPTION

Immediately or within a few days after the loss of the limb there develops within the patient the sensation that the limb is still present. This may persist in a variable degree for a period of months to years after the amputation (3, 16, 45). It is particularly vivid immediately after the loss. The patient may be possessed by the phantom to such an extent as to forget the defect entirely as well as the fact of the amputation (17).

The sensory phenomenan consists of a mild tingling which forms the basic part of the phantom in nearly every case, stronger pins and needles may be induced temporarily by touching a stump neuroma and occassionally there are superadded sensations which may be disagreeable and painful (21). Riddoch (42) said that as many as 60 per cent described a sensation of pain in the immediate period after the loss; however ultimately as time went on less than 10 per cent sought relief for the pain (11).

From his observations Riddoch stated,

> "There is a continuous pain commonly described as a dull ache, or more often as burning or throbbing, and frequently the hand or foot is the seat of painful rigidity of a cramp

> which waxes and wanes. In all but the slighter cases the pain is continuous but subject to exacerbations. The continuous pain varies in severity and in addition periodic cutting or darting pains aggravate the patient's distress or he feels that his absent fingers or toes are being cut off. These paroxysms may occur for no apparent reason but usually they are evoked by obvious stimuli."

I might add here that not infrequently the patient feels that he is wearing a tight pair of shoes or gloves, or that pliers or a vise are pinching the digits of the hands or feet.

Mitchell (30) and others (21,42) related that sometimes such action as micturition, defecation, or yawning temporarily accentuated the sensation or caused pain, they believed the cause to be muscular contraction in the stump or vascular congestion from venous obstruction. It is interesting to speculate concerning two possibilities which suggest themselves. If one were to observe a normal individual with all limbs intact going through any one of these procedures it would be noted that the entire skeletal system takes part in such an action. There occurs a tensing of the voluntary musculature and apparently in the case of a subject with a missing part, the pattern of behavior developed before the amputation is still brought into play and one feels these parts participating. The sensation therefore may be interpreted as painful by some and merely as an intensification of the phantom by others.

Sensory Homunculus from Penfield and Rasmussen(34)

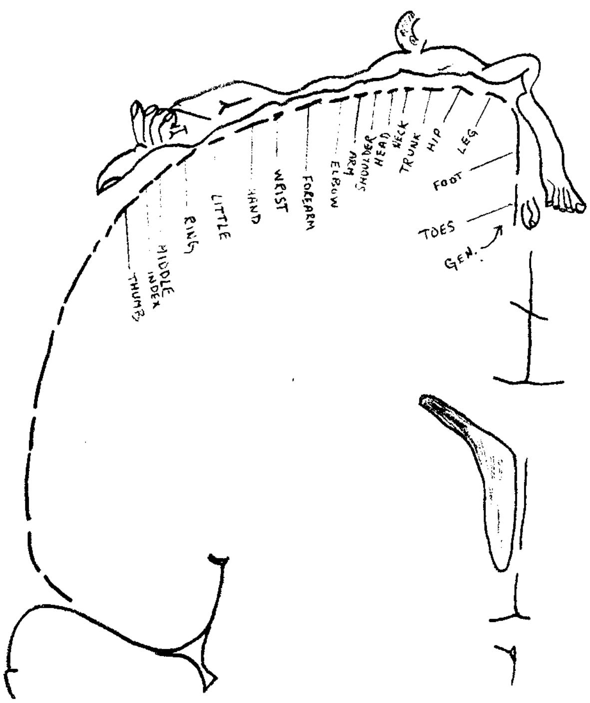

Fig. 1. "The right side of the figurine is laid upon a cross section of the hemisphere, drawn somewhat in proportion to the extent of the sensory cortex devoted to it. The length of the underlying block lines indicates more accurately the comparative extent of each representation."

On an anatomical basis it might be postulated that this sensation is due to the fact that the sensory representation of the genitalia (See Fig.1.) which includes the rectum and buttocks seems to be within the longitudinal fissure of the sensory cortex adjacent to the foot and at a short distance from the arm areas according to Penfield and Rassmussen (34) and these areas are in a state of altered reactivity due to loss of the parts which they innervate. Thus when the cells for the genitalia discharge they cause a simultaneous discharge of the cells for the extremities. In my experience I have found that the pain or increased sensation is confined to the foot and especially the great toe. (the representation of these being closest to that of the genitalia).

Nervousness, worry, fatigue, and exposure frequently aggravate the symptoms, and according to Schmidt (46): "diverting the patient's attention to a suitable occupation has an anodyne action." During the course of conversation unless the attention of the amputee is called to his loss when he is not thinking about it he will not experience the phantom.

Not infrequently the position in which the patient lost the extremity is preserved in the phantom. It is as though the last posture of the limb has been recorded in the sensorium (17,29,30). Gallinek (16) stated that wounds present in the actual limb may be also perceived in the phantom, and according to Harman (19) the phantom limb remains crushed and bleeding as the real part was. Riddoch (42) agreed with these findings when he wrote that continuation of preamputation pain in any part of the limb was the general rule and in fact with regard to both pain and the prevailing posture of the part it was as if the limb had not been removed.

Gerstmann (17) called attention to the fact that in some patients the limb was motionless, in others there was the sensation that it moved spontaneously or at will; movements of the healthy limb or parts of it were apt to produce the experience of a similar or equal movements in the corresponding parts of the phantom.

Henderson and Smyth (21) said that the movements of the phantom were stereotyped and were most developed in relation to leading parts of the limb, and in addition were associated with observable contraction of the appropriate stump muscles. However Livingston (29) found that with amputations at the wrist level voluntary movements of the phantom fingers were accompanied by appropriate contractions of the forearm muscles, but that the patient with the upper arm amputation stated with assurance that he carried out identical movements even though there was no evidence to support his statement.

