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Research Article

STUDIES ON THE RELIEF OF PAIN BY COUNTERIRRITATION

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Counterirritation has always been one of the most important methods available to physicians for the relief of pain, yet it is poorly understood and in recent years has claimed scant attention. Our purpose was to experience, study, and analyze the phenomena of counterirritation in the hope of obtaining information which would lead to the improvement of the clinical methods now in use.

The extreme difficulty of evaluating a patient's statements regarding the discomfort from which he is suffering need not be emphasized. Therefore, it seemed wise to begin by inducing pain in ourselves and to experience the effects of the various forms of counterirritation upon it. The larger part of this communication is a report of such experiences. Preliminary reports have already appeared (1).

In this way the stimuli commonly used in counterirritation—heat, cold, rubbing, scratching, etc. —were tested and their relative effectiveness assayed. Also, the utility of electrical stimulation of varying strength, duration, and frequency, was investigated.

Later we performed experiments designed to give insight into the physiological mechanism of the relief secured; first on ourselves, and second, with the help of Dr. D. W. Bronk, on animal preparations.

Finally, we attempted to make some use of the information gained by applying it to relieve the pains of over 80 patients. This phase of our work merits a preliminary report only. But the results have convinced us that the ordinary clinical methods of relieving pain by counterirritation are far from the best which can be devised.

TECHNIQUE

Methods employed to induce pain in ourselves

(*1*) *Application of irritants to the skin.* When an ointment containing 3 per cent capsicum,[1] 10 per cent turpentine and certain other irritants was rubbed into the skin, burning pain began in about 10 minutes and lasted several hours. By large dosage and vigorous rubbing the discomfort was made as great as could be tolerated. The pain could, however, be ended by repeated applications of petrolatum rubbed into the area and then wiped off.

(*2*) *Subcutaneous injection of irritating solutions.* A 10 per cent sterile solution of NaCl proved most satisfactory for our purpose. Injection of amounts up to 0.25 cc. could be tolerated. The violent pain which followed immediately was characteristically a deep seated ache with an occasional more severe "shooting pain" and was sometimes accompanied by tingling. This pain lasted with little diminution of intensity for about 20 minutes and then slowly subsided; experiments were possible for about 30 minutes. Tenderness and induration persisted for about 24 hours. In one of us (S) the pain remained localized, in the other (G) it radiated markedly up and down the arm and to the opposite surface.

Methods of counterirritation

(*1*) *Temperature changes* were secured by application of an ordinary rubber hot-water bottle or ice bag. In some experiments measurements of skin temperature were made by means of a thermocouple.

(*2*) *Vibration* was secured by an alternating current vibrator which produced a movement of about 1 mm. 60 times a second.

(*3*) *Tactile* sensations were induced by rubbing the skin with cotton for mild effects and by scratching it with a sharp wooden edge for stronger effects. An air jet was used in a few experiments to secure rapidly interrupted stimulation. Both a fan and a source of compressed air were used.

(*4*) *Electric* stimulation was usually secured by a stimulator, designed and constructed by Mr. J. P. Hervey, which permitted alteration in the strength, frequency, and duration of the stimuli. A Harvard inductorium was also occasionally employed. The stimulating electrode consisted of a pad of cotton moistened with normal salt solution and the indifferent electrode was a large copper plate.

(*5*) *Static electricity* generated by a Wimhurst machine of the type commonly used in the treatment of hysterical manifestations was employed in some experiments.

Conduct of experiments on ourselves

The subject sat with his arm extended on a table and took careful note of the variations in intensity and character of the pain produced in the flexor surface of the forearm by one of the methods mentioned above. A few minutes were allowed for the discomfort to become

[1] Capsolin from Parke Davis and Co.

