absorption is too inadequate at present for further speculation in this regard.

Summary

Egg-yolk lipid has a relatively high iodine value and a relatively high content of polyunsaturated fatty acids, but when fed to a man a rapid rise in serum-cholesterol levels follows.

The feeding of fractionated egg yolk reveals that this activity resides in the acetone-soluble fraction, but on saponification of this fraction neither the unsaponifiable nor the saponifiable fractions give a rise in serum-cholesterol levels when fed separately. For a rise to be seen they have to be fed together, because a delay of only six hours between the feeding of the one and the other considerably nullifies this effect.

It was shown by substitution that the effects of the unsaponifiable and saponifiable fractions could be reproduced by cholesterol on the one hand and a fat of a similar iodine value on the other. Cholesterol fed with oils of high-iodine value was without effect.

Further experiments revealed that the range of intake of cholesterol where an effect on the serum levels was observed was between 40 to 500 mg. daily, which is below the usual daily intake expected in non-vegetarian diets.

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REFERENCES

- Abell, L. L., Levy, B. B., Brodie, B. B., and Kendall, F. E. (1952). *J. biol. Chem.*, **195**, 357.
- Ahrens, E. H., jun., Hirsch, J., Insull, W., jun., Tsaltas, T. T., Blomstrand, R., and Peterson, M. L. (1957). *Lancet*, **1**, 943.
- Anderson, J. T., and Keys, A. (1956). *Clin. Chem.*, **2**, 145.
- Beveridge, J. M. R., Connell, W. F., Mayer, G. A., and Haust, H. L. (1960). *J. Nutr.*, **71**, 61.
- Bronte-Stewart, B. (1961). *Fed. Proc.*, **20**, Suppl. 7, p. 127.
- Antonis, A., Eales, L., and Brock, J. F. (1956). *Lancet*, **1**, 521.
- Chaikoff, I. L., Siperstein, M. D., and Dauben, W. G. (1952). *J. biol. Chem.*, **194**, 413.
- Connor, W. E., Hodges, R. E., and Bleiler, R. E. (1961). *J. Lab. clin. Med.*, **57**, 331.
- Gordon, H., Wilkens, J., and Brock, J. F. (1958). *Lancet*, **2**, 244.
- Horlick, L., and O'Neil, J. B. (1958). *Ibid.*, **2**, 243.
- Howe, E. E., Bosshardt, D. K., and Huff, J. W. (1960). *J. Nutr.*, **72**, 379.
- Keys, A., Anderson, J. T., and Grande, F. (1957). *Lancet*, **1**, 66.
- Mickelson, O., Adelson, S. F., and Fidanza, F. (1956). *J. Nutr.*, **59**, 39.
- Kinsell, L. W., and Sinclair, H. M. (1957). *Lancet*, **1**, 883.
- Lea, C. H., and Rhodes, D. N. (1954). *Biochem. J.*, **57**, xxiii.
- Marinetti, G. V., Erbland, J., and Stotz, E. (1959). *Biochem. Biophys. Acta (Amst.)*, **31**, 251.
- Mayer, G. A., Connell, W. F., de Wolfe, M. S., and Beveridge, J. M. R. (1954). *Amer. J. clin. Nutr.*, **2**, 316.
- Mellville, D. B. (1944). In *Vitamins and Hormones*, edited by R. S. Harris and K. V. Thimann, vol. 2; p. 29. Academic Press Inc., N.Y.
- Messinger, W. J., Porosowska, Y., and Steele, J. M. (1950). *Arch. intern. Med.*, **86**, 189.
- Okey, R. (1946). *J. biol. Chem.*, **165**, 383.
- Pollak, O. J. (1958). *J. Amer. Geriatr. Soc.*, **6**, 614.
- Reiser, R. (1951). *J. Nutr.*, **44**, 159.
- Stoffels, W., Chu, F., and Ahrens, E. H., jun. (1959). *Ann. Chem.*, **31**, 307.
- Swell, L., Boiter, T. A., Field, H., jun., and Treadwell, C. R. (1955). *Amer. J. Physiol.*, **180**, 129.
- van de Kamer, J. H., ten Bokkel Huinink, H., and Weyers, H. A. (1949). *J. biol. Chem.*, **177**, 347.
- Wijs, J. J. A. (1898). *Z. Untersuch. Nahr.-u. Genussmitt.*, **1**, 561.
- Wilkens, J. A. (1959). *S. Afr. med. J.*, **33**, 1076.