In relation to movements of the stump either active or passive, Mitchell (30) said that the lost limb and especially the arm was usually found to follow the stump, while in some instances it never left its place. He also added that in-voluntary movements of the absent fingers and toes were frequent and in many were precursors of a change in weather.

There was a general agreement among most observers that in the painless phantom the complete extremity was almost never felt to be present (16,17,19,21,29,30,37,42,45). In an upper arm amputation the patient was usually aware of the fingers and hand; occasionally the wrist; rarely of the elbow and almost never of the forearm or of the arm between the stump and phantom elbow (29). As regards the lower limb the heel is that part of the foot which appeared to be most indistinct, whereas the great toe and knee were of more predominant sensation; while the area between the knee and ankle was rarely perceived (16). Worthy of note was the further differential of Henderson and Smyth (21) that there was no strictly progressive diminution as the stump was approached, for the digits were not of equal intensity, the elbow was less than the forearm and the palm was sometimes weaker than the wrist.

Pisetsky (37) and others (16,19,42) agreed that the painless variety of phantom after a few weeks became less noticeable and approached and tended to melt into the stump. However stimulation of the stump by pressure on the nerves or faradization of the nerves recalled the former sensation and temporarily lengthened the phantom limb only to shorten again when the stimulation had ceased. That the upper limb phantom was more intense and of longer duration than the lower was expressed by some observers (2,30,45).

Browder and Gallagher (4) observed that if an artificial member were substituted for the lost limb the sense of sight referred the hand or foot to its former position. Gallinek (16) said that the prosthesis was identified with the phantom limb. This occurence I have found to exist for when the prosthetic appliance is not worn it is difficult to describe the location of the phantom foot even though the stump is in plain sight, yet when the appliance is being worn the phantom foot seems to be inside the shoe of the artificial member. While walking I have noted that the sensation of the great toe and ball of the phantom foot is that of pressure against the ground. It would seem that the identification of the phantom with the prosthesis is a sort of self-hypnosis, or reinvestment of the loss in the appliance.

PATHOPHYSIOLOGY

The survey of the literature would appear to show a unity in the description of the phantom and its progressive course, however the mechanisms postulated concerning its physiology are multiple. There are apparently peripheral, central, psychogenic, and neurotic bases for the phantom sensations and according to most observers these cannot and do not exist independently.

This paper must attempt to cite explanations for the sensation of pain in the phantom as expressed by some patients as opposed to other individuals who relate that they merely feel the presence of the limb that has been removed.

Gallinek (16) cited Pitres who concluded that the phantom limb originates from the nerve ends in the scar and that with anesthesia to the stump the phantom disappeared only to recur when the anesthesia was no longer effective. Gallinek himself noted that when the phantom had already disappeared it could be made to reappear by peripheral, stimulation and the perception of a phantom already present could be intensified by such stimulation. He proposed that peripheral sensory stimulation of some kind not necessarily pain was a significant factor in the formation of the phantom limb, therefore such stimulation had an important role in that the phantom must be brought out by a process involving the whole nervous system. "Peripheral stimulation from the stump is eventually carried into the same region which would be reached by peripheral stimuli from the limb if this were still present." He stated,

> "Peripheral stimuli are the blood which the sensory ghost must drink in order to be awakened to its phantom existence."

Of importance in relation to Gallinek's theory was the observation of Stopford (49) who said that if a localization fiber which previously extended down to an end organ on the dorsum of the thumb grows down on regeneration to an end organ at the wrist a stimulus will first be localized at, or referred to the old site.

In addition Gallinek said that he had never observed a phantom penis or breast and therefore the phantom was not in agreement with the psychoanalytic theory. The narcissistic inability to renounce the integrity of the body should be even more pronounced after the loss of these parts. This proposition may be countered with the reports of Schilder (45) and Mitchell (30) who recorded cases of phantom breast and penis, while Riddoch (42) told of a patient with amputation of the nose due to lupus erythematosus who at times felt an itchy sensation around the nostrils and unconsciously was apt to put up a finger to scratch it.

Head and Holmes (20) based the existence of the phantom part on the presence of the "plastic model" which develops in the sensorium:

> "By means of perpetual alterations in position we are always building up a postural model of ourselves which constantly changes.
>
> Every new posture or movement is recorded on the plastic schema and the activity of the cortex brings every fresh group of sensations evoked by altered posture into relation with it. Immediate postural recognition follows as soon as the relation is complete . The cerebral cortex is the organ by which we are able to focus attention on the changes evoked by the sensory impulses.
>
> In addition to functions as an organ of local attention the sensory cortex is also the storehouse of past impressions. These may rise into consciousness as images but more often as in the case of spatial impressions remain outside of central consciousness.

> Here they form organized models of ourselves which may be termed schemata. Such schemata modify the impressions produced by incoming sensory impulses in such a way that the final sensations of position or of locality rise into consciousness charged with relation to something that has happened before."

Similarly they went on to state that the plastic models of the body are constructed through the process of localization of innumerable tactile, thermal, and painful impressions which arise from the surface of the body. Further, the immediate disappearance of a phantom limb at all events a painless one, can so far as is known only follow a severe and extensive lesion of the sensory cortex of the opposite hemisphere.

In 1941 Riddoch (42) discussed the pathological physiology of the phantom limbs at great length. His report stated that stimulation due to healing processes at the proximal ends of the divided nerves evokes sensations which are projected and interpreted as if the limb were still present.

These paresthesias, he proposed, through excitation of the "schema" underlying tactile localization and shape are projected and animate the surface of the absent part. In like manner, irritation of fibers subserving postural sensibility keep alive the postural model so that the phantom is correctly placed and moves with the stump. In the absence of pain the sensations are so weak that only those parts more richly endowed with sensory end organs and fibers are represented in the phantom, thus he explained the prominence of the hand or foot.

