Brain (1972) 95, 163–168.

CAUSALGIA TREATED BY SELECTIVE LARGE FIBRE STIMULATION OF PERIPHERAL NERVE

BY

G. A. MEYER AND H. L. FIELDS[1]

(From the Walter Reed Army Medical Center, Washington, D.C., and Division of Neurosurgery, University of Texas Medical Branch, Galveston, Texas, 77550)

INTRODUCTION

ALTHOUGH much of medical treatment has been placed upon a rational basis during the last half century, the treatment of severe recurring or chronic pain remains relatively empirical.

Accumulated clinical and experimental evidence indicates that the sensation of pain involves central pathways which are also responsive to non-nociceptive stimuli. Stimulation of large myelinated sensory fibres exerts a segmental inhibitory effect on input to certain dorsal horn interneurons in the cat (Wall and Cronly-Dillon, 1960; Wall, 1964). These same interneurons are activated by impulses in small diameter afferent fibres responsive to noxious stimuli. Selective stimulation of peripheral nerve produces pain only when the threshold for small diameter afferents has been exceeded, while at lower stimulus intensities only non-painful paræsthesiæ are produced (Collins, Nulsen and Randt, 1960). Thus the possibility of suppressing pain by selective large fibre stimulation arose. Consistent with Melzack and Wall's "Gate Control" theory (1965), preliminary clinical studies (Wall and Sweet, 1967; Sweet, 1968) demonstrated dramatic relief of pain using this technique. Stimulation of the dorsal columns, which presumably is selective for the central projections of large diameter afferents, has also been reported to relieve pain (Shealy, Mortimer and Hagfors, 1970).

This report presents the results of our experience using the transcutaneous stimulation of peripheral nerve in patients with causalgia. It is concluded that this technique is of value as an adjunct to physical therapy in the management of causalgia.

METHOD

Walter Reed General Hospital patients with pain secondary to nerve injury and who had obtained incomplete relief from non-narcotic analgesics were referred for study by members of the

[1]Present address: Neurological Unit, Boston City Hospital, Boston, Mass. 02118.

hospital staff. Patients were asked to refrain from taking analgesic medication the day of stimulation and ward physicians were instructed not to tell the patients anything about the procedure. At the initial session, patients were asked about the nature and duration of their pain, and a neurological examination established the nerve injured. The site of injury, its extent and additional information relevant to the nature of the lesion, was established by surgical exposure in four patients and by electrodiagnostic studies in a fifth.

Patients were only told that the procedure was safe, non-painful and that we were attempting to obtain information of diagnostic value concerning their condition. No patient had heard of the procedure in advance of the first session.

An accessible site, central to the point of injury was then selected for stimulation. The stimulation parameters were 0·1 msec duration, unidirectional square pulses of variable voltage, delivered at a rate 100 Hz. Electrodes consisted of insulated stiff copper wires, tipped with stainless steel balls of 3 mm diameter and 2 cm separation moistened with electrolyte paste and applied directly over the course of the nerve trunk being stimulated. If the electrodes were properly placed, paræsthesiæ were elicited in the distribution of the nerve stimulated (Wall and Sweet, 1967). Although we did not monitor stimulus current, the voltage was adjusted so that no motor activity was produced and the sensation perceived was not reported as painful. This ensured that only larger diameter, more rapidly conducting fibres were activated (Collins *et al.*, 1960).

In order to produce satisfactory paræsthesiæ it was necessary to stimulate a section of nerve proximal to the point of injury. Stimulation of affected nerves distal to the lesion usually exacerbated the pain, while stimulation of intact, near-by nerves was ineffectual. We were not able consistently to stimulate the sciatic or tibial nerve by the transcutaneous technique. In all cases, the upper extremity nerves were stimulated at the anterior axillary fold and the common peroneal was stimulated at the knee.

After paræsthesiæ had been elicited in an area supplied by the nerve being stimulated for at least two but no more than three minutes, the stimulator was removed and the patients were asked if there had been any change in their condition. When pain relief was reported, patients were asked to estimate the percentage remaining pain relative to that just prior to stimulation. They were also told that if their pain recurred they were to record time and percentage of original pain that returned. As supporting data we questioned ward staff and examined the nurses' notes.

Placebo stimulation consisted of stimulating areas of skin in proximity to the painful area but well away from the course of any major nerve trunk. Paræsthesiæ were not produced by placebo stimulation.

