STUDIES OF ELECTRICAL SKIN RESISTANCE IN PERIPHERAL NERVE LESIONS*

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INTRODUCTION

Changes in electrical skin resistance have been reported by Richter and his associates on the basis of extensive experimental and clinical studies to provide an accurate and practical clinical test for peripheral nerve injuries. They have designed a simple apparatus for this purpose which is now on issue to the U. S. Army Medical Corps.

Areas of skin deprived of their sympathetic nerve supply show a marked increase in electrical skin resistance as compared to surrounding normal areas containing active sweat glands. This is due largely to the inactivity of sweat glands in the denervated skin. Differences in surface moisture can be usually seen or felt, and the areas of high resistance coincide with the absence of sweating, as shown by the Minor starch-iodine test. Vasodilatation plays a very small role, if any, in these skin resistance changes. Vasodilatation produced by (1) prolonged application of a blood-pressure cuff caused no consistent changes in skin resistance, and (2) vasodilatation by niacin failed to produce a significant change (confirmed by one of us in initial experiments).

The difference in resistance becomes greater and the line of demarcation between denervated skin and surrounding normal areas becomes sharper as the normally innervated sweat glands are stimulated, either by increasing the surrounding temperature, increasing body metabolism, or by certain drugs that stimulate the sweat glands through the sympathetic nervous system. Under optimal conditions, the transition from an area of high resistance to an area of low resistance is very sharp, usually detected by movement of the testing electrode about ¼ of an inch. Areas of high resistance usually correspond exactly to accurately determined areas of sensory loss.

Experimental studies of skin resistance changes in animals following sympathectomy (Richter2,4) have shown that there is an initial rise, which shortly reaches a very high level and falls, in the monkey, after several months, to a permanent level still far above that observed preoperatively.

METHODS

The methods used were essentially the same as those outlined by Richter and his associates.16 A small D.C. current (maximum of 50 microamperes) was passed through the skin and the change in resistance from a denervated

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to a normal skin area indicated on a sensitive meter. Representative values of resistance in ohms were recorded. In experimental studies with animals, the resistance of the central foot pad of the hind limb was measured on both sides after section of one sciatic nerve.

Various ohmmeters have been used, including several commercial instruments and special designs. Recently a new dermohmmeter has been designed by one of us which has proven most satisfactory. The details of this instrument have been described in a separate communication.* In initial experiments with animals an especially designed A.C. and D.C. instrument

![Image of dermatohmmeter with ear clip and handle inserted.](image)

**FIG. 1.** Photograph of dermatohmmeter with ear clip attached to patient, and handle with the roller electrode inserted.

was employed in order to assess the merits of these two types of measurement. Extremely high values of resistance encountered in animal studies were measured with the R.C.A. "volt-ohmyst."

The fixed electrode consisted of a silver clip which was attached to the ear. The resistance of the lobule of the ear was first greatly reduced by rubbing the lobule with electrolytic jelly. The jelly, when rubbed in, made the resistance at this point so low that it was not found necessary to puncture the skin with a pin as has been recommended (Richter and Woodruff*), even though this does reduce the resistance at this point still further.

The exploratory electrode consisted of a bakelite handle with a socket into which could be fitted various forms of electrode. These electrodes consisted of flat silver discs (4 and 9 mm. in diameter) mounted on a copper rod.

* See page 257 of this issue of the *Journal.*
and a roller electrode, as illustrated in Fig. 1. This latter type has proven very satisfactory, particularly for the rapid mapping of larger areas. It can be rolled over the skin from a high to a low resistance area, keeping contact with the skin at all times.

We found, initially, considerable difficulty in obtaining accurate results in some patients due to inadequate sweating of normal skin areas and to cumbersome methods of diaphoresis. This was particularly true with spinal cord injuries and sympathectomies. In most cases of peripheral nerve injury satisfactory results could be obtained, especially with the new dermohmometer, without artificial diaphoresis. The use of overheated rooms, bakers, electric blankets, hot drinks, and aspirin in our initial studies were so unsatisfactory that the routine use of this test was discouraged.