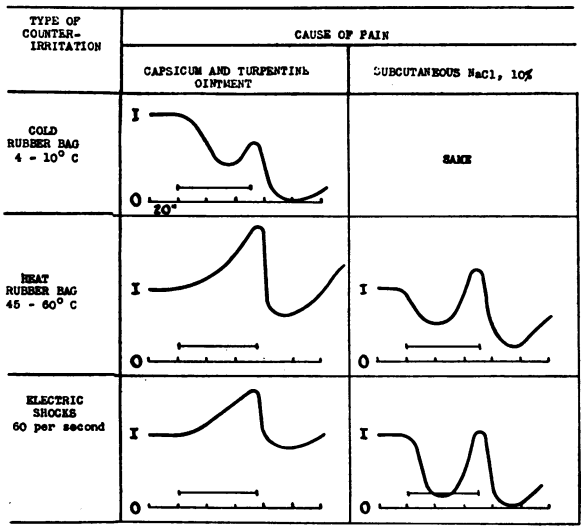

FIG. 1. EFFECT OF COUNTERIRRITATION ON PAIN INDUCED BY SKIN IRRITANTS AND BY SUBCUTANEOUS 10 PER CENT NaCl (LEFT AND RIGHT COLUMNS, RESPECTIVELY).

Ordinate is the amount of pain, I representing the initial intensity, and O no pain. Abscissa time in 20-second intervals. The duration of counterirritation is indicated by the horizontal bar. The top row shows the result of the application of cold; the middle, of hot water in rubber bags. The lower row gives results obtained after electric shocks at a rate of 60 per second.

constant before counterritation was applied. The original pain was arbitrarily graded at 100, and subsequent pain was assessed in percentage of the original.

Our experience consisted of some 50 applications of painful stimuli and over 200 tests of various types of counterirritation. On three occasions the effect of counterirritation on spontaneous headache in one of the authors was studied.

RESULTS

Deductions drawn from experiments on the authors

General pattern of the response. Irrespective of the type of painful stimulus, or of the counterirritant, the effect of the latter on the sensation of pain had a characteristic pattern. On the application of a counterirritant the pain was decreased or abolished immediately, but it soon began to return slowly, and within a minute had regained its original intensity even though counterirritation had been continued. If the counterirritant was then removed, prompt relief of the pain followed again; this relief was also temporary and within a minute the pain came back to its original intensity. Figure 1 gives typical examples of this pattern.

The pattern described above did not occur invariably. Mild pains were often permanently relieved and did not recur during the counterirritation; the severest pains were not relieved at all. The typical pattern was generally found in pains of moderate severity; in these temporary relief following the application of the counterirritant was the rule, but the relief following its removal occurred in only about three-fourths of the experiments.

One other subjective phenomenon occurred so frequently that it deserves mention. Immediately following the application of counterirritation a sharp, but very transient, increase in pain frequently preceded the relief. A similar transient increase was often noted before the relief which followed removal of counterirritation.

Relation between intensity of counterirritation and the relief produced. This relation was tested with cold, heat, tactile, and electrical counterirritation, and a general statement concerning the results seems warranted. The most effective intensity of counterirritation was slightly less than that which produced manifest discomfort when applied to normal skin. If counterirritation was too strong, a most disagreeable summation with the pain resulted; if too weak, there was but little effect on the pain.

With *electrical counterirritation,* the most effective strength, just below that which summated with the pain, caused twitching of the adjacent muscles. The sensation thus produced was not disagreeable, but a slight increase in current strength made it so.

The electric stimulus was applied as a series of single shocks, the frequency of which was varied between 1 and 300 per second. A slow frequency, such as one per second, was far less effective than more rapid rates and both subjects chose rates of 50 to 60 per second as the most effective. At rates above this the individual stimuli could hardly be distinguished and relief was less marked.

Cold stimuli were most effective when applied at a temperature of about 4 to 10° C. The ordinary ice bag felt too cold and was not so effective as more moderate temperatures.

The optimum temperature for *heat* counter-

irritation approximated 40° C.; this was effective in relieving the pain produced by subcutaneous injection of saline. But the pain produced by skin irritants, far from being relieved, was markedly intensified by all degrees of heat. This phenomenon has been described as characteristic of a stage of inflammation of the skin called by Sir Thomas Lewis (2) the "susceptible state," and the condition of the skin after the application of irritants in our experiments seemed identical with that described by him.