Retention of the phantom in spite of antagonistic action of visual and other senses he ascribed to the abnormal qualities of the sensations in spite of their relative weakness.

During the healing of divided nerves the decrease in sensory impulses resulting in fainter sensations, he judged to be the mechanism whereby the phantom became less obvious in outline and defective in projection. Thereafter he speculated that gradually the phantom approaches the stump into which it finally disappears and fades away; a new shape of the body is now accepted. The inconstancy of appearance and disappearance of the phantom Riddoch ascribed to an interaction of two processes at once complementary and antagonistic, that is peripheral stimulation and central inhibition:

> "Persistence of painless phantoms after the stump had healed is due to local chemical and circulatory changes acting on peripheral or central sensory fibers in a condition of altered excitability. As in all neural activity excitation cannot act apart from inhibition, and the psycho-physiologic inhibition, apart from the peripheral stimulation, influences the development of the phantom as well as its persistence.
>
> With a strong inhibition and slight peripheral stimulation either there is no phantom or it is transient, with massive stimulation from the periphery the inhibition is overcome and the phantom remains. When inhibition and therefore also adaptability are subnormal the painless phantom may last indefinitely. Inhibition may be reduced by ill health or emotional disturbance with the resultant

reappearance of the phantom or its intensification."

These postulates of Riddoch offer me one aspect of understanding my observation that diverting attention from the fact of amputation, hence increasing central inhibition, causes the phantom to be erased from consciousness.

Henderson and Smyth (21) attributed the behavior and evolution of the "natural" phantom to a temporary state of heightened activity of related cerebral centers the later subsidence of which results in a telescoping of the phantom, and its eventual fading from the consciousness and possibly in the disappearance from subconscious levels of its neuronal patterns.

The disappearance of neuronal patterns I would question, for how could one explain the fact that five to ten years or more after the amputation stimulation of the stump or thinking about the amputation causes either a reappearance of the phantom or its intensification if present.

Bailey and Moersch (2) hesitated to accept the theory of peripheral irritation and labelled the origin of the phantom as more likely intracranial and most probably psychic. They believed that the problem was more than one of irritation of peripheral nerves in scar tissue or of dilated or constricted blood vessels either locally or in the arachnoid meninges. In favor of the central origin they claimed was the absence of peripheral end organs to account for sensory impressions of posture, touch, movements and the like. The patient usually feels most vividly the parts of the limb with the greatest representation in the cortex. Further that the position of the limb is commonly reported to be that in which the injured limb was last seen by the patient, and lastly evidence of nervousness and emotional instability which may be evident by the time the patient seeks medical assistance are said to indicate a temperament that favors the development of an obsession neurosis.

Livingston (29) disagreed with the idea of an obsession neurosis with evidence derived from treating more than 30 patients. He injected novocaine into the sympathetic ganglia and over two-thirds of his subjects experienced a change in symptoms. He said that the fixed posture of the phantom previous to the therapy might suggest an obsession neurosis, but to have the fixed posture change so abruptly after the innoculation, to the surprise of the subject and exactly like changes reported by other patients suggested that some physiologic alteration had taken place to alter the central perception. In discounting the factor of suggestibility Livingston said that the patient probably knew nothing about the purpose of the injection made at a considerable distance from the stump where he had no reason to expect a change in a long standing complaint. Yet, each recipient reported the same train of subjective alterations in the phantom as the others.

These results led Livingston to deduce that the internuncial pool in the spinal cord might be the physiologic agency which, acted on by the irritants, acquired the momentum to produce the sensory perception of the absent limb.

Though he recognized that peripheral stimulation was a significant factor in phantom limb formation Gallinek (16) listed his evidence for the importance of the central theory: (1) the experience of the arm is less than the hand (the central representation of the hand is more expansive); (2) phantoms are lacking in congenital defects or injuries in early childhood because the missing part has never been represented in the body image; (3) disappearance of the phantom part after injury of the post-central convolutions and parietal region; (4) the influence of hypnosis and of mescalin on the phantom.

Bornstein (3) linked the interpretation of the phantom limb with the psychic existence of a corporeal image that represents a final product not only of an arithmetical sum of the psychosomatic perceptions of the various sensorimotor organs but also of the optic and kinesthetic perceptions. She stated that the important psychic functions which constitute the existence of the corporeal scheme are localized in the parieto-occipito-thalamic bundle. Riddoch (43) described the phantom as a projection arising from the post-central sensory associational areas in the cerebral cortex.

Though he recognized that cocainization of nerves, peripheral changes and application of ethylchloride to the stump made the phantom disappear, Schilder (46) said that there is no question that peripheral phenomena are not sufficient to explain the image of the body as it appears in the phantom; that we can only understand the sensation when we assume that the body image and the phantom are based on complicated cerebral mechanisms. In agreement with others (4, 16, 29,55) he maintained that the paresthesias, the peripheral sensations, are only an activating factor. Thus the phantom phenomenon, he summarized, cannot be considered central or peripheral but rather that there are peripheral and central components.

This same author then stated, "Our own body and image of our body is, of course, the object of the strongest emotions. After the amputation the individual has to face a new situation but since he is reluctant to do so he tries to maintain the integrity of his own body. Persons afflicted with the loss of a limb want to create again the integrity of the body. They are especially successful in this recreation when there are paresthesias of the peripheral type which help the constructive process."

In Schilder's theory I found the first mention of the fact that the paresthesias may serve in a beneficial manner. I believe that it is the existence of these paresthesias that are a factor in making the prosthetic appliance a more animate object, and in referring the phantom parts to the position of the parts of the missing member.

Schilder's explanation for the increased prominence and longer persistence of the hand and foot part of the phantoms was that the psychological representation of these parts must be different from psychological representations of other parts of the body. According to this writer the postural model of the body is especially developed by contact with the outside world and those parts of the body which come in a close and varied contact with reality are the most important ones. Thus, he stated: "The hand is that part of the arm with the closest relation to the external world, the other parts of the arm have comparatively little contact with the varied experience which the touch of objects give, the foot gives us the most intimate touch with the earth."