CARPAL-TUNNEL SYNDROME

WITH PARTICULAR REFERENCE TO SURGICAL TREATMENT

BY

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The history of this common disorder was briefly summarized in a previous publication (Garland, Bradshaw, and Clark, 1957). In 1963 every British neurologist will have seen large numbers of victims, but from personal observation we know that the syndrome is not recognized in many countries in Eastern Europe and Asia. There is still, however, no unanimity in Great Britain as to the optimum method of treatment. Although our main purpose is to show the excellent results of surgical treatment, the diagnosis is still sometimes incorrectly made, or, more frequently, the symptoms are attributed to something else, so that diagnostic criteria must be discussed.

The diagnosis is usually very easy to the trained neurologist but perhaps to few others, and we think this is easily explained. In our experience the commonest, the most important, and sometimes the only physical sign is weakness of the abductor pollicis brevis, the sole action of which is to abduct the thumb at right angles to the palm (Figs. 1 and 2), though this was not the experience of Kendall (1960). This can be difficult of assessment in an uncooperative patient, and in minimal degree can only be assessed against a control, which might be the unaffected hand of the patient; obvious wasting of the abductor pollicis brevis is very much less common. Another pitfall is the testing of objective sensory change in the usual median nerve distribution, and, since pain is frequently the only modality to be affected, it is often difficult or impossible, even in the most experienced hands, to make an accurate assessment; this is made still more complex because pain sensation may be diminished or accentuated. Another common and misleading feature of the syndrome, for which no adequate explanation has yet been given, is the complaint of pain proximal to the wrist and which is sometimes claimed to reach as high as the shoulder.

We have not infrequently seen patients who have failed to improve after surgical treatment (not advised by ourselves) because they were suffering from a cervical root pain, and in fact this is the only common differential diagnosis; further, because of the age-group usually involved, a large number of these patients have radiological evidence of cervical disk damage, and indeed some may be suffering from ipsilateral root pain as well as the carpal-tunnel syndrome. Ipsilateral cervical rib never produces the syndrome under discussion.

The main cause of failure, of which we have had little experience, arises through the surgeon's failure to make a complete division of the anterior carpal ligament (Goodman and Gilliat, 1961). In 1963 we are surprised to find that there are those who feel that surgical treatment is either unnecessary or frequently

may be a failure. In skilled hands the operation can only be ranked as a simple and minor procedure. It is interesting that in the first large series of surgically treated patients (Kremer, Gilliatt, Golding, and Wilson, 1953) 3 out of 40 operations were unsuccessful until a second exploration made it clear that the anterior carpal ligament had been incompletely divided, and subsequent division relieved the symptoms. We believe that if this operation is carried out correctly almost every patient is immediately relieved of pain and that all signs and symptoms soon disappear. To this

FIG. 1.—Testing the abductor pollicis brevis—the right way.

FIG. 2.—Testing the abductor pollicis brevis—the wrong way.

categorical statement there is one amendment—namely, that those known to suffer from notable neuroticism before operation are liable to complain of incomplete relief or subsequent relapse, even though the objective signs of median nerve compression, including electrical changes, have disappeared (11 in this series).

Heathfield (1957) submitted 51 of his 80 patients to splinting, though he stated that “results of operation are so good that in case of failure the wrist should be explored.” Kendall (1960) referred to 116 patients submitted to operation satisfactorily, four different surgeons being concerned. He also submitted 173 patients to conservative treatment with plaster-of-Paris splints for two weeks; 88% were relieved while in plaster, but almost half had relapsed within 18 months and most of these were then subjected to surgery, all with complete relief. In view of these findings it is surprising to discover Lishman and Russell (1961) opposing surgery and making claims for conservative

measures. In their rather small series it is interesting, however, to note that of five different methods of treatment only one was completely successful—a surgical operation (six patients). Lees and Liversedge (1959) claimed considerable therapeutic value from the use of oral steroids in a small number of patients followed up for a very short period.