Following the work of Guttman on the use of furmethide in testing sweat secretion in man, we have used this drug (2.5 to 5 mg. subcutaneously) in certain cases to clarify skin resistance measurements. This is a parasympathomimetic drug (furfuryltrimethylammonium iodide) which stimulates sweat glands whose nerve supply is intact but does not affect the denervated ones.

SUBJECTS

Traumatic injuries of peripheral nerves due to gunshot or shrapnel wounds formed the bulk of our clinical material. Other conditions studied

<table>
<thead>
<tr>
<th>Peripheral Nerve Lesions</th>
<th>No.</th>
</tr>
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<tbody>
<tr>
<td>Ulnar</td>
<td>6</td>
</tr>
<tr>
<td>Median</td>
<td>7</td>
</tr>
<tr>
<td>Radial</td>
<td>3</td>
</tr>
<tr>
<td>Sciatic</td>
<td>5</td>
</tr>
<tr>
<td>Common peroneal</td>
<td>4</td>
</tr>
<tr>
<td>Trigeminal</td>
<td>2</td>
</tr>
<tr>
<td>Ruptured Intervertebral Discs</td>
<td>3</td>
</tr>
<tr>
<td>Fracture Dislocation of the Spine</td>
<td>4</td>
</tr>
<tr>
<td>Sympathectomies</td>
<td>3</td>
</tr>
<tr>
<td>Hysterical anaesthesia</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>39</strong></td>
</tr>
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were ruptured intervertebral discs, fracture dislocation of the spine, sympathectomies and hysterical anaesthesias. A summary of the cases studied is shown in Table I.

The duration of peripheral nerve injuries varied between one month and two years. The patients studied were largely service personnel at the Montreal Neurological Institute, the Royal Canadian Naval Hospital, Halifax, and at the St. Annes Military Hospital.
The resistance of the central toe pads of the hind feet of 6 cats was studied over a period of 85 days following complete section of the sciatic nerve on one side. The other side served as a control.

RESULTS

A.C. and D.C. Measurements in Animals. During the first two weeks following unilateral sciatic section the electrical skin resistance (E.S.R.) of the central toe pads of both sides was measured both for Direct Current (maximum of 50 microamperes) and for Alternating Current (60 cycles). Measurements were taken on the 2nd, 5th, 8th, 10th, and 14th postoperative days. Results of the 8th postoperative day are presented as typical of this series for comparison of A.C. and D.C. values (Table II).

| Table II |
|------------------|------------------|
| Animal | A.C. Resistance (in megohms) | D.C. Resistance (in megohms) |
| 1 | 0.310 | 0.030 |
| 2 | 0.210 | 0.025 |
| 3 | 0.310 | 0.031 |
| 4 | 2.000 | 0.140 |
| 5 | 2.300 | 0.056 |
| 6 | 0.585 | 0.064 |
| Average | 0.936 | 0.058 |
| Ratio | 16 | 142 |

It is clear that the A.C. resistances are consistently lower than the D.C. values and, what is more important for this study, the ratio of resistance in normal and denervated skin is much higher for D.C. resistance than for 60 cycle A.C. Measurements of A.C. resistance were consequently abandoned.

Course of Change in D.C. Resistance Following Sciatic Nerve Section in the Cat. On the day following section of one sciatic nerve the denervated central foot pads of the six animals showed an average increase in resistance of about 20 times over its preoperative level. It was about the same amount greater than that of the control side (2.4 megohms as compared to 0.112 megohms). The resistance of the control side varied between 0.100 and 0.275 megohms throughout the 85 days the animals were studied. On the 4th day there was a further slight increase in resistance of the denervated skin, while on the 8th day it had reached 15 megohms and continued to increase to 38 megohms on the 13th and 20th days. The resistance then fell to about 4.5 megohms on the 35th day to rise slightly to 9.7 on the 85th day. These changes are shown in Fig. 2.
These observations confirm the results of Richter$^{2,4}$ and Tower and Richter$^{12,13,14}$ following sympathectomy in animals, namely that there is an initial moderate rise in resistance of the denervated skin followed by an increase in resistance to an extremely high level. The initial rise is probably due to the interruption of reflex innervation of the sweat glands. The extreme rise probably represents complete denervation and absence of autogenous function. The subsequent fall in resistance to a constant lower level, which is still many times greater than that of the normal skin, probably represents some return in sweat gland function due to a form of autogenous innervation, possibly on a humoral basis.