With such reasoning, if it be acceptable, I may possibly understand why in my observation the heel disappeared first and the anterior part of the foot, especially the great toe, persisted. The contacts of this part are more varied than those of the heel.

The telescoping of the most prominent part of the phantom toward the stump was explained on a psychic basis by both Mitchell (30) and Schilder (45).

Mitchell said that in health even with closed eyes we know where and how far removed the periphery of an extremity may be at any one time and this knowledge is due to long continued and complicated sensory mechanisms; ocular, muscular and tactile. When these are lost by amputation we cease to have consciousness of the periphery of a limb as set at any fixed distance. To the lost hand alone are sensations referred; there are none in the intervening portions of the lost limb and the stump is the lowest <u>visible</u> point where pain or touch is felt. Therefore it is there that the sensorium learns by degrees to associate in place the lost hand which seems to feel with the stump.

Schilder thought that the shrinking of the phantom was due to the self experience of childhood returning. "It is one of the inherent characteristics of our psychic life that we continually change our images; we multiply them and make them appear differently. This general rule is also true for the postural model of the body. We let it shrink playfully and come to the idea of Lilliputians, or we transform it into giants. Therefore we have an unlimited number of images. Probably the amputated person tries in a more or less playful way to find which one he can use."

I found Gallinek's description (17) of a psychotic amputee highly interesting:

> "The phantom limb has all the characteristics which it has in the normal amputee, in addition however additional symptoms have been added which originate from the psychotic experience of the patient and are of the same type as his other hallucinations. He feels the phantom hand but he also feels rings on the fingers given

to him by God."

Gallinek said that the psychotic hallucination was imposed on the natural one. Though the two symptoms originated from different roots they were felt and interpreted in the same way. The interpretation was entirely within the range of psychosis.

A discussion of painful phantom sensations must be preceded by a differential diagnosis. I present here Browder and Gallagher's (4) concept of this differential:

1. Causalgia

   This infrequently follows major amputations; a cold clammy perspiring, cyanotic hand or foot associated with a burning type of pain commonly occurs after a minor amputation. The typical example is usually seen following the removal of a digit. The stump and regional area is exquisitely sensitive, the slightest superficial touch or thermal change precipitates an explosive type of pain that radiates up the extremity and lasts long after the stimulus has been withdrawn. A phantom digit may be present but the causalgic pain is usually not referred to the absent part.

2. Stump Neuralgias

   (a) A more or less continuous dull ache usually about the end of a major stump, somewhat aggravated by pressure, said to be more severe in damp weather and presenting a problem in the fitting of the prosthesis. It would seem to be attributable to some pathologic alteration in the cut end of the bone and muscles.

(b) That associated with excessive mesoblastic and axonal growth at the end of a larger peripheral nerve. This pain is often described as being shooting and electric-like; it is often initiated by pressure or other mechanical stimuli. In some instances it is associated with a jumping stump. Since the phantom is an almost sequel to major amputation, there are ~~both~~ patients with both painful neuromas and phantom limbs. The pain here is different from that of the phantom which is painful, it is intermittent and sharp and shooting in character and is said to arise in the stump and radiate into the phantom rather than reside in it.

When I speak of the "painful phantom" I refer to a pain which resides within the phantom limb and is independent of the stump. The stump is perceived in most cases no more than the corresponding portion of the intact limb. An abnormality of the stump is when present due to inherent pathology situated within the stump.

According to Coleman (8) and others (2, 37) a satisfactory pathological explanation has not been found for the painful phantom limb. This can be readily understood when we realize that more often than not objective findings are lacking and we must depend on the patient's complaint to learn of its presence. In addition, pain is a relative experience which is not felt or tolerated in like manner by all individuals.

Casamajor and Wilson (59) in a discussion of Wortis' paper said that we cannot know the sensations of our patients except by their description of them, which of course is a matter of speech. Also they remarked that sensory testing must be largely subjective since the results must be interpreted from the information which has sifted through the patient's consciousness and hence is liable to great inaccuracy:"...the understanding of sensation will bridge the gap between neurology and psychiatry."

Campbell and Whitfield (6) noted that there is considerable variation not only in tolerance to, but in actual sensation of pain.

As regards phantom pain Ewalt, Randall, and Morris (12) said that the phantom pain is merely an interpretation of a phantom sensation by certain individuals who show psychopathology. They observed that the adjectives used in the description of the painful phantoms were identical with those utilized by amputees describing the painless phantom sensation. They concluded: "It was merely a matter of semantics, and that the unstable individual tended to get into a vicious circle of taking larger doses of drugs for pain which in turn became more severe needing more sedation."

Lehrman in (59) and others (13,45) said that there is such a thing as a post-operative neurosis, if the organ operated on has a special significance in the mental life of the patient a subsequent condition develops that may be called a pathoneurosis.

Here might be mentioned the case recorded by Pisetsky (37) in 1946 of a fifty-five year old male with involutional psychosis precipitated by traumatic loss of both legs with very painful phantom limbs. After electroshock therapy there was improvement in the psychosis and disappearance of the phantoms.

I think that I would agree with Browder and Gallagher (4) who realized that there is no comprehensive explanation of the phantom part, yet did not exclude the fact there was such a symptom complex. ......"to relegate it to the domain of a neurotic trait adds nothing to the knowledge of the subject and serves no useful purpose so far as the patient is concerned." Finally they stated that neurotic traits would greatly alter the type of sensation from the phantom part, but the possibility that the incidence of the phantom limb problem is more among neurotic persons is difficult to evaluate as the symptoms produced by an amputation are likely to bring out neurotic tendencies in a relatively stable individual.