Our definition of causalgia is: a severe, burning, intractable pain which is referred to (or perceived in) the distribution of a partially damaged peripheral nerve and is intensified by emotional and certain sensory stimuli (Wilkins and Brody, 1970; Mitchell, 1872).

Results

Our results were similar to those of Wall and Sweet (1967). If the electrodes were properly placed, the effect of stimulation was immediate dramatic relief of pain during stimulation for six of the eight cases. After stimulation, pain relief persisted for periods varying from five minutes to ten hours. Although the degree of pain relief varied from patient to patient, it was consistent for a given patient from trial to trial.

Case number three is illustrative and representative.

C. C., aged 19. A helicopter pilot was wounded by grenade fragments in early 1969. Initial examination showed massive blood loss from a penetrating fragment wound of the left arm, loss of function of the left median nerve and ulnar nerve, and a large macerated avulsion wound of the left

buttock. The disrupted left brachial artery was immediately repaired with autogenous vein and the buttock wound debrided and packed open.

Shortly after awakening from anæsthesia, he had a sharp burning pain, in the left palm and flexor surface of the forearm. Ten days later Army physicians noted good function of the repaired artery, but the pain in his left arm persisted. He was transferred to the Walter Reed General Hospital seven weeks after wounding.

Three months after wounding the pain was still present. There was marked palmar erythema, no ulnar nerve function, a trace of movement of several median innervated muscles, and small irregular patches of retained sensation alternating with areas of hyperpathia in the median distribution. Electrodiagnostic studies confirmed total loss of function of the ulnar nerve with minimal function of the median nerve. Nerve repair and sympathectomy were delayed for several weeks because of suppuration in the left buttock wound. The patient obtained some relief by applying warm compresses to the painful area. The pain was sharply accentuated by emotional stimuli.

Three stellate ganglion blocks with local anæsthetic were done, two giving excellent pain relief for three hours while the third was technically unsatisfactory.

Several days after the last sympathetic block, large fibre stimulation was used to try to give relief. The patient's median nerve was stimulated at the anterior axillary fold. During stimulation non-painful paræsthesiæ in the median nerve distribution were reported by the patient. Immediately after stimulation the patient said that 90 per cent of his pain had been relieved. Relief persisted for two hours but was followed by a half-hour period during which the intensity of pain was greater than that prior to stimulation. After this the pain subsided to its original level. Repeating the stimulation during this rebound of increased pain intensity was as effective as the original stimulation.

This procedure was carried out daily for the next three weeks with no significant change in degree or duration of pain relief. During this time repeated stimulation of the skin away from the nerve trunks afforded no pain relief. During one of these "placebo" stimulations, the patient asked to place the electrodes himself, saying impatiently, "Doc, that's not quite the right spot; it's not going to do any good." After this the patient was allowed to place the electrodes himself. Stimulation immediately before physical treatment improved his ability to co-operate with passive and active exercises.

Four months after wounding, the patient had a left anterior cervical sympathectomy and had total relief of pain although he expressed displeasure about his drooping lid. Ten days later he began to have intermittent episodes of similar but much less severe pain. Stimulation of the proximal median nerve again produced marked relief.

At eighteen weeks after wounding, the nerves in the left upper arm were surgically exposed. The ulnar nerve was found severed with a proximal neuroma and a 6 cm gap between proximal and distal ends, it was transposed to the flexor aspect of the elbow and a neurorrhaphy accomplished. The median nerve was encased in scar tissue adherent to the arterial venograft. After freeing the median nerve, inspection showed that more than half its fascicles were intact, it was therefore left in continuity and neurolysis completed.

Eight months after wounding there was marked improvement in sensory and motor function of the median nerve. Tinel's sign had progressed down the course of the transposed ulnar nerve. The patient had had intermittent recurrence of burning pain which he relieved by tapping on the flexor surface of his forearm over the course of his now functional median nerve.

In this case daily stimulation produced relief consistent in duration and degree for three weeks but progress toward permanent relief of pain only began after definitive surgical repair of the median nerve. It is important to stress that sympathectomy, though helpful, did not relieve the pain.