Effect of counterirritation at different positions relative to the site of the painful stimulus. As experience has already taught, the most effective position for counterirritation is over the site of the painful stimulus. However, when counterirritation was applied to the arm 6 inches proximal to the painful area, along the course of the nerve supplying it, considerable relief was secured. When it was applied to the arm distal to that area, relief was clearly detectable, but the effect on the pain was less. A similar statement can be made concerning strong counterirritation applied at remote points, such as the back or the other arm; slight but definite relief of pain in the arm followed. But more important than the degree of relief, the pattern was found to be similar to that shown in Figure 1, in which the counterirritant was applied over the site of the painful stimulus.

Relative effects of different kinds of counterirritation. When counterirritants were applied over the painful area produced by an injection of 10 per cent salt solution, both authors judged the relative effectiveness to be in the following descending order: cold, electric stimulation, heat, tactile stimulation, vibration, and the air jet. On the other hand, only cold gave effective relief from the pain caused by skin irritants.

Interrupted counterirritation. Inasmuch as there is a temporary relief of pain following the application of a counterirritant, and again after its removal, we concluded that the most effective means for the relief of pain would be the periodic application and withdrawal of a stimulus at an appropriate frequency. With electrical stimulation, the bombardment was switched on and off by means of contacts on a rotating sector operated on a synchronous clock motor. With heat and with cold, water bottles were applied and removed by the subject's partner. A similar effect was achieved by a lamp or a fan operated by a time switch. Figure 2 shows the sensory effects of such periodic stimulation.

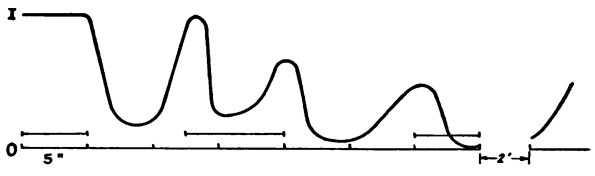

FIG. 2. EFFECT OF INTERRUPTED COUNTERIRRITATION BY COLD ON PAIN INDUCED BY 10 PER CENT NaCl

Time intervals 5 seconds with an interruption of 2 minutes. Bars indicate periods of application of cold bag.

There was no doubt in the authors' minds that by means of interrupted counterirritation far greater relief of pain could be attained than by a continuous application of counterirritation. Indeed in some cases severe discomfort could be relieved completely and continuously by a rhythm that approximated 5 seconds "on" and 10 seconds "off." In other instances, the relief could not be made complete, but the average level of pain was always markedly lowered by this method.

Analysis of certain factors concerned in counterirritation

A. Experiments on ourselves. When heat and cold are used for counterirritation, both stimulation of sensory nerve endings and changes in the caliber of adjacent blood vessels follow. We therefore designed experiments to ascertain whether the relief obtained was dependent on one or both of these factors.

In preliminary experiments, the effect of obstructing the circulation by an inflated cuff was studied. Figure 3 shows typical results. Inflation of the cuff to a pressure a little over the systolic promptly exaggerated the pain of skin irritation, and first diminished and then increased that from 10 per cent NaCl. Release of the cuff quickly decreased both types of pain. Venous obstruction produced much less effect. Inflation of the cuff to 30 mm. slowly augmented pain from capsicum and there was further increase on release. The same procedure had little effect on NaCl pain. These characteristic effects of circulatory obstruction (Figure 3) were not changed by immersion of the arm in hot (45° C.) or cold

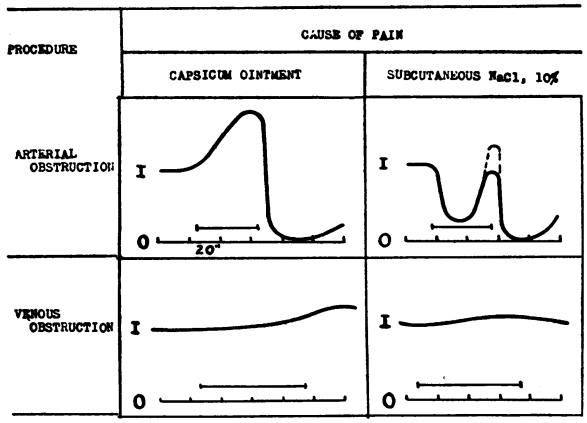

FIG. 3. EFFECT OF TOTAL OBSTRUCTION AND RELEASE OF THE CIRCULATION ON PAINS FROM SKIN IRRITANTS AND 10 PER CENT NaCl.