A startling statement was made by Astley (1962)—namely, that the carpal-tunnel syndrome “must, after all, be a self-limiting condition.” We admit that occasionally the symptoms undergo “spontaneous” relief so that some patients give a history of relapse and remission; all those experienced in this condition are aware that it may appear in pregnancy (Wilkinson, 1960), and disappear after parturition (only one in our series), but these examples constitute only a small proportion of any series, and indeed patients may experience continuing symptoms for 30 years (Table I). In this context we are not sure what a “self-limiting condition” could mean; the disorder under discussion only results from compression of the median nerve in the carpal tunnel, and although many pathological factors may be involved we are not looking at “a disease” and the condition must of necessity be self-limiting as regards its anatomical substratum. The only other naturally limiting factor would appear to be the grave.

TABLE I.—Duration of Symptoms

	Unilateral	Bilateral	Total
Less than 1 year	35	68	103
1 to 10 years	18	46	64
Over 10 years	3	6	9
Maximum	18 years	30 years	
Mean	28 months	37 months	32 months
Total (nerves) ..	56	120	176

Diagnostic Criteria and Clinical Material

We believe, as do most British neurologists, that the syndrome under discussion results only from compression of the median nerve in the carpal tunnel. It would seem that contraction of the tunnel develops, especially in women, in middle age, and the basic reasons for this are unknown; gross and obvious local pathological changes are sometimes seen, including rheumatoid or degenerative disease of the carpal joints, ganglia, previous fractures, and other disorders (amounting in this series to 15 patients—20 nerves). Such compression results in episodic pain which is referred to the whole or part of the distribution of the median nerve in the hand; a very common feature, already referred to, is pain proximal to the site of the compression, and this is probably the main reason why the long-known syndrome of “acroparaesthesiae” remained a pathological mystery. The pain is almost invariably worse at night and is often purely nocturnal, so that insomnia is frequent. Observations at operation sometimes make it quite certain that oedema of the nerve is often considerable, and this would seem to be the basis of those examples that develop during pregnancy and terminate immediately after parturition. Tingling in the four median-innervated fingers is common, but such tingling is probably never felt above the wrist.

Although the symptoms are almost only of a sensory kind, the most constant physical sign is a motor disturbance, and this conforms to the general rule that with compressive lesions of mixed peripheral nerves the motor fibres appear to be more vulnerable than the sensory, as opposed, for example, to the commonest

neuropathy seen in diabetes. There is probably a stage in the early history of the syndrome where no physical signs are demonstrable. Testing of the opponens pollicis is unreliable and therefore unimportant. Manual compression over the carpal ligament frequently precipitates tingling in some or all of the four median fingers, and this is not seen in the normal person; we have only used this sign of recent years. Pain sensation in the median distribution may be depressed or enhanced; we no longer test other sensory modalities (Table II). Symptoms may be precipitated in the fingers by occlusion of the brachial artery, but this sign has been discarded as being of little practical value. Measurement of the nerve-conduction rate, though of academic interest, is

TABLE II.—Major Symptoms and Signs in Order of Frequency

Symptoms	No.	%	Signs	No.	%
Pain	138	79	Weakness of abductor pollicis brevis .. .	159	91
Tingling	128	72	Tingling on carpal compression .. .	63	68*
Pain above wrist .. .	82	47	Pain on carpal compression .. .	48	52*
Pain in shoulder .. .	32	18	Median hypalgesia .. .	71	40
Numbness in fingers ..	30	17	Median hyperalgesia .. .	32	18
			Wasting of thenar eminence .. .	23	13

* Percentage of number tested (131).

considered to be of little practical importance in diagnosis. The nerve-conduction rate can be normal, especially in those with a short history, even when the diagnosis is not in question (Goodman and Gilliat, 1961), and the conduction rate is sometimes found to be slowed in those who have neither signs nor symptoms of median nerve compression; the main clinical value of this sign is perhaps to show objective evidence of improvement after treatment in the patient who claims to be no better.

On the basis of the above criteria 116 patients have been seen in the past 13 years (up to the end of 1961), including those previously reviewed (Garland *et al.*, 1957). The syndrome was bilateral in 60 and unilateral in 56, so that the total number of nerves involved was 176. Of these, 149 were treated surgically. There were 95 women and 21 men (4.5:1). The age at onset ranged from 22 to 78 years, with a mean of 48 years, and with no significant age difference between the sexes. Our findings in relation to handedness are inadequate but suggest that those with symptoms on the left are more commonly left-handed.

