

to occur when using alpha-chymotrypsin but that this increase may be due to the slight increase in mechanical intervention.

There seemed to be a slightly higher percentage of cases showing increased opacities in the vitreous in this series than in our previous cases. We feel that the difference was not great enough for us to draw a definite conclusion. There was no increase in the amount of the opacities in any case during the follow-up period.

In our series the vitreous face was carefully inspected over a period of a year. The appearances were compared with earlier cases of our own and with the descriptions and statistics of previous authors relating to uncomplicated intracapsular extractions without the enzyme.

We believe that there is no greater tendency either to bulging forward of the vitreous face or to the appearance of rents and tears in the anterior hyaloid membrane when alpha-chymotrypsin is used.

There was no tendency towards deterioration in the vitreous face during the 12 months of the study.

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## AETIOLOGY, DIAGNOSIS, AND TREATMENT OF PARAESTHESIAE IN THE HANDS\*

BY

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This paper is primarily concerned with the syndrome of the carpal tunnel and the disturbance of median-nerve function arising therefrom. The clinical features, aetiology, diagnosis, and treatment of this condition are considered in relation to 327 patients under my care in the years 1948–58.

The term "acroparaesthesia" was introduced by Schultze (1893) to apply to a condition in which pain and tingling in the hands were the prominent features and in which physical signs were scanty or lacking entirely. Affecting women mainly, it tended to appear in middle life and most commonly between the ages of 35 and 55. In the next 50 years various theories were advanced to explain the symptoms of this disorder and varying therapeutic measures were advised—some rational, some bizarre—all having in common their relative inefficacy in relieving the symptoms of which the patients complained.

There are, of course, numerous conditions in which paraesthesiae may occur in the fingers, hands, and arms, usually as an incidental feature in association with other symptoms, and it was probably the recognition of the fact that paraesthesiae may at times result from the presence of a cervical rib that directed attention away from a possible distal mechanism.

Kinnier Wilson (1913) regarded the condition as invariably arising at the thoracic outlet and described two clinically distinct types—(a) that in which local wasting of the thenar eminence is pronounced, with paraesthesiae on the radial side of the hand, and (b) that in which generalized atrophy of the intrinsic hand muscles leads to a claw hand. He also described trophic and vasomotor changes and mentions the occurrence of gangrene of the index finger. Sargent (1921) reviewed 95 patients under his care in whom pain, paraesthesiae, disorders of circulation, affections of cutaneous and other forms of sensation, weakness, and wasting occurred in varying combinations. He mentioned the quite frequent absence of visible wasting in the muscles. Of 32 patients with muscle-wasting in the hands, 12 presented with wasting in the thenar muscles, and it is significant that operation on the neck often failed to relieve these latter patients.

Walshe, Jackson, and Wyburn-Mason (1944) and Walshe (1951) describe various mechanisms in relation to cervical rib, the first rib, the subclavian artery, and the clavicle, by which they consider acroparaesthesia may be produced. It is suggested that the localized wasting of thenar muscles may be due to a constant relationship of the fasciculi in the outer head of the median nerve to the subclavian artery—an observation that becomes untenable in the light of the work of Sunderland (1945) (see below). The same writers suggest that dilatation of the subclavian artery, with or without thrombosis and distal emboli, may play a part

\*This study was carried out for, and was successful in, the South-west Metropolitan Regional Hospital Board's competition for research reports, 1959.

An exhibition of 1,200 British books on science, technology, medicine, and surgery has been assembled by the British Council for touring Japan early next year. This first large exhibition of its kind sent to Japan by the Council has been organized in collaboration with the Japanese Publishers' Association for Cultural Exchange. It is planned that the books will be exhibited first at the main universities of Tokyo and then in the principal university cities of Japan. There will be 33 sections in the exhibition covering all the main branches of science, technology, medicine, and surgery, and a 94-page catalogue listing each book has been prepared.

in the production of symptoms. Walshe states, however, that conservative treatment is usually unavailing and the results of scalene section are "not rarely negative."

The median nerve, by virtue of its situation on the volar surface of the wrist, is not uncommonly damaged by lacerations of the wrist—a type of injury quite commonly encountered in civilian life. It is now quite generally recognized that the nerve may be involved in closed injuries of the wrist and carpus. Paget (1863) refers to a patient at Guy's Hospital who sustained a fracture of the lower end of the radius "repaired with an excessive quantity of new bone." The median nerve was in consequence compressed, with resultant paralysis of the thenar muscles. The patient also developed ulcers on the tips of the index and middle fingers. The condition was cured by immobilization of the wrist in flexion. Watson-Jones (1926), in a paper on dislocation of the carpal semilunar bone, pointed out the frequent association of median nerve damage with this comparatively rare injury. Zachary (1945) described two cases treated by division of the transverse carpal ligament, in which bony deformity was associated with nerve injury. Cannon and Love (1946), in an account of "tardy median palsy," recorded 38 patients with signs of median nerve injury at the wrist; five had no deformity of the bone structure of the wrist or carpus. These writers draw attention to the common presentation with paraesthesiae and thenar atrophy.