Effect of venous congestion by a cuff inflated to 30 mm. Hg. Obstruction of circulation indicated by bars. Time, 20 seconds.

(5° C.) baths during the experiments, so they were not dependent on temperature changes secondary to circulatory alteration.

If, after first inducing pain, the cuff was maintained at a pressure a little over the systolic for 5 minutes or longer, a plateau of painful sensation was secured which made tests of counterirritation possible. Under these conditions it was evident that heat, cold, and electrical stimulation had their usual effects on pain in spite of complete obstruction of the circulation. Venous congestion likewise caused no alteration of these effects.

In other experiments we induced pain by skin irritants and by 10 per cent NaCl in regions in which maximal vasodilatation had previously been induced by histamine or mecholyl iontophoresis, or by immersion of the arm in water at 45° C. for 20 minutes. We also produced pain in areas of vasoconstriction caused by adrenalin iontophoresis. Under all these conditions heat and cold produced their characteristic effects on the pain. We therefore concluded that the immediate action of these counterirritants in relieving pain was not dependent on any change in the circulation that they might produce.

In five experiments we measured skin temperature when applying heat and cold to either type of pain. In pain following 10 per cent NaCl the skin temperature bore no relation to the fluctuations in the pain when counterirritants were applied. In the case of pain from capsicum the relation was closer, for heat increased it and cold decreased it. There were, however, temporary decreases in pain on removal of both heat and cold which had no counterpart on the skin temperature record.

B. Animal experiments. Our data indicated that part of the relief of counterirritation might be accomplished by an effect on the peripheral sensory nerves or their endings. Therefore, we turned to animal experiments in order to obtain records of action potentials of sensory nerves while we repeated on the animals the experiments which we had done on ourselves. In this way we sought to determine whether there was a peripheral basis for the sensations we had experienced in analogous experiments. It was not, however, possible to repeat the exact technique of all the human experiments in the animal preparations. The application of rubber bags containing hot or cold water set up tactile impulses which confused or obscured the response in the discharging pain fibers. In the case of heat the difficulty was overcome by using a radiant source.

With the assistance of Professor D. W. Bronk we experimented on a number of cats anesthetized with nembutal. Some hundreds of experiments were run on ten preparations. Cutaneous nerve twigs were freed and placed on electrodes leading to a suitable amplifier. Photographic records were made by means of a Matthews oscillograph. An area of skin on one limb was shaved and, after control records of the effects of counterirritants had been made, the shaved skin was rubbed with our irritant, capsolin ointment. This brought about a steady discharge of nerve impulses of high frequency. After this discharge had been established, the application to the treated skin of radiant heat of a degree insufficient to initiate a discharge from normal skin caused further exaggeration of the discharge (Figure 4*a*). In contrast to this, the application of cold by ice bags to the skin decreased or abolished the discharge (Figure 4*b*). Obstruction of the artery to the limb resulted in an increase in the discharge and on release this either diminished below the initial level or disappeared altogether for a few seconds (Figure 4*c*).

These responses in the cutaneous nerves followed in a general way the changes which would be expected if these nerve impulses caused the