Treatment

In order to be certain that the median nerve shall be truly decompressed it is essential that the subcutaneous exposure shall be extensive. Even a few strands of the transverse carpal ligament left intact are sufficient to cause failure. Not infrequently the site of compression is at the proximal part of the palmar fascia distal to the transverse carpal ligament, and this area ought always to be exposed to make sure that there be no subcutaneous ganglion or other pathological change. The long subcutaneous exposure is absolutely obligatory when the carpal-tunnel syndrome constitutes the presenting symptoms of rheumatoid disease or "osteoarthritis" of the wrist, or is in relation to local deformity caused by previous fracture in the vicinity.

Although the subcutaneous exposure must be extensive it is preferable that the skin incision shall be as small as is compatible with the needs of the decompression and that the resultant scar shall become invisible.

These desiderata are best attained by placing the incision in the crease in the palm at the base of the thenar eminence and then curving it to the transverse crease across the anterior aspect of the wrist to run medially to the pisiform bone (Fig. 3). The flap so formed when pulled distally and medially exposes the proximal part of the palmar fascia. After nicking the palmar fascia with a knife the subcutaneous exposure can be easily extended with scissor cuts distally into the palm and proximally into the forearm by severing the transverse

FIG. 3.—Incision used in exploring the carpal tunnel.

carpal ligament. The tip of the surgeon's little finger inserted under the skin of the forearm will make quite certain that all the transverse carpal ligament and the neighbouring fascial envelope of the forearm have been divided; the palmar exposure is immediately under the eye.

Any smaller subcutaneous exposure will inevitably mean, sooner or later, that the operation will fail and so have to be repeated. It is a surgical truism that the exposure must be large enough for the surgeon accurately to achieve his object even though a large wound may be necessary. In this operation all that is required can always be obtained through the moderate-sized opening described and yet leave a scar which will eventually become invisible. Even in the unlikely event of a surgical accident the incision could readily be extended to any length up the medial margin of the forearm or down to the finger webs and still leave a scar in a position where it would be least noticeable.

The operation is usually performed in a bloodless field produced by a pneumatic tourniquet round the upper arm. In the majority of patients the exposed median nerve will show no detectable abnormality, but in many, in spite of the presence of the tourniquet, tiny blood-vessels will appear running longitudinally down the nerve at the site of the previous compression. The discovery of these vessels is a good prognostic sign and immediate relief of symptoms is to be expected. It is probable that such vessels would always be detectable if a prolonged search were carried out on the nerves not instantly showing them. It is advisable to forgo the tourniquet when operating on older people, diabetics, or on any patient known to have arteriosclerosis, lest there should be any permanent ill-effect on the circulation of the limb. Even without the tourniquet troublesome bleeding is unlikely to occur provided traction on the two lips of the incision be maintained with the aid of small rake retractors.

In this series the 19 patients (involving 27 nerves) who were not subjected to operation received no treatment

at all. Of the 116 patients, 19 were followed up for more than six years, 64 for one to six years, 30 for less than one year, and three were not seen again. The maximum period of follow-up was nine years. The results of surgical treatment and the symptomatic relief obtained in those improved but not cured are shown in Tables III and IV, while possible explanations of failure to respond to surgery are given in Tables V.

TABLE III.—Results in Those Patients Followed Up for at Least One Year (131 Nerves)

	Operation		No Operation	
	Unilateral	Bilateral	Operation Advised	Operation Not Advised
Symptom-free ..	26 (93%)	59 (72.5%)	0	8 (73%)
Improved ..	2 (7%)	20 (25%)	1 (9%)	1 (9%)
Unchanged ..	0	2 (2.5%)	10 (91%)	2 (18%)
Total (nerves) ..	28 (100%)	81 (100%)	11 (100%)	11 (100%)

TABLE IV.—Symptomatic Relief in Those Improved But Not Symptom-free After One Year

	Pain	Tingling
Total relief ..	5 (22.5%)	3 (13.5%)
Partial relief ..	17 (77.5%)	17 (77.5%)
No relief ..	0	2 (9.0%)
Total (nerves) ..	22 (100%)	22 (100%)

TABLE V.—Probable Reasons for the Persistence of Symptoms One Year After Operation

	Improved but not Symptom-free	Unchanged
Severe neuroticism ..	11 (50%)	1 (50%) (with previous post-traumatic neuroma and causalgia)
Coincidental cervical spondylosis ..	2 (9%)	0
Advanced rheumatoid disease ..	2 (9%)	0
No obvious reason ..	7 (32%)	0
Operation by another surgeon ..	0	1 (50%)
Total (nerves) ..	22 (100%)	2 (100%)

The reasons why some patients were not submitted to operation were either because the symptoms were so mild and intermittent that we felt no operation was necessary or that, despite our advice to the contrary, the patient refused to undergo surgical treatment. The difference in the fates of these two subgroups is shown in Table III.