Bailey and Carter (1955) described two cases of median-nerve palsy after acute infection of the hand. De Abreu and Moreira (1958) give an account of a patient who sustained a crush injury of the wrist, followed seven months later by pain in the thumb and index and middle fingers, leading to gangrene of the tips of these digits. The symptoms were relieved by division of the flexor retinaculum, and at operation the median artery was found thrombosed.

The fact that the median nerve may be damaged at the wrist without history or signs of external injury has received remarkably slow recognition. Putnam (1880) described 31 cases suffering from nocturnal paraesthesiae in the median territory. Marie and Foix (1913) described the case of a patient who, at post-mortem examination, displayed bilateral thenar wasting with the appearance of a neuroma of the median nerve at the wrist, and Hunt (1911) described three cases in which the lesion was theoretically localized to the flexor retinaculum.

Brain, Wright, and Wilkinson (1947) were probably the first to describe the carpal-tunnel syndrome, its clinical manifestations and surgical treatment. Kendall (1950) described 14 cases of median-nerve palsy arising at the wrist, and distinguishes the "spontaneous" carpal-tunnel syndrome from median palsy after prolonged direct pressure upon the palm. Since 1950 numerous papers on this subject have been written, among them those of Phalen (1951), Kremer, Gilliatt, Golding, and Wilson (1953), Reid (1956), Phalen and Kendrick (1957), Heathfield (1957), and Garland, Bradshaw, and Clark (1957). Further reference to the work of these writers is made in considering aetiology and treatment.

Paraesthesiae have long been recognized as a symptom of acromegaly, and there is now little doubt that they result from compression of the median nerve in the carpal tunnel. This is referred to by Woltman (1941) and Kellgren, Ball, and Tutton (1952).

More recently, Murray and Simpson (1958) have observed symptoms of the carpal-tunnel syndrome occurring in 26 out of 38 patients suffering from myxoedema.

### Symptoms of Carpal-tunnel Syndrome

The cardinal symptoms of this disorder are paraesthesiae and pain mainly referred to the fingers and hand, numbness of the fingers, muscular weakness or clumsiness, muscular wasting, and trophic disturbance in the fingers.

#### Paraesthesiae

Predominantly nocturnal, paraesthesiae are by far the most common of the symptoms enumerated above and were the presenting symptoms in 313 (95.7%) of the 327 patients here considered. The remaining 14 made no complaint of sensory symptoms. Of the 313 patients, 118 (38%) complained of tingling at night only; in 17 (5%) tingling was diurnal only; and in 178 (57%) tingling occurred both by day and by night, but in all these latter the symptoms were much worse by night.

The description given was remarkably constant. Patients referred to the intense burning quality of the pricking sensation that roused them from sleep. Although this was often poorly localized, most of them describe the sensation as predominantly in the radial half of the hand, affecting particularly the middle finger, the index finger, and the thumb, the middle finger being the one most constantly affected. Many patients say that all the fingers are affected, but on being directly questioned, decide, often after some thought, that the little finger escapes. The tingling often radiates to the palm of the hand and occasionally to the wrist and lower part of the forearm. More frequently, however, the paraesthesiae occur distally and there is complaint of an aching pain felt at the wrist and sometimes proximally, extending well up the forearm, even to the elbow. While the tingling lasts, the tips of the affected fingers may be hyperaesthetic to light touch, and during this time a few patients have described how voluntary movement of the fingers requires a great effort of will—a condition probably analogous to "pseudo-cramp" that can be demonstrated in experimentally induced peripheral nerve lesions. Most patients describe the manoeuvres that they adopt to obtain relief—hanging the arm out of bed, shaking the wrist, massage with the unaffected hand, walking round the room, bathing the hand with warm or cold water, and, commonly in female patients, making a cup of tea.

In the present series paraesthesiae were predominantly unilateral in 225 (72%), the dominant hand being affected in the great majority. The remainder had bilateral symptoms but the hands were seldom affected equally.

Diurnal paraesthesiae were seldom constantly troublesome, but tended to follow use of the hands, particularly in knitting, sewing, and writing. Less commonly they followed more massive use of the arm in carrying weights, gardening, scrubbing, wringing, and polishing. In general it was observed that the longer the history the greater was the likelihood of sensory symptoms appearing by day as well as by night.

A misleading feature of the sensory symptoms is the frequency with which complaint is made of pain in the arm, extending often to the elbow and sometimes even to the shoulder, in association with nocturnal paraes-

thesiae in the fingers. This phenomenon may occur when paraesthesiae are induced experimentally after the release of a pressure cuff on the arm or forearm. This is a symptom which has so commonly led to the erroneous diagnosis of "costo-clavicular syndrome" when in fact the trouble is occurring at the wrist.