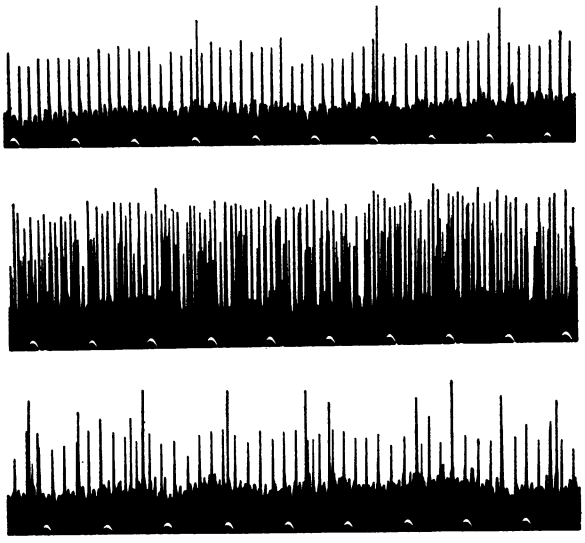

Figure 4*a*

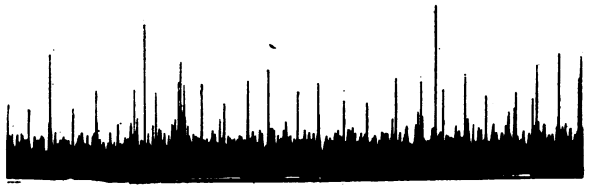

Figure 4*b*

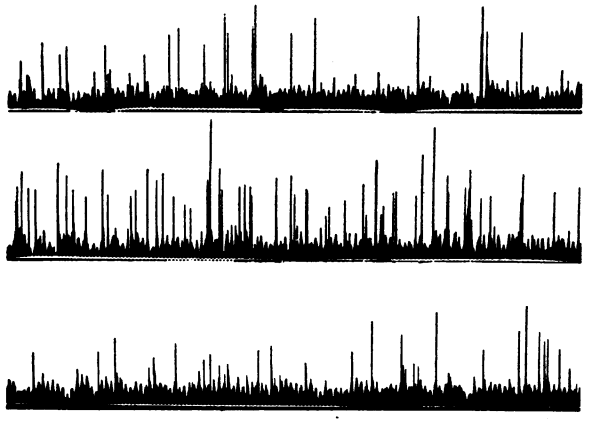

Figure 4*c*

modification of sensation which we observed under similar conditions in ourselves. For this reason it appears likely that the records we obtained were impulses from pain receptors. While we made no detailed analysis of the conduction velocities, the fibers were of the rapidly conducting type similar to those observed by Heinbecker and Bishop and others (3) to be responsible for pain.

The alterations in the sensory discharge in the animal preparations and in the sensations experienced by ourselves in similar experiments were comparable in a general way but not in all details. In the case of circulatory obstruction the parallelism was quite clear. It was also apparent in the case of the *application* of heat and cold, inasmuch as heat increased the peripheral discharge and cold diminished it. We did not, however, observe a temporary reduction in the sensory discharge on *removal* of the heat or cold, as one might have expected from the changes in sensation in similar experiments. For these temporary fluctuations in sensation some basis other than an altered peripheral sensory discharge must be sought.

Clinical experience

It is not to be expected that all the different types of pain encountered in the clinic will fall into the same pattern and be relieved by the same methods which have been successful in relieving the pain induced in our experiments. When experimenting on ourselves we worked with pains originating from a site at which counterirritation could be applied. In patients counterirritation must often be made at regions remote from the site of origin of the pain. Furthermore, we have demonstrated that some forms of counterirritation relieve one type of pain and increase another. In spite of these obstacles, our experience has given us a new point of view concerning relief of pain by counterirritation. We know well the great

FIG. 4. RECORD OF IMPULSES IN CUTANEOUS NERVES OF CATS

The nerves led from an area of skin treated by capsolin ointment. *a*; the top is a control; midline, effect of radiant heat; lower, after removal of heat. *b*; upper, control; lower, after application of cold. *c*; upper line control; middle line, during occlusion of the artery to the part; lower line, on release of circulation. Time 4*a*, one-fifth second; 4*b*, *c*, one second.

difference made by variations in the strength and mode of application of the counterirritant. So, using our experience as a starting point, we proceeded on the basis of trial and error, giving our patients the opportunity to decide what type of counterirritation was most effective in relieving them.

Common experience has shown the value of repetitive counterirritation in the relief of pain; when discomfort occurs one rubs or scratches repeatedly. But when physicians have prescribed counterirritants the stimulus has been constant. Constant counterirritation is certainly easier to apply, but our results indicate that it is far less effective than periodic counterirritation.

With the assistance of Mr. A. J. Rawson apparatus was constructed to permit the periodic application of heat and, indirectly, of cold. An electrical heating unit and a small fan were mounted on adjustable arms attached to a table on wheels. A simple adjustable commutator controls the current, permitting the intermittent application of heat, or of a cooling breeze, or of both alternately. This device has been used in the wards for 2 years, tests being made on over 20 patients with moderate or severe pain.