White (56) cited a communication from Lorente de No which said that a nerve made anoxic fires off repetitive stimuli, suggesting that impaired circulation in the neuroma may be a source of pain. White then noted that some pains were relieved in patients who contracted malaria fever and postulated that this relief might have been due to improved circulation.

Leriche (28) said the cause was a vasomotor disturbance due to suspended sympathetic activity.

Opposing the preceding theory ~~are~~ were the findings of Brown and Foreman (5) in 1950 that no correlation has been found between the severity of phantom pain and ability of stump temperature to rise during body warming or following drugs. However in reviewing their results of experiments they found that after one and a half to two hours of body cooling the temperature at the end of the stump was less than at the corresponding site on the contralateral limb, and in the stump the distal fall of temperature per unit distance along the limb was increased. In addition they found that after body heating, ingestion of alcohol, sympatholytic drugs and procaine injection of sympathetic ganglia the skin temperature in the normal extremity rose to levels indicating full vasodilatation whereas in the case of the stump the temperature failed to rise in all except three subjects. ..."the three exceptions where there was partial or full vasodilatation occurred in wearers of suction socket prostheses." Perhaps the mechanical effect of the vacuum produced by the suction socket, predisposes the stump vessels to a response with the stimuli used by Brown and Foreman.

Trotter (52) was of the opinion that tender neuromas were usually associated with painful phantoms and that adherence of the end bulbs to the scar of the amputation was another source of pain from the traction of stump movement. In agreement, Livingston (29) asserted that when pain forms an important feature in the sensations it was much more common to find associated stump changes.

Adrian (1) referred to the fact that the neuroma which often develops on the proximal end of a divided nerve consists of numerous naked fibers and of others without fully developed sheaths embedded in a mass of new tissue, "...it is often sensitive to pressure and traction and may also be the source of pain referred to the phantom extremity apart from external excitation." Under these circumstances he postulated that efferent currents spread to afferent fibers when they are not properly insulated. Herrmann and Gibbs (22) attributed the intractable phantom pain to irritation of centrally conducting axons by neuromas, local inflammation and abnormal scar tissue formation. Riddoch (43) thought that the liability to pain in the phantom was increased when prolonged sepsis was a complication before or after amputation or both. With such a complication the end bulbs and the nerve trunks became enlarged and very sensitive.

Bailey and Moersch (2) questioned the status of the neuroma as a causative factor. Fifty-five patients were described who sought relief for their phantom limb sensations, of these 11 had palpable neuromas. Removal of the neuroma gave relief in over one-half of the cases.

They stated that pressure on the stump either in the absence or presence of palpable neuromas causes a shooting pain felt in the absent part, yet pressure on the sciatic nerve several inches above the stump occasionally stops the pain in the phantom and at times causes the sensory ghost to disappear. However, they wanted to know why temporary pressure brought relief in one case yet cutting of the nerve did not bring permanent relief from symptoms.

Unsuccessful peripheral nerve treatment was reported by Morton (3) who described his five cases of interinnomino-abdominal amputation with phantom sensations in varying degrees and proportionate estimation of nuisance value. His attempts to modify these by treatment of the severed sciatic nerve by different methods failed to have any appreciable effect on the sensations. Here it would seem that the magnitude of the loss introduces more psychic factors.

In evaluating the mechanism which causes the phantom pain it would seem that it is important to know the duration of the pain, that is, how much time has elapsed since the loss of the extremity. Additionally, information on the emotional attitude of the patient would prove helpful.

It would appear that in most instances the pain results from anatomic abnormalities but as time goes on if there is no correction of these the pain persists and perhaps becomes psychogenic even though treatment is carried out at a later time.

It was White (55) who said a waiting period of over six months in any but the most stable individuals is dangerous because the psychic effects may become irreparable. Strauss (51) proposed that neither psychic nor somatic components are solely responsible for the phantom limb or pain, also that persistence of psychogenic pain or psychogenically determined perpetuation of pain that was originally somatogenic often covers an already established drug addiction. "....people stick to their pains in order to provide a subjective justification for continuing to take the drug to which they are habituated."

Pflügge (36) was of the opinion that pain was the result of an attempt to restore the psychic body scheme, he believed it to be a form of narcissism. To Henderson and Smyth (21) it appeared that the superadded disagreeable sensations were psychogenically determined from the highest cerebral level, while Schilder furthered the psychogenic mechanism by saying that two factors apparently play a role in the creation of the body image; "One is pain and the other is motor control over our limbs." Thus in trying to retain the body image pain could be the result.

Penfield and Boldrey (34) observed in their work on stimulation of the cerebral cortex that only eleven times out of well over 800 responses did the patient use the word "pain" to describe a cortical sensation. This they thought probably indicated that pain has little if any cortical localization.

Riddoch (43) thought that emotional instability in varying degrees was an inevitable complication in phantom pain as in all disorders in which incessant severe pain is a prominent symptom therefore its continuance by a vicious circle mechanism may be explained by Jones' findings (25):

> "Significantly different responses were obtained between neurotic groups and controls in tests measuring response to pain, cold, and persistence."

In explaining the voluntary movements of the phantom Mitchell (30) said that the volition to move certain phantom parts is accompanied by a mental condition which represents to the consciousness the amount of motion, its force, and ideas of the change of place in the phantom parts so willed to move. A part of those ideas which we are presumed to obtain through the muscular sense are really coincident with, and necessitated by the originative act of will, or else are messages sent to the sensorium from the spinal ganglia which every act of motor volition excites, according to this writer.

Schilder (45) said that from actual experiences we build up a plan for movements and that the plan as such is already the beginning of the motor activity which originates from an intention of our inner directing towards a goal which comes through in actual movement. When the amputee tries to move his phantom he already has a plan for movement.