#### **Numbness of Fingers**

Numbness of the fingers is a rather less common symptom, and, of those with sensory complaints, approximately 30% experienced some degree of numbness. Often varying in intensity, it affects most frequently the tips of the index and middle fingers, and the thumb less commonly. When present constantly it may constitute severe disability and cause clumsiness in the performance of fine movements—a disability which is, in fact, far greater than that produced by loss of the thenar muscles, even when the latter loss is severe. This is well demonstrated after surgical treatment; sensory recovery being the rule and motor recovery the exception. The ultimate disability is remarkably slight.

#### **Muscle-weakness**

A minor degree of weakness of the short abductor of the thumb was demonstrated in the absence of visible wasting in a high proportion (44%) of those with unilateral symptoms. (It is, of course, impossible to assess minor degrees of weakness when both hands are involved.) Severe weakness and wasting of the short abductor and opponens pollicis was present in 21% of the whole series. Fourteen patients (5%) presented motor symptoms alone, and most of these were men whose employment resulted in direct trauma to the palm of the hand.

Weakness and wasting are undoubtedly related to length of history, and neither was observed in any patient with a history of less than four months. All those with marked motor signs had histories extending over a year or more, and most of those with severe wasting had histories of at least five years' duration.

#### **Trophic Changes**

Severe cyanosis of the thumb and first and second fingers was observed in five patients. In two of these, symptoms could be related to known external trauma. Necrosis of the tips of the affected fingers had appeared in three. In two other patients intermittent pallor and cyanosis of the first and second fingers was present and closely resembled Raynaud's phenomenon. It was, however, induced by active use of the hand rather than by exposure to cold. A minor degree of trophic disturbance, presenting as an atrophy of the terminal pulp of the thumb, first, second, or third fingers, was quite common and was observed in 65 (20%) patients. Severe trophic change, like severe motor change, was related to duration of symptoms, and none of the five patients referred to above had histories of less than three years' duration.

#### **Physical Signs of Carpal-tunnel Syndrome**

The early records would suggest that acroparaesthesia is commonly present without associated physical signs. It is my contention that this lack of signs was more apparent than real and arose from the failure to undertake a really careful examination of cutaneous sensation on the fingers.

The physical signs present may be sensory, motor, or trophic, singly or in combination.

Sensory signs, as would be expected from the symptoms, are by far the commonest, and were present in 281 (86%) of the present series. The intensity of the sensory impairment varies within very wide limits, and, when present, was always confined to superficial sensation only, and for the most part it was possible to demonstrate only impaired perception of pain.

Most commonly it is possible to demonstrate impairment of perception of pin-prick over the volar surface of the two terminal phalanges of the index and middle fingers. Involvement of the terminal phalanx of the thumb is less common, and, when the ring finger is involved, loss is usually demonstrable on both the radial and the ulnar side. In no case was any disturbance of sensation found on the little finger, nor would such loss be expected, and in no case did loss of sensation extend beyond the distal transverse crease of the palm.

Loss of a demonstrable degree of thermal sensibility did not appear significantly, and impaired perception of light touch could be demonstrated only in those patients whose fingers were subjectively numb. Postural sensibility is never impaired.

Motor weakness, in the absence of wasting, is difficult to assess, but some degree of weakness appeared to be present in approximately 40% of patients. Most often this weakness will appear first in the short abductor of the thumb. The opponens pollicis is usually affected rather later and to a less degree.

Weakness is, of course, readily demonstrated when wasting is present. Wasting in its smallest degree is best observed by viewing the outstretched palm and digits from the lateral side. In this way quite a small degree of flattening of the thenar eminence may become obvious. More severe wasting is usually most marked in the short abductor of the thumb, the area of which muscle may ultimately become hollowed.

The disability from wasting and weakness of the thenar muscles is remarkably slight—the greater part of the disability arises from disordered sensation. This is clearly demonstrated after surgical treatment, when sensory recovery precedes motor recovery by weeks or months. This lack of disability must be ascribed to the unimpaired function of the long flexor muscles and interossei: when the former muscles are weakened by a median-nerve injury at a higher level, disability becomes very severe.

Trophic changes have already been described under "Symptoms," and further reference to them is made under "Aetiology."

Other signs have been described in the carpal-tunnel syndrome but have not been readily demonstrated in the present series.

Tinel's sign is said to be positive at the wrist in an appreciable number of patients by Phalen (1951) and Phalen and Kendrick (1957), who demonstrated this sign in 89% of 71 patients. I have never succeeded in inducing tingling by percussion over the wrist or palm.

Gilliatt and Wilson (1953) described a test in which they suggested that by cutting off the circulation in the arm by means of a cuff the patient's sensory symptoms could be reproduced. These writers distinguish between the paraesthesiae induced under such circumstances in normal subjects and those induced when "an irritative lesion of the median nerve in the carpal tunnel was suspected." In the latter case they found the induced sensory symptoms to be more severe

and mainly in the median-nerve territory. This finding was present in 24 out of 45 patients in one series described by Heathfield (1957).