Two patients, 9 and 14, were clearly helped by large fibre stimulation. In both cases the affected part was immobilized by pain. Both were able to begin physical therapy following their first trial of stimulation. Both patients were free of severe pain within one week and neither required sympathectomy or surgery on the injured nerve. It should be stressed that in both cases the pain had been present for less than six weeks.

In contrast, patients 8 and 12 were helped very little by large fibre stimulation. Pain had been present for over three months in both cases. In Case 8, paræsthesias could not be produced consistently in the region of pain. Case 12 is presented.

P. S., a 43-year-old Staff Sergeant, had an idiopathic ulnar palsy with atrophy of interossei, severe sensory loss and delayed nerve conduction at the elbow. His ulnar nerve had been transposed six months before, but deterioration of ulnar function continued. There was a tender neuroma of the ulnar nerve where it was angulated at the intermuscular septum. In addition to burning pain, the patient had a more severe "pins and needles" sensation along the course of the ulnar nerve. Stimulation of the ulnar nerve at the anterior axillary fold for two minutes relieved his pain consistently but the relief lasted only five minutes after the stimulator was removed. Subsequent neurolysis provided permanent relief.

This history and description was not typical of the cases of causalgia in our series but was included because it did fit the definition and serves to emphasize that pain of longer duration is less amenable to therapy.

TABLE I.—RESULTS OF TREATMENT

Patient	*(Age)*	*Type of injury*	*Nerve injured*[1]	*Duration*[2] *(weeks)*	*Description and location of pain*	*Relief Per cent*	*duration (min)*	*Final diagnosis (method)*	*Comment*
3 C. C.	(19)	Multiple fragment,[3] upper arm	Median,* ulnar complete	12	Burning, median palm	90	120	Surgical exposure	Relief from sympathectomy and median neurolysis
6 J. S.	(23)	Gun shot,[4] upper arm	Median*	3	Deep burning, first two digits	0	0	Exam	Surgery not required
8 T. C.	(20)	Gun shot, calf	Common peroneal*	15	Sharp burning, dorsum of foot	0	0	Surgical exposure	Removal of neuroma and re-anastomosis relieved pain
9 J. R.	(20)	Multiple fragment, calf	Common peroneal,* posterior tibial	5	Burning dorsum and sole of foot	85	180	EMG	Surgery not required
10 L. T.	(21)	Multiple fragment, upper arm	Median* ulnar	6	Burning, median palm	50	60	Surgical exposure	Relief from sympathectomy
11 M. G.	(22)	Gun shot, calf	Common peroneal*	8	Burning, foot	90	420	Exam	Surgery not required
12 P. S.	(43)	Entrapment	Ulnar*	52	Burning and pins and needles	100	5	Surgical exposure	Surgical revision of ulnar nerve relieved pain
14 R. W.	(25)	Fracture, sacrum	Sciatic[5]	3	Burning, foot and toes	90	60	History	No surgery required

[1] All injuries were partial, asterisk indicates the nerve stimulated.

[2] Duration of pain prior to stimulation.

[3] This is either a grenade or land mine, relatively low velocity missile.

[4] Gun shot, usually high velocity missile, producing greater damage at a distance from entry site.

[5] The common peroneal was stimulated in this case. This is unusual in that relief was produced by stimulation distal to the site of injury. Xylocaine block at this point also relieved the pain.

Table I summarizes our results in eight patients. All were men between the ages of 19 and 43. The most prominent component of the pain was burning, in all but one case, and was reported as exceptionally severe by all patients. Six patients had evidence of motor loss, sensory loss and pain in the distribution of the nerve stimulated. In Case 9, although the common peroneal was partially damaged, the region of most severe pain was in the distribution of the posterior tibial nerve. In this case stimulation of the common peroneal was effective.

Cases 6 and 14 had no objective evidence of nerve damage. In both cases the onset, following injury, of burning pain at a site remote from the trauma but in the distal distribution of a nerve passing through the region of trauma was taken to be sufficient for the diagnosis of causalgia. In Case 6 large fibre stimulation produced paræsthesias in the area of pain but no definite relief was reported. In this case the pain was managed with narcotic analgesia and recovery was complete within two weeks with active physical therapy.