In addition, 60 cases with pain were tested with various other forms of constant and interrupted counterirritation. All were offered heat and cold; a smaller number were tested with counterirritation by repeated electrical stimulations and also by a Wimhurst static electrical machine. Tactile counterirritation was used in some cases as well.

The results must be stated with the greatest reserve, for the difficulty of conducting an investigation into the sensations of persons often emotionally upset by their troubles will be apparent to all clinicians.

When rhythmic counterirritation was applied by the machine we let the patients choose the degree and duration of heat and cold which most effectively relieved them. The great majority preferred the heat alternating with the cold, or intermittent heat without the cold. The intervals selected were generally about 40 seconds of heat and 30 seconds without it.

Almost every patient was relieved somewhat and some were loud in their praises of the treatment, but how much of this was due to the presence of the machine, the extra attentions from the staff, and the solicitude of the authors is very hard to say.

When the various other forms of counterirritation were offered to the larger group of 60 cases, about 90 per cent obtained some degree of relief. The agent causing maximum relief varied in the different cases, and we obtained some evidence that the choice depended on differences in the origin of the pain.

Thus in a group of 13 cases, pain was relieved by heat and increased by cold. In three-fourths of these cases the cause of the pain was peripheral nerve or root irritation: in 4 cases a mass lesion compressed nerves; in 3 cases there was peripheral neuritis; in 2 cases, herpes zoster.

In a contrasting group the pain was exaggerated by heat and relieved by cold. This group contained cases of Buerger's disease and superficial burns. The results are analogous to those secured by Lewis and Hess (2). In other cases both heat and cold were equally effective.

The patients always preferred heat or cold to electrical or tactile counterirritation.

In spite of the difficulties in judging, we have the impression that our new methods of applying counterirritation, which depend upon a rational choice of the type of stimulus and its periodic application, are far more effective than our former haphazard practice of ordering either a hot water bottle or an ice bag indiscriminately. We still have much to learn and the possibilities have hardly been touched.

We have not been able to ascertain how static electricity secured its reputation as aiding in the diagnosis of hysterical pain. Perhaps its success in the suggestive treatment of hysterical paralyses, etc., led to the expectation that relief following its application was evidence of the hysterical origin of pain. In any event, the belief is erroneous. Static electricity is an effective form of counterirritation. It will relieve pains experimentally induced and spontaneous pain undoubtedly organic in origin, as well as hysterical pain.

It should perhaps be pointed out that the results herein described apply to the immediate effects of counterirritation on pain. We have made no experimental tests on pain of long duration nor of the long-time effects of counterirritants on chronic pain. Undoubtedly, other factors enter into these cases.

DISCUSSION

In seeking an explanation for the differing effects of counterirritation upon pain from salt and from capsicum, it is necessary to consider the differences in origin of the pains. Capsolin causes pain by stimulating superficial cutaneous endings; sodium chloride, by stimulating nerve fibers as well as nerve endings lying deeper in the subcutaneous tissue. Furthermore, capsolin is applied to a large area of skin, while NaCl is injected into a small area, thereby making a spatial difference in the fibers and endings stimulated.

Since the capsolin-activated skin endings are quite superficial, their temperature can be rapidly altered by surface applications, and it is therefore not surprising that the capsolin pain is easily affected by local temperature shifts. Since the irritability of nervous tissue varies in the same direction as temperature change (4, 5), heat and cold applied over skin treated by capsolin increase or decrease the *peripheral sensory discharge,* as we found by direct observation, and thus increase or decrease pain.

On the other hand, surface applications could not readily alter the temperature of the deeper-lying nerves which are stimulated by subcutaneous NaCl. Consequently, it would be unlikely that sensation would fluctuate in direct relation to surface temperature. We indeed found no correlation between pain and skin temperature. Both heat and cold temporarily decrease NaCl pain. We must therefore look for some explanation other than an altered peripheral sensory discharge secondary to temperature change to account for these shifts in sensation in the case of NaCl pain.