I have carried out this manoeuvre and was not successful in inducing specific paraesthesiae in any instance—a finding which is not unexpected when considered in relation to certain anatomical facts and physiological experiments referred to below. Tingling in the median territory was occasionally noted after release of the cuff, and this is more in keeping with the experimental work.

Other signs occasionally observed are deformity of the wrist from old bony injury or arthritis, and callosities on the palm at the site of habitual pressure from tools or instruments used occupationally.

In general, it may be said that the signs are predominantly sensory, in which case they are confined to the distal part of the median territory, that they are often very slight, but that careful examination will nearly always reveal some change.

#### Differential Diagnosis of Carpal-tunnel Syndrome

Once the frequency of this condition is fully realized its recognition seldom presents difficulty, but it must be borne in mind that paraesthesiae may also occur in the hand from other disorders of the central and peripheral nervous system. Among these, disseminated (multiple) sclerosis is probably the most common. In my experience, such symptoms appeared in 107 out of 235 patients with disseminated sclerosis and were the presenting symptoms of an attack in 89. In this disease the paraesthesiae tend to be light and continuous without particular relation to use of the affected limb and without special predilection for night-time. Sensory attacks of this kind are seldom of great duration and do not as a rule exceed two to three weeks. Some difficulty may arise in the absence of abnormal signs, but such is seldom the case, and the diagnosis is usually made clear by the presence of other symptoms and signs and perhaps by a history of previous episodes. Further, the dysaesthesia in this disease is usually of a wide distribution in the limb and is seldom, if ever, confined to the territory of the median nerve.

Symptoms arising in association with a cervical rib or the costo-clavicular syndrome should not give rise to much confusion in diagnosis, although hitherto a lesion in this situation has all too often been held responsible for symptoms which in fact arise at the wrist. A large number of my present cases had previously had treatment directed toward the neck and shoulders; two patients had had cervical ribs removed without benefit, and three had been subjected to scalene section with equal lack of relief. During the period under review, I have seen five patients in whom the diagnosis of costo-clavicular compression was made: four were subjected to operation for removal of an accessory rib and all four experienced some degree of symptomatic relief. The predominant symptoms were, in order of frequency, (a) vascular, with coldness of the affected limb and with typical Raynaud's phenomenon in three; (b) muscular wasting affecting all the intrinsic hand muscles—present in four patients; and (c) sensory symptoms and signs consisting of subjective numbness and objective disturbance of superficial sensation, the latter being present to some degree in all five patients and having a distribution

corresponding to the first dorsal nerve root. Dysaesthesia at night was notable for its absence and its presence by day did not constitute a major symptom.

Cervical spondylosis may cause tingling in the fingers, but the associated symptoms will usually indicate the site of the disturbance. Notable among these are radicular pains—pain and stiffness of the neck. Selective weakness and wasting of the thenar muscles is very rarely seen in this condition. Disturbance of sensation, when present, is usually radicular in distribution and it does not correspond with the anatomical distribution of a peripheral nerve. Loss or reduction of a tendon reflex is not uncommon. X-ray examination of the neck may confirm the diagnosis, but it must be borne in mind that some degree of arthritic change is usual in subjects 50 years old or over, and in the great majority does not result in the production of symptoms.

The various forms of polyneuritis, both acute and chronic, are associated with signs such as loss of tendon reflexes and widespread motor and sensory changes, such as are never encountered in the carpal-tunnel syndrome.

Motor neurone disease may cause some difficulty in its early stages if the wasting should present first in the thenar eminences, but the absence of sensory symptoms and signs and the possible presence of fasciculation usually indicate the true nature of the condition.

It will be seen that the two disorders most likely to be confused with the carpal-tunnel syndrome are cervical rib and cervical osteoarthritis, but that the clinical manifestations of both are usually characteristic enough to prevent confusion arising.

#### Anatomical and Experimental Considerations

Sunderland (1945) has made a detailed study of the internal topography of the median nerve. He found that the nerve divides into its cutaneous and thenar muscular branches at an average distance of 37 mm. distal to the radial styloid line. The thenar muscles are innervated by a large branch containing one large funiculus and by a smaller branch containing two bundles. The bundle containing the digital cutaneous branch from the third interspace has the longest intra-nerve course. He found that the bundle groups of the terminal branches remain separate over the distal 50 mm. of the nerve. At a higher level the funiculi contain mixed fibres destined for many muscular and cutaneous areas. This observation would appear to make it most unlikely that any proximal lesion of the nerve could produce any consistent pattern of localized wasting in the hand.

Blunt (1959) has investigated the vascular anatomy of the median nerve in the forearm and hand by suitable injections of amputated limbs. He has shown that the median nerve below the elbow derives its blood supply from three main sources: proximally in the forearm from the median artery, by a branch of the ulnar artery just proximal to the flexor retinaculum, and more distally by branches from the superficial palmar arch. The latter branches course transversely just distal to the terminal gangliform enlargement of the nerve to give branches to the digital nerves, and continues with the nerve to the thenar muscles. Ascending branches arise from the same source and lie on the anterior aspect of the nerve and in the interfascicular connective tissue. These

branches anastomose with the branch from the ulnar artery, which latter also gives a branch to the common flexor sheath in the carpal-tunnel. The median artery arises from the common interosseous artery, the ulnar artery, or the anterior interosseous artery, and it seldom reaches the wrist.