Previously I mentioned that voluntary movements of the phantom may occur with or without the simultaneous movement of the stump. In my own experience I find that the phantom cannot be made to move without the associated movement of the stump. To explain this I can perhaps call on Schilder's thought that movements of the stump may help give the vivid coloring of a sensation to these impressions.

Riddoch (42) agreed that voluntary movement of the painless phantom fingers on toes is usually possible and often considerable, and that one of the main factors for its preservation depended on preservation of postural sensibility of the stump. Citing his stipulation of the painless phantom I noted that when I attempted to move the phantom foot without moving the stump at the same time the toes instead of moving took on an intensified perception or became painful, yet if I accompanied my will with movement of the stump the toes moved without any change in paresthesias.

The literature has also called attention to the presence of the phenomenon of associated movements. That is, movements of the healthy limb provoked the impression in the patient that the phantom was moving in an identical way.

Gerstmann (17) interpreted this in terms of transmissions of cortical intention and formula of movement from normal to phantom side. Schilder (45) theorized a transfer of movement from the intact side to the phantom by stating that the plan of movement and the cortical kinesthetic melody of movement is transferred symmetrically to the phantom. He said that the impression of movements in the phantom was not due to activity of the stump muscle since movements of the toes and foot of the healthy side were also transmitted to the phantom and the amputation had taken place on the upper leg. Further, he asserted that even when innervation of the upper part of the healthy leg was transmitted to the phantom the interplay of muscles of the stump did not coincide with experienced movement of the phantom.

To entertain the possibility of spread of excitation within the spinal cord from the side of the intact limb to the side of the missing part; "the neurons for the absent member may be existing in a state of altered sensitivity." Yet I cannot definitely accept this for in my own experience I have found that associated movements in the phantom are not perceived without a goodly amount of concentration on the phantom part. Could there be here a possibility of self-hypnosis.

TREATMENT OF THE PAINFUL PHANTOM

Relief of the phantom limb sensation is generally sought by those unfortunate individuals who experience the "sensory ghost" as a painful one.

Varied treatments have been carried out on patients for the painful phantom, but only in few instances have they been successful or of long enough duration to warrant their employment as a general practice. Therapy has been predominantly surgical and many men found the procedures non-beneficial and in many instances actually harmful (4, 8, 45, 49, 56).

White (40) approved only a single resection of a painful neuroma, providing the pain disappeared when the neuroma was infiltrated with procaine. He termed this a minor procedure which was occasionally successful especially if performed before the development of a local functional disturbance in the sensory cortex. In 1950 Russell and Spaulding (44) published the results of their treatment which entailed percussion of the stump neuromas with a mallet or electric vibrator. This depended on the view that if the thousands of fibers in a neuroma are repeatedly subjected to trauma they degenerate, cease to be tender, and lose capacity for causing spontaneous pain.

They made an effort to locate all tender neuromas which on pressure caused paresthesias referred to the absent part, these they said,"...were more vulnerable to minor trauma, and

and if they were continually hammered the nerve fibers would gradually degenerate and be replaced by fibrous tissue."

Of 33 patients considered suitable for the treatment (they recommended sympathetic block for cold and diffusely tender stumps) 19 had good or excellent results and five said that they experienced an improvement in the painful symptoms.

Reamputation of the stump was condemned (4, 55) for the pain always recurred in the new stump and was usually made worse. There was only one exception (55), that of a badly constructed stump and here the procedure had to be carried out early if there was to be any chance of relieving the pain.

Randall, Ewalt, and Blair (41) declared that with revision or repair of the stump there was pain frequently referred to the missing member; these procedures focus the patient's attention on the injury and at this time doubts, uncertainties, and depressive symptoms appear and are the basis for the pain.

Periarterial sympathectomy as advocated by Leriche (28) was termed a non-specific procedure (55); the effects were due to a transitory rise in peripheral circulation due to increased elimination of heat after an injury to the tissues. Brown and Foreman (5) felt that there was no correlation between the severity of the phantom pain and the ability of the stump vessels to dilate following body warming or administration of vasodilating agents.

Intrathecal injection of alcohol (56) was successful in one of seven trials, but it also carried the risk of bladder paralysis.

Pool (39) claimed relief after posterior cordotomy alone or in combination with sympathectomy. The cordotomy was condemned by others who said that it produced no relief (2, 8, 55). Sweet (52) offered a possible explanation for the unsuccessful posterior cordotomy by stating that in patients with phantom limb pain there is no method of post-operative testing which enables the surgeon to be sure that he has divided the pain pathways beginning in the phantom. "..... in a number of cases where the pain was unrelieved by this operation a tiny group of spinothalamic fibers in the spinal cord possibly remained intact and lead from an area of the limb now amputated; therefore a few cut but still irritated fibers in the stump may have their central connection still intact and the pain continues."

Browder and Gallagher (4) said that the posterior cordotomy should be carried out only on those patients with complaints of intractable pain resulting from abnormal posture of the phantom part. This treatment they said, ".... seemingly abolishes the knowledge of the posture of the phantom foot and at the same time the cramp-like pain associated with the distorted posture.

Posterior rhizotomy was called a dangerous and mutilating procedure that did not produce relief (2, 4, 55) White (55) stated that after section of the posterior roots of the brachial plexus there was widespread and complete anesthesia of the stump but the patient still perceived phantom pain.

Spinal anesthesia of as many as six to eight segments above the segmental supply of the lower limb was of no help (2); though sympathetic ganglionectomy was condemned as a therapeutic measure (4), White (55) said it might be successful if performed very early in the experience of the phantom pain.

In 1950 Wortis (59) cited a case of a man suffering from a severe painful phantom of two fingers which had been amputated a year previously. The patient was observed to have a convulsion involving the side of the amputated fingers and to be relieved of his pain for some time after the convulsion. It was then felt that by attacking the problem at the cortical level more relief might be obtained than by other methods: "The post-central cortex corresponding to the missing fingers was identified by electrical stimulation under local anesthesia and extirpated. The result was good."