Loss of sensation in the foot pad accompanied the elevated skin resistance and persisted until the final measurement on the 85th day.

**CLINICAL STUDIES**

It was in the peripheral nerve lesions that the best results were obtained and seemed to be of most practical value. If the lesion was distal to the point where the sympathetic fibres joined the nerve, then the area supplied by that nerve showed a great increase in resistance. There was a sharp line of demarcation between the denervated and normal areas. If the nerve section was proximal to the point where the sympathetic fibres joined the nerve there was no change. This was illustrated in a patient who had had a posterior rhizotomy of the trigeminal nerve. There was a sensory loss, but no change in the E.S.R. Another patient had had a depressed fracture of the zygoma which severed the infraorbital nerve. This man showed a marked increase in E.S.R. which corresponded with the sensory changes.

Two typical cases of ruptured intervertebral disc at $L_5$ and $S_1$, with definite sensory changes corresponding to the dermatomes, were tested. There was no change in E.S.R. This again is what one would expect, as the sympathetic fibres have not as yet joined the nerve, whereas in lesions of the sciatic in the thigh there was a very marked increase in E.S.R. corresponding to the skin area supplied by that nerve.
In all but two of the 27 patients with peripheral nerve injuries the area of high resistance coincided with the area of sensory loss to within $\frac{1}{4}$ to $\frac{1}{3}$ of an inch. Discrepancies occasionally found between the E.S.R. and sensory examination were later found to be due to inaccuracies of the latter.

The first exception was M.L., a soldier who had received a shrapnel wound of the thigh 10 months previously. The sciatic nerve was not sectioned by the original injury, but shortly following there developed a haemorrhage in his cast which resulted in a profound ischaemia of the entire leg. When the cast was removed there was complete loss of sensation below the knee. When examined about 10 months later he showed an area of sensory loss corresponding roughly to that supplied by the deep and superficial peroneal nerves, although there were additional areas of sensory loss which did not correspond to any specific nerve lesion insofar as could be determined. The area between the first and second toes on the dorsal surface showed complete anaesthesia but a low skin resistance. There was a sharp line of demarcation between this area and the surrounding high resistance area. In other words, there was sensory loss without increased skin resistance. As this was a complicated lesion, it is quite possible that the sympathetic fibres were either intact or had recovered while the sensory fibres were still not functioning.

The second exception was H.T., a soldier who sustained a partial lesion of the radial and ulnar nerves. In the area supplied by the ulnar nerve there was analgesia without loss of touch sensation, and this area showed a definitely increased E.S.R. There was also analgesia without loss of touch in the skin area supplied by the radial nerve, but a portion of this area, between the 1st and 2nd metacarpals, showed a decreased E.S.R.

In partial nerve lesions this decrease in resistance in areas of sensory loss had been considered to represent an irritative lesion of the sympathetic fibres.15

In partial nerve lesions with causalgia the affected skin area showed an abnormally low resistance, even when compared with the homologous area of the normal limb.

None of the cases in this series could be followed long enough to evaluate the use of this method in the estimation of regeneration. The results of our examinations would have been of more definite value in many cases if they could have been compared with earlier ones. This may be illustrated by the case of W.F., whose right median nerve was injured on January 1, 1944. Skin resistance examination 10 months later showed only a slightly increased resistance in the median palm area with a gradually increasing resistance to a high level at the tips of the fingers. This observation on one examination indicates either a partial lesion or beginning recovery. An earlier examination for comparison would have helped in deciding whether re-exploration was necessary.

Two cases of hysterical anaesthesia were examined and no skin resistance changes were found over the presumably involved areas.

Four cases of transverse lesion of the spinal cord were