The venous drainage of the nerve follows the arterial pathways.

Distal to the flexor retinaculum there is a marked increase of perineural connective tissue containing vessels of relatively large size. The surface vascular plexuses and the intraneural vessels run mainly in a longitudinal direction.

Blunt points out that there is nothing in the local vascular architecture to suggest that the median nerve is particularly liable to ischaemia at the wrist, but it may be relevant that in the carpal-tunnel the nerve lies in relatively avascular surroundings. The architecture of the nerve itself in its distal 3 in. (7.5 cm.) is highly fascicular and therefore resistant to compression. In this connexion Bentley and Schlapp (1943) have demonstrated that a peripheral nerve may be oxygenated by diffusion from surrounding tissues after occlusion of its nutrient vessels. The avascular nature of the carpal-tunnel may therefore be of singular significance.

Lewis, Pickering, and Rothschild (1931) studied the subjective and objective results of experimental lesions of peripheral nerves in man, and their results have been further studied by Weddell and Sinclair (1947). The latter writers observed two subjective responses, temporally distinct, that follow experimental compression of the arm with a cuff. They noted, first, a light tingling sensation perceived in the fingers when or shortly after the cuff is inflated, usually very brief and having a pleasant quality, and sometimes associated with a velvety numbness of the finger-tips. This phenomenon they call compression tingling. After release of the cuff a phenomenon referred to as release pricking appears, taking the form of a continuous tingling punctuated by sharp pricking sensation—the common "pins and needles." This is much more prolonged and persists for five minutes or more. They considered that compression tingling is produced at the site of the cuff and that release pricking may arise in any part of the limb, commonly at or near the peripheral nerve endings. The latter phenomenon they ascribe to the release of (unspecified) metabolites.

Other observations by these writers were: that compression at the wrist causes symptoms in the fingers only; that compression of the ulnar nerve without compression of major blood-vessels does not result in significant dysaesthesiae, and thence release pricking must bear a relationship to the state of the peripheral circulation.

Merrington and Nathan (1949), while mainly agreeing with the findings of Weddell and Sinclair, conclude that the symptoms induced by compression arise in the nerve trunks alone and not at the periphery. They produce convincing experimental evidence to support their contention.

It would appear, therefore, that symptoms having the character of those associated with the carpal-tunnel syndrome may be induced artificially by a cuff applied to the arm, and there is strong evidence to suggest that these symptoms arise from ischaemia of the nerve trunks. Can such experimental observations assist in

elucidating the mechanism whereby the sensory symptoms of the carpal-tunnel syndrome arise?

It has been stated above that the median nerve in the tunnel receives its blood supply from above (from the ulnar artery) and below (from the superficial palmar arch) and these two sources anastomose in and around the nerve in the tunnel. It would therefore seem possible that a relative degree of ischaemia might arise from any cause which tended to reduce the blood flow either proximally or distally. In the absence of deformity, it is unlikely that internal bony compression or external compression could be operative factors. Two possibilities remain: the area of the nerve immediately proximal to the flexor retinaculum could be compressed directly by the surrounding tendons, thus interfering with the circulation at the point of entry of the branch from the ulnar artery, or the artery itself might be the subject of direct compression by muscle action. Of these, the former would seem the more likely.

Brain, Wright, and Wilkinson (1947) consider that the condition has an ischaemic basis and results from repeated dorsiflexion of the wrist. In support of this, they indicate that the available space for the median nerve in the tunnel is reduced by dorsiflexion of the wrist. Kendall (1950) considered that more dynamic factors were operative. He observed that the combination of slight dorsiflexion of the wrist with tension on the flexor tendons caused compression of the nerve at the wrist in the cadaver and that, with the wrist in this position, active contraction of the flexor tendons and of the palmaris longus tendon would tend to compress the median nerve between the two.

I support the view that compression of the nerve at the proximal border of the flexor retinaculum (with, of necessity, interference with its blood supply) by muscle action is the main factor in inducing the carpal-tunnel syndrome. This contention is supported in the present series by the striking absence of macroscopic abnormality within the carpal tunnel of the nerve or surrounding structures in the great majority of patients submitted to operation. A wide diversity of opinion has been expressed by various writers about the appearance of the median nerve at operation. Harris (1947) states that the median nerve is normally somewhat enlarged proximal to the tunnel. It is generally accepted that the normal nerve is flattened within the tunnel and that it spreads out into a reddish gangliform swelling at the lower margin of the transverse carpal ligament (see Piersol, 1930). It would seem not unlikely that "abnormalities" described at operation may be due to failure to recognize the normal changes in external configuration of the nerve as it passes from the wrist to the palm.