Discussion

Sympathetic block and mobilization of the affected part form the basis for treatment of causalgia. In general, the earlier treatment is instituted, the more likely it is to be successful. Intense pain, accentuated by movement often precludes adequate co-operation with passive and active exercises. When the patients in our series could co-operate with their therapist, they obtained some general long-term relief of pain and improved range of joint motion. Daily sympathetic nerve blocks were not always feasible. In one case a suppurating wound precluded early sympathectomy. Stimulation-induced analgesia permitted him to receive the full benefit of physical therapy. In two cases sympathectomy was not needed. In two cases pain recurred after sympathectomy but was still responsive to large fibre stimulation. This indicates that the mechanism of pain relief produced by selective large fibre stimulation is at least partially independent of effects on the sympathetic nervous system.

Although a placebo effect cannot be ruled out with absolute certainty it seems unlikely for the following reasons: patients were not led to expect pain relief prior to the first stimulation and the degree of relief was reported to be about the same in all stimulation trials; secondly, stimulation distal to the lesion had either no effect or worsened the pain; thirdly, stimulation of the skin without producing paræsthesiæ had no marked effect. Relief was immediate and dramatic in those who did obtain it.

Our results are comparable to those of Wall and Sweet (1967) except that the duration of pain relief was longer in our series than theirs, even though our stimulus parameters were identical. Their patients had had pain for an average of eighteen months versus only three for our patients and it may be that the duration of relief is inversely related to the duration of the nerve injury.

Our findings are predicted by the "Gate Control" theory (Melzack and Wall, 1965). The critical factor in nerve injury leading to severe pain is that the gate be shifted to a "more open" position. This happens most often with partial nerve

injuries, which seem to have a larger functional effect on large diameter fibres. That activity in small diameter afferents is necessary for the production of pain is indicated by the fact that causalgia is rarely seen with complete nerve transection. Case 14 is instructive in that distal nerve block with xylocaine abolished pain presumably by lowering background discharge in small fibres while stimulation abolished pain by increasing activity in large fibres.

The persistence of pain relief in the post-stimulation period is explained by Wall and Sweet (1967). Because small fibre input is also reduced by nerve injury, more time is required to build up to pain threshold following complete inhibition by large fibre stimulation.

At present, selective transcutaneous large fibre stimulation is not a substitute for sympathectomy but we think that it should be tried in conjunction with physical treatment for at least a week in all cases of causalgia of less than two months' duration. This technique may have a place in the treatment of post-traumatic pain syndromes where surgery is contra-indicated, refused or ineffective.

Summary

A series of eight patients with causalgia were studied for the analgesic effect of selective large fibre stimulation of peripheral nerves. Immediate, dramatic relief of pain was obtained in six patients during stimulation and for a variable period after stimulation stopped. Patients were able to co-operate with physical treatment immediately after stimulation and in two cases no other treatment was needed for permanent relief. Pain recurring after sympathectomy was relieved by this technique in two cases.

Acknowledgments

We wish to thank the collaborating therapists and ward personnel at Walter Reed Hospital, and also Dr. Calvin Early at the Bethesda Naval Hospital, for permission to include Case 14. We are indebted to Professor P. D. Wall for guidance and encouragement at all stages of the study.

References

Collins, W. F., Nulsen, F. E., and Randt, C. T. (1960) Relation of peripheral nerve fiber size and sensation in man. *Archs Neurol., Chicago*, 3, 381–385.

Melzack, R., and Wall, P. D. (1965) Pain mechanisms: a new theory. *Science, N.Y.*, 150, 971–979.

Mitchell, S. W. (1872) "Injuries of Nerves, and their Consequences." Philadelphia: Lippincott.

Shealy, C. N., Mortimer, J. T., and Hagfors, N. R. (1970) Dorsal column electroanalgesia. *J. Neurosurg.*, 32, 560–564.

Sweet, W. H. (1968) Lessons on pain control from electrical stimulation. *Trans. Coll. Physicians Phila.*, 35, 171–184.

Wall, P. D. (1964) Presynaptic control of impulses at the first central synapse in the cutaneous pathway. *Prog. Brain Res.*, 12, 92–115.

——, and Cronly-Dillon, J. R. (1960) Pain, itch, and vibration. *A.M.A. Archs Neurol.*, 2, 365–375.

——, and Sweet, W. H. (1967) Temporary abolition of pain in man. *Science, N.Y.*, 155, 108–109.

Wilkins, R. H., and Brody, I. A. (1970) Causalgia. *Archs Neurol., Chicago*, 22, 89–90.

(Received 21 July 1971)