Discussion

Our experience suggests that there may be some unknown aetiological factor which determines whether the syndrome be unilateral or bilateral, for the following reasons. The ratio of females to males in unilateral examples is 2.5:1 but in the bilateral examples is 9:1; this difference is statistically highly significant ($P < 0.01$). A similar distinction may also be observed by consideration of the results of surgical treatment in the two groups. Although in view of the small numbers involved the figures are not significant at the 5% level, the observed difference is strongly suggestive and certainly important. Our findings show results of surgical treatment which are so satisfying that they can rarely be excelled in any surgical procedure. The patient need not be detained in hospital for more than a few hours, and the wound is healed in 10 days, which is the only period during which the patient is incapacitated. Splinting is a more disabling procedure which has to be carried out for a longer period and for which the relapse rate is admitted to be considerable.

The injection of hydrocortisone into the carpal tunnel may give immediate relief, but the relapse rate is again high (Goodman and Foster, 1962) and this form of treatment should perhaps be reserved for the pregnant woman or those in whom surgical treatment is refused. We can see little justification for the use of oral steroids, which are presumably effective only by reducing oedema (Lees and Liversedge, 1959), which are known to be followed by a considerable incidence of relapse, and which must be unjustified in the long-term treatment of any minor malady, no matter how unpleasant.

Summary

Compression of the median nerve in the carpal tunnel is a common condition. It is more than four times commoner in females than in males, and the age of onset varies from 22 to 78 years. In 116 patients seen in 13 years the syndrome was unilateral in 56 and bilateral in 60.

The most frequent symptom is pain, which may involve the whole hand or extend up to the shoulder. A more common symptom is tingling, which is limited to the hand. The symptoms do not involve the little finger. The most common physical sign is weakness of the abductor pollicis brevis, and the diagnosis usually turns on the correct testing of this muscle. Pain or tingling on carpal-tunnel compression is frequent, objective sensory change in the hand is less common, and muscle-wasting is rare.

The syndrome is produced by compression of the median nerve in the carpal tunnel and occasionally there are obvious causes such as arthritis or previous injury. There seems to be some unknown aetiological factor determining whether one or both sides are affected. The ratio of females to males in unilateral cases is 2.5:1 and in bilateral 9:1.

The diagnosis can be made on purely clinical assessment requiring no laboratory aids.

Surgical treatment is simple and very effective. All other forms of treatment are less effective and relapse may occur; relapse does not occur after surgical treatment.

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REFERENCES

- Astley, C. E. (1962). *Brit. med. J.*, **1**, 1007.
- Garland, H., Bradshaw, J. P. P., and Clark, J. M. P. (1957). *Ibid.*, **1**, 730.
- Goodman, H. V., and Foster, J. B. (1962). *Ann. phys. Med.*, **6**, 287.
- and Gilliat, R. W. (1961). *Ibid.*, **6**, 137.
- Heathfield, K. W. G. (1957). *Lancet*, **2**, 663.
- Kendall, D. (1960). *Brit. med. J.*, **2**, 1633.
- Kremer, M., Gilliat, R. W., Golding, J. S. R., and Wilson, T. G. (1953). *Lancet*, **2**, 590.
- Lees, F., and Liversedge, L. A. (1959). *Ibid.*, **2**, 1120.
- Lishman, W. A., and Russell, W. R. (1961). *Ibid.*, **2**, 941.
- Wilkinson, M. (1960). *Ibid.*, **1**, 453.

More than 80% of all babies born in Hong Kong during the last three months of 1962 received B.C.G. vaccinations under the Government's anti-tuberculosis campaign. Statistics released by the Director of Medical and Health Services there show that of the total of 36,101 B.C.G. vaccinations carried out during the quarter 26,754 were given to newborn infants. The total of 36,101 represented an increase of 33.3% over B.C.G. vaccinations carried out in the preceding quarter.