If ischaemia of the nerve can produce symptoms from pressure occurring proximal to the tunnel, a similar ischaemia arising distally and interfering with the blood flow to the nerve from the superficial palmar arch may account for those patients in whom the appearance of the carpal-tunnel syndrome can be directly linked with the use of tools habitually held firmly in the palm, such as chisels, screw-drivers, lathe handles, and the like.

A number of theories have been put forward to account for the fact that the sensory symptoms of the carpal-tunnel syndrome are so troublesome by night and, as a rule, so little noticed by day. Heathfield (1957) suggests that oedema occurs in the wrist structures by night and also suggests lying on the arm as a factor.

The latter is hardly tenable in those patients whose symptoms are bilateral. Osborne (1959) suggests nocturnal venous stasis as a cause. Others have suggested the nocturnal release of metabolites. All these theories overlook two facts: immobilization of the wrist by day will almost invariably relieve the sensory symptoms at night, whereas the use of night splints alone is usually without beneficial effect; secondly, there is a striking resemblance between the burning and the tingling of this disorder and the symptoms experimentally induced by release of a pressure cuff applied to the arm. It would therefore seem reasonable to suppose that the factors producing the symptoms by night operate by day, and that use or overuse of the wrist and fingers can produce a relative ischaemia, probably as a result of local swelling, and that release of this ischaemia takes place as the swelling subsides during the night's rest.

This contention is further borne out by the comments so frequently made by patients that they dare not knit or sew because of the knowledge that by doing so they will cause severe symptoms at night.

#### Aetiological Factors

*Age.*—The age incidence in the present series is set out in the Table.

Age:	20-30	31-40	41-50	51-60	61-70	70+
No.	17 (5.1%)	59 (18%)	94 (28.4%)	112 (35%)	42 (12.6%)	3 (0.9%)

It will be seen that the condition is most frequently encountered in the fifth and sixth decades.

*Sex.*—The majority of patients were women: only 20 (6%) men were seen with this condition.

*Occupation.*—Of the female patients, 96% were housewives, the majority doing no more than normal household duties. Four were part-time seamstresses, and among the remainder aggravation of symptoms by needlework was a very common complaint. The relationship of symptoms to physical activity was a clear one and patients commonly noticed that their symptoms lessened or even vanished on holiday or during enforced rest as a result of illness or operation. The appearance of symptoms occasionally coincided with the undertaking of new and unaccustomed physical activity. All the 20 male patients were doing heavy manual work: 12 were habitually using tools or machinery involving either a continuous powerful grip or repeated percussion in the palm of the hand.

*Pregnancy.*—Eighteen patients experienced the onset of symptoms during the latter half of pregnancy. Seven developed symptoms during the three months after delivery. No special significance can be attached to this, but it is obvious that increased finger activity (knitting, etc.) is likely in pregnancy, and extra work is also involved in the care of a young child.

*The Menopause.*—No particular connexion with menopausal symptoms was noted, although the maximum age incidence falls at the menopausal age. Young (1950) has postulated an endocrine factor in the production of symptoms in view of their not uncommon appearance in association with the menopause, pregnancy, and acromegaly. (Garland *et al.*, 1957) have suggested that fluid retention in pregnancy may be a factor.)

Bony deformity from old fractures with malunion and from arthritis of the wrist and carpus was present in 12 patients.

The right hand was affected three times as often as the left and the disorder was bilateral in 44 patients. In the bilateral cases the dominant hand was almost always the more severely affected.

It will be seen that the disorder is most common among "ordinary" housewives and that no common factor appears to be operative other than a normal degree of hard work.

#### Treatment

Two lines of treatment were adopted: conservative treatment, by means of which the affected limb was rested; and operative treatment, in the course of which the flexor retinaculum was divided.

The choice of treatment was decided by several factors, principal among which were the physical signs present. In general, all those patients in whom only sensory signs were present and those who displayed only a minor degree of motor weakness without wasting were treated conservatively in the first place. Secondly, the nature of the patient's work was considered: those intending to return to heavy manual work were more likely to experience relapse after conservative treatment, and many of these were submitted to operation without a trial period of rest.

All patients who showed definite muscle-wasting were advised to have surgical treatment, and the majority accepted this advice.

Various means of resting the wrist were considered and tried. Some degree of relief was often obtained by the wearing of a sling by day, but most patients succumbed to the temptation to use the hand.