Since this successful instance 28 patients who were all treated by resection of the sensory cortex have been assembled and analyzed: The results were good in 19; fair in four; and poor in five (59).

Two conditions must be considered to avoid unwarranted optimism: one is the duration of the relief obtained. The other, the complications and sequelae of the practice. Echols and Colclough (11) reported a case of an intensely painful foot relieved by dissection of the portion for the leg and foot in the sensory convolution. That part of the sensory gyrus on the medial aspect was removed at the same time. They noted: "Before the ablation of the cortex was complete the patient announced spontaneously that the phantom foot and pain had vanished." Though eleven months later no phantom or pain had returned, there had been incapacitating atrophic arthritis with pain, and limitation of motion had developed. Most affected were both shoulders, all fingers, the right knee and ankle and both temporomandibular joints. Both hips were spared.

The treatment of ablating corresponding cortical areas was developed with the intent of removing the point of registration of the impulses beginning in the stump (9). The hypothesis that such sensations registered only in the post-central cortex and in specific areas has been shown to be false by work on cortical localization (9, 33, 34, 58).

Horrax (24) said that in a patient with the phantom pain cortical excision was followed only by transient relief. Mahoney (9) agreed that this procedure was only partially effective; he further said that due to the presence of a secondary sensory cortex the possibility of eliminating all sensation from a part by removal of cerebral cortex is not feasible, with such an extensive cortical localization adequate excision would be associated with other unjustifiable disabilities.

According to Penfield and Rasmussen (34) ablation of the post-central gyrus results in loss of tactile discrimination and position sense in the arm and leg. They also stated:

> "No removal of cortex anywhere can prevent pain from being felt, and only rarely does a patient use the word pain to describe cortical stimulation. It is obvious therefore, that the pathway of pain conduction reaches the thalamus and consciousness without essential conduction to the cortex."

Walker (53) has shown that pain is appreciated on the opposite side of the body after hemi-decortication; destruction of one thalamus including the nucleus for the termination for the spinothalamic tract; and also after mesencephalic tractotomy.

In reviewing the surgical procedures employed to eradicate the pain Wortis (60) stated:

> "Phantom limb pain can probably rarely be relieved by a surgical attack directed against the mere interruption of anatomic pathways for pain impulses between the periphery and consciousness. Whatever surgery may accomplish would appear to be the result of its interruption, breaking-up, or altering of some abnormal physiologic mechanism that has taken place in the central nervous system.
>
> Surgical interruption of the pain pathways at the peripheral level only occasionally relieves phantom

> limb pain, the same is true for surgery at the spinal cord level whether cordotomy or section of the posterior columns. Adequate section of pain pathways at higher levels to relieve pain that is, to shut off all pain impulses from the cortex is probably impossible."

Pre-frontal lobotomy has received much consideration for the relief of the phantom pain. Freeman and Watts (14) said that this procedure did not interfere with the perception of the pain, nor did it abolish the normal reaction to pain, but it did reduce the persistent obsessive, emotional substrate of continued pain. According to Sweet (51) the patient still answers that he has the pain but he doesn't mind it or ask for analgesics.

Sweet did mention that if the patient lives long enough he may again in months or years begin to complain of his pain, therefore he would restrict it to cases with a short life expectancy, Purdon (40) agreed with this restriction.

Campbell and Whitfield (6) said that they and others had had good long term results with the phantom pain and that it was the exception.

Rylander (44) asked whether the operation did not in certain instances remove something that was more valuable than the therapeutic effect. He considered a thorough analysis of the heredity, personality and environment of the patient very important. In defense of the operation Mahoney

(9) said that the patients are heartbreaking and most of them are desperate and ready to commit suicide, The per cent of narcotic addicts is high, and the problem demands radical measures and under such circumstances the leukotomy is not unreasonable. Burlinghame (5a) declared that the effects on the processes of intellect, imagination, and initiative depended on the original endowments of the patient and how much if any deterioration had set in. "....deterioration is often more apparent than real and often the patient was merely desocialized as a result of protracted illness or long stay in the hospital."

It may be that a preventive type of medicine will best be employed in the future by careful attention to the personality and background of the patient. If possible this could be instituted prior to the amputation or shortly thereafter by psychotherapy.

Occupational therapy is another consideration in the rehabilitation of the amputee, since it is recognized that diverting the patient's attention has an anodyne effect. Such employment can withdraw the patient from his state of introspection, and deter focussing of all attention on the injury.

Licht (14) said that once the patient has been discharged from the hospital his new skills and hobbies will give him less time to think about himself and less boredom to punctuate with unsocial ideas and acts.

ANATOMICAL FINDINGS

Gowers in 1879 (18) described a portion of the cerebral cortex in a case of congenital absence of one hand.

There was a diminution in size of the ascending parietal convolution on the opposite side of the brain. This area of diminution occupies precisely the area stimulation of which causes movements of the opposite hand (deduced from monkey experiments).

Microscopic examination of the convolutions of each side showed very little difference in their structure. However the atrophy was strictly limited to the hand region.

His explanation for the similarity of microscopic structure of the two sides was that the forearm muscles of the hand were present though they could not have been used, or the representation of parts in the brain is nowhere exclusive but only preponderent. Penfield (33) showed the latter to be true 100 years later by work on human subjects.

Dickinson (10) in 1868 recorded the changes in the nervous system which he found, following amputation, by anatomical examination in post-mortem studies. He did five such studies and sought to trace evidence of changes by commencing at the stump and working upwards hoping to secure evidence of a more positive kind.

He concluded that loss of the extremities was not followed by loss of weight or by appreciable change of structure either in the cerebellum, or in the hemispheres or great ganglia of the cerebrum.