Nor does a change in the peripheral discharge account for the temporary decrease in capsolin pain on removal of the heat or cold, for we found no modification at this time in the records of the nerve impulses.

We are thus led to consider the possibility that counterirritation may act by altering some central mechanism. Such a theory is not new; Cushny (6) suggested, on the basis of Head and McKenzie's data, that counterirritants act centrally. Several of our observations strengthen this possibility. Thus, while it is well known that the most effective site of counterirritation is over the painful area, nevertheless counterirritation applied elsewhere is by no means ineffectual. Furthermore, we also found the typical pattern of relief on application and removal of the counterirritant, whether it was applied over the painful area or at some distant site unrelated in peripheral nerve supply.

A possible basis for a central sensory depression or inhibition is provided in recent experiments of Bronk (7). When a nerve cell which is stimulated chemically has its activity increased for a short time by electrical stimulation, there follows a period of diminished irritability during which the cell responds to the same chemical stimulus, either at a lower frequency or not at all.

If such a mechanism operates within the central nervous system it would explain our observation of the relief of pain on stopping counterirritation. The duration of the relief is of the same order of magnitude as Bronk's post-stimulatory depression, that is, a few seconds. It would account also for the fact that to obtain maximum relief the counterirritant must be of an intensity near that which augments pain, and therefore would explain the frequent increase in pain which we observed just preceding relief. For, as we saw above, to obtain Bronk's post-stimulatory inhibition, the activity of the nerve cells must be temporarily increased, and therefore the pain should be temporarily exaggerated. Finally, the identical effects of counterirritants which stimulate different types of specific skin endings—temperature, tactile, etc.—could be explained, provided the various fibers converged somewhere upon the cells activated by the painful stimulus. There is such a convergence within the optic thalamus, and thus it is possible that central depression could take place at this level.

To summarize: We can account for the effect of cold in relieving capsolin pain on the basis of a decreased peripheral sensory discharge due to lowering the temperature of pain endings. Our evidence suggests a central, post-stimulatory depression of the type described by Bronk for peripheral structures to explain the relief of pain on stopping counterirritation. The temporary relief of pain, which immediately follows the application of the counterirritant, is also due to a depression of sensation by alteration of some central mechanism, for a similar temporary relief occurs

when the counterirritant is applied to remote areas, as well as over the painful site. This inhibition of sensation suggests an analogy to motor inhibition, a subject which has been recently discussed by Gasser (8) and Eccles (9). On the sensory cortex Bard (10) has observed a masking effect of one tactile stimulation upon a second. In the present state of our knowledge we can only call attention to these possible relationships; none of them provides a complete analogy or explanation of our findings.

Although we concluded that the effects of altered circulation are not responsible for the effects of counterirritation which we have observed, it is of interest to note that the alterations both in sensory discharge and in sensation which followed circulatory obstruction run parallel to the changes in nerve irritability under oxygen lack. Nerves deprived of oxygen (11), or human nerves with the circulation cut off by an inflated cuff (12) first become more irritable to stimulation, then gradually less so. Restoring oxygen or blood brings about a temporary but large decrease in irritability.

SUMMARY

After inducing pain on themselves by the subcutaneous injection of 10 per cent NaCl or the application of irritant ointments, the authors studdied the relief brought about by counterirritation of various types, *e.g.*, heat, cold, the electric current, vibration and tactile stimulation.

Irrespective of the type of pain and counterirritant, a definite pattern usually appeared: the application of counterirritation caused temporary relief; its removal was also followed by temporary relief.

Experiments demonstrated that the relief secured was not due to changes in the circulation. Animal experiments in which the discharge from sensory nerves was recorded yielded results which are analogous to some of the changes of sensation experienced. On the other hand, other changes of sensation could not be accounted for by an altered sensory discharge. We have discussed the possibility that they are due to a central depression of the pain.

As periodic counterirritation produced the maximum of relief of pain induced in the authors themselves, apparatus was devised for the intermittent application of heat and cold to patients.

While there is great difficulty in judging the effectiveness of agents acting on the sensation of patients, we have gained the impression that by wise selection and periodic application of counterirritants much more relief can be secured than by the haphazard application of hot water bottles and ice bags which was our former practice.

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