Night splints of various kinds were tried, with uniform lack of success—patients treated in this way usually stated that they were obliged by their symptoms to remove the splints. It was therefore decided to use plaster-of-Paris to obtain more or less complete immobility of the wrist. Plaster was applied as for a Colles fracture, extending from the base of the thumb and leaving the fingers free. It was very soon found that the relief of nocturnal symptoms obtained in this way was so rapid and so complete that application of plaster could be used as a very reliable diagnostic test in cases of doubt. Frequently, relief of symptoms occurs on the night after application of plaster, and patients described quite dramatically how they had had their first peaceful night for weeks or months. The plaster was removed in all cases after 14 days. 173 patients (53%) were treated in this way, the results being as follows:

Symptoms relieved while in plaster-of-Paris	152 (88%)
Symptom-free after 2 months .. ..	123
"    "    6    "    "    "    "    "    "    "	114
"    "    18    "    "    "    "    "    "    "	89

Nineteen patients either failed to attend for follow-up or did not reply to a questionnaire. Reliable figures for a longer period have not been obtainable, but the inference to be drawn from failure of patients to attend or reply may perhaps be a favourable one.

The prolonged relief of symptoms after this procedure, in spite of return to normal activity, is interesting and possibly results from the fact that it was always explained to the patients that their symptoms had arisen from overuse; possibly thereafter they exercised extra care.

Forty-six patients who suffered relapse or whose symptoms were only partially relieved by immobilization of the wrist were subsequently treated surgically. All



but one were completely relieved, the majority within a few days of operation. The one patient was subsequently relieved by a second operation when it was found that the flexor retinaculum had not been completely divided.

### Surgical Treatment

Although four surgeons were concerned in the treatment of patients in this series, the operative technique did not vary significantly. In all instances a longitudinal incision was made, extending distally from the wrist. In all cases the flexor retinaculum was divided throughout its length. No other surgical manoeuvre was carried out. 116 patients were submitted to operation, and in nine of them bilateral operation was performed on consecutive occasions: it was not considered desirable that both wrists should be immobilized simultaneously.

In the great majority of patients no abnormality of the normal anatomical appearances was observed at operation. The exceptions were those patients in whom trauma had occurred in the palm of the hand in the course of their occupation. In these latter, marked thickening of the transverse carpal ligament was usually present, together with increased flattening of the median nerve in the distal part of the carpal tunnel.

The results of surgical treatment were entirely satisfactory. In only two patients was relief of sensory symptoms incomplete. Objective sensory changes may persist for a time after operation, the actual duration depending on the intensity of the pre-operative changes present. Objective change is usually undetectable after four to six months. Subjective sensory symptoms at night were rapidly relieved, usually prior to discharge from hospital (one to four days).

Motor recovery is very variable. When severe wasting is present, material recovery is not to be expected, but there is remarkably little disability from this. Minor degrees of muscle weakness and wasting usually disappear within three to six months.

Those patients whose work entailed the use of tools likely to press on the palm of the hand were subsequently supplied with sorbo pads to wear during working hours.

No case of keloid scar has been observed and no disability has arisen directly attributable to operation other than a minor degree of tenderness over the incision, which is usually short-lived. So far, no patient whose symptoms have been relieved by surgery has suffered any relapse.

Bilateral operation was not carried out on all patients with bilateral symptoms. It was usually found that after having the more severely affected side cured, the less affected hand improved spontaneously, no doubt because of the increased use made of the treated hand.

Recently, treatment with injection of hydrocortisone into the carpal tunnel has been advocated. I have no personal experience of this treatment, but have had referred to me nine patients so treated elsewhere, in none of whom had material benefit arisen. The rationale of this form of treatment is obscure: possibly the occasional association of the carpal-tunnel syndrome with such disorders as "tennis elbow" has led to its trial.

### Summary

The carpal-tunnel syndrome comes within the category of minor ailments. Nevertheless, it is not

only very common but is also a potential cause of much disability and distress, particularly as a result of its tendency to interfere with sleep. It is a condition which in the past has been all too commonly misdiagnosed and much time and effort have been directed toward treatment of the neck and shoulders in the mistaken belief that the symptoms are related to the "costo-clavicular syndrome." The concept of the latter as a common cause of peripheral paraesthesiae dies very hard. I have found, and still find, that the great majority of patients with the carpal-tunnel syndrome are sent to hospital for investigation of "cervical rib" or "costo-clavicular compression." It is also common to learn that patients have frequently been subjected to manipulation of the neck and neck-stretching with slings before the true diagnosis has become apparent.

Much time and distress could be avoided by the earlier recognition of this condition, and doubt may be readily dispelled by the simple diagnostic (and therapeutic) expedient of immobilizing the wrist in plaster-of-Paris.

While it is clear that the disorder is basically an ischaemic one, in which overuse of the wrist and hand plays an essential part, the exact mechanism by which this comes about is not entirely clear. From the available anatomical and experimental evidence, it seems likely that the blood supply to the median nerve in the carpal tunnel may suffer interference either proximally or distally, the former possibly by local intermittent swelling of a degree sufficient to interfere with the branch from the ulnar artery, the swelling or oedema occurring in the tendon sheaths or the carpal ligament or both.

In the case of the distal blood supply, this may suffer interference by direct pressure, externally applied, affecting the branches from the superficial palmar arch.

While there is still some difference of opinion with regard to the "normal" appearance of the median nerve at the wrist and in the carpal tunnel, there was seldom any convincing macroscopic abnormality in the majority of patients submitted to surgery in the present series.