Since his subjects had lived on for many years after the loss he recorded that when a limb has been absent as the result of surgery for twenty or more years the following changes are found:

1. Atrophy of the nerves of the stump of which a large proportion of fibers have perished, however supported by fibrous tissue which enters into their structure they retain their bulk and external appearance almost without alteration.

2. There is a wasting of nerve roots especially the posterior.

3. Slight loss of bulk in the gray matter of the cord on the side of the lost member near the origin of its nerves, without any intimate change discernible microscopically.

4. Remarkable shrinking of the posterior column of the cord on the side of the mutilation attended by condensation of areolar tissue. The atrophy extends upwards and in the case of loss of an arm can be traced in the medulla to the upper limit of the decussation of the pyramids.

He stated that he has no explanation for the greater degree of atrophy of the sensory than the motor roots or for the peculiar wasting of the posterior columns passing vertically upwards and in the case of an arm affecting the medulla--with the course not corresponding with that of the sensory fibers which soon lose themselves in the gray matter.

He cited the investigation of M. Vulpian who studied 2 cases one of 47 years standing and the other of 20 and found that the cord was slightly lessened in bulk on the side of the amputation and which affected the gray matter generally, and the white matter with the exception of the posterior column.

None of the reports make any reference to the presence or absence of phantom sensation or pain. The only thing that we can salvage from Dickinson's analysis is that there is no atrophy of cortical areas after post-natal amputation, while Gower's case is related to an atrophy of the cortical area that is intended to subserve the missing part.

COMMENTS

It has been shown by a search of the literature that 95 per cent of individuals who are subjected to the loss of an extremity report the presence of a phantom limb. There has been no case reported with a phantom limb where the missing part was due to a congenital defect, an intrauterine amputation, or a loss in early childhood.

Evidence presented by Mitchell (30), Riddoch (42), Schilder (45) and Head and Holmes (20) indicates the presence of a body image which resides in the sensorium and relates us to the outside world and to objects around us. The neurophysiology of a cut nerve is altered, and the proximal end gives rise to impulses by one of many mechanisms, either chemical or physical. These impulses excite paresthesias and as a result the body image is brought into consciousness.

It seems likely that the phantom is brought out initially in this manner. But why does an amputee still feel the limb with the knowledge from sight and other senses that the extremity is no longer there? It is seemingly an illogical occurrence, but psychically that is not the case. According to Fenichel (13) the body image and the ego are one and the same; in the case of the amputee there is also an objective body....to accept the objective body would be to reject the integrity of the body image. Since the body and body image are the focus of our strongest emotions (45) the body image developed during the course of life is maintained and with it the phantom.

Initially after the loss the phantom would appear to be painful due to one of two reasons:(1)the recently severed nerves in the extremity are more sensitive to any type of stimuli and therefore in their altered environment are discharging in a corresponding manner;(2)this is a period of mental and physical adjustment to a severe loss. The psyche, during the transition, is attempting to retain the integrity of the body (the body image), this speculation reminds us of Schilder (45) who said that pain was one of the important ways of building the body image, hence to maintain the body image in the face of such danger the psyche draws on pain.

If the pain continues and there is found to be a neuroma in the stump, or a poorly constructed stump these should be corrected without delay (55). In those cases where no relief results, White advised against repeating the treatment or attempting other neurosurgery.

It may be that the continued pain after therapy results from incompleteness; an irritable focus elsewhere in the nervous system; an inability to adjust to the loss; or to some conflict of the id, ego, and superego, hence a psychic need for guilt. The dynamics are little understood. At any rate the treatment to a great extent will depend on the individual per se. His former environment, his personality, emotional attitudes, life situation, and maturity are all factors that must be considered in seeking a way to relieve the pain and understanding the course of the phantom.

Reports inform us that much of the surgery attempted has been unsuccessful either due to a return of the phantom pain or to development of other complications or sequelae. This might suggest injury to other mechanisms during the surgery, or since one avenue for release of a psychic product has been blocked the unconscious has paved another route.

Any discussion of the significance of the phantom limb and the pain would be deficient without consideration of the effect on the amputee. We have an individual who has been subjected to one of the extremes of physical and mental trauma. He is aware that the part is no longer there, yet he feels it and often it is painful. The trend of neglect of this syndrome has been toward not informing the patient before, in those cases where possible, or shortly after the removal of the part, of the occurrence of the phantom limb, and of the possibility of an associated pain.

It has been found that at times the afflicted individual will not talk about the sensations or allude to them for fear that he will be considered insane (28). Thus the patient's lack of familiarity with his condition serves only to make matters worse.

The problems and possibilities of the phantom limb are so complex that a superficial study of the phantom limb does not allow grasping them. These people do not have the delusion that the part is present, but they have the sensation as though it were present.

The student of the phantom limb must take such ideas as peripheral stimulation (1,29); body image (42,45); tonic sympathetic activity (27); reaction to the loss in the form of psychopathology (46); isolation of the thalamus by interruption of its afferents due to the amputation and its consequent discharge of hypersynchronous impulses (59); and altered reactivity of cortical cells in the cerebrum, and criticize them, take them apart into pieces and try to replace them with others.

SUMMARY

A review of the literature has been made to study the

phenomenon of the phantom limb as a complication of amputation.

1. Though Weir Mitchell first observed the presence of the phenomenon in 1872, its pathological physiology is today still little understood.

2. Though absent in congenital absence or congenital amputation of limbs it is generally agreed that 95 per cent of amputees experience the sensation of the limb still being present. Of these some one tenth seek relief for the discomfort.

3. Etiology has been based on peripheral, central, psychogenic, and neurotic factors or combinations of two or more of these.

4. The treatment of the painful type of phantom sensation still appears to be inadequate to date.

5. The phenomenon is more enduring and stronger in the case of the upper extremities. The cause for the amputation does not seem to be a factor in development of the sensations.

6. The prognosis in treatment appears to be related to the duration of symptoms, and to the personality and emotional attitudes of the individual.

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