In conclusion, it may be said that this condition, once diagnosed, is readily and satisfactorily treated and that the delight of the treated patient makes the disorder one of the most satisfactory of minor ailments encountered in neurological practice.

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## FUTURE PLACE OF LUMBAR SYMPATHECTOMY IN OBLITERATIVE VASCULAR DISEASE OF LOWER LIMBS

BY

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With the steady increase in the popularity of direct arterial surgery, in the form of grafting or disobliteration, the place of lumbar sympathectomy by itself in the treatment of obliterative vascular disease of the lower limbs is uncertain. It therefore seems worth while to consider the future status of this operation in the light of the results it achieves. The following observations are based on a review of 100 consecutive cases of obliterative disease followed up for between one and seven years (Table I) after lumbar sympathectomy. All the patients except two were

TABLE I.—Interval Between Operation and Review in 100 Consecutive Patients

Interval in years	1-2	2-3	3-4	4-5	5-6	6-7
No. of patients ..	35	22	13	9	16	5

Note.—25 of the patients were dead and 2 untraced by the time of review.

TABLE II.—Reason for Sympathectomy in the 100 Patients

Ischaemic skin lesion or rest pain without claudication ..	14
..... with .. .. .	27
Uncomplicated claudication .. .. .	59

traced, and follow-up examination was carried out personally on all the survivors.

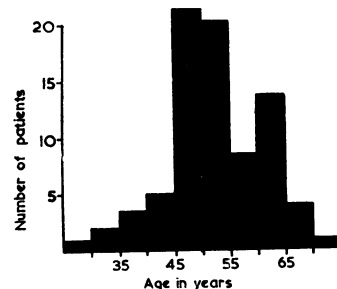
The various reasons for operation are set out in Table II, and the results achieved are discussed under four headings: (1) sympathectomy and intermittent claudication; (2) sympathectomy and limb survival; (3) life prognosis after sympathectomy; and (4) the selection of patients for sympathectomy.

### Sympathectomy and Intermittent Claudication

Intermittent claudication was complained of by 86 of the 100 patients. It is a predominantly male symptom, there being in the present series 6.6 males to each female. Contrary to the widely held belief that atherosclerosis is a disease of old age, the mean age at onset of the symptom was 52 years. Moreover, as illustrated in the Chart, there was a striking rise in the incidence after the age of 45. Indeed, claudication

may be encountered in patients in their late twenties or thirties, and the early age of onset makes it a symptom of great importance.

Claudication is felt typically in the calf, this being the site in 93% of the patients who complained of it (Table III). Calf pain may be associated with buttock or thigh pain in patients with high arterial occlusions, and sometimes it is associated with pain in the foot. In only 7% of the patients was pain limited to the small muscles of the sole, which is perhaps surprising as these muscles are constantly in contraction during weight-bearing to assist in maintaining the longitudinal arch of the foot. By the time most of the patients were originally seen they were being forced to stop by the pain, and the claudication distance most commonly was 100 to 200 yards.



Age at onset of claudication in the 86 patients suffering from this condition.

TABLE III.—Site of Pain in 86 Patients Suffering from Intermittent Claudication

Site of Pain	No. of Patients
Buttocks, thigh, and calf .. .. .	8
Calf only .. .. .	60
.. and foot .. .. .	12
Foot only .. .. .	6

### How Far Were the Patients with Intermittent Claudication Benefited by Sympathectomy?

Of the surviving non-amputated patients attending for review, 47 had been sympathectomized for claudication uncomplicated by skin lesions. These patients were therefore specially questioned about any improvement after operation. Twenty-one claimed that their claudication had been improved and 26 were emphatic that they had not been benefited in this respect. This suggests that a little under half the patients were improved by operation. However, more critical consideration of the 21 patients claiming benefit revealed positive improvement in only six, or 13%. A number of the patients who had claimed an increase in their walking distance admitted, on further questioning, that they had learned to walk much more slowly, and that if they walked as quickly as they had done before operation claudication pain came on as rapidly. Other patients did not claudicate after operation simply because claudication in the other leg, or anginal pain, forced them to stop before the pre-operative claudication distance for the sympathectomized leg was reached.

Blood-flow measurements, both at rest and in activity, and in limbs with normal and with occluded arteries, certainly give no support to the view that sympathectomy produces more than a transitory increase in muscle blood-flow (Grant and Holling, 1938; Wilkins and Eichna, 1941; Stein, Harpuder, and Byer, 1948; Shepherd, 1950; Dornhorst and Sharpey-Schafer, 1951; Duff, 1951; Barcroft, Dornhorst, McClatchey, and Tanner, 1952). The great difficulty in assessing the effect of treatment on such a purely subjective symptom as intermittent claudication lies in the fact that it is prone in its natural history to wide spontaneous fluctuations in severity. This is what makes the value of sympathectomy in the treatment of intermittent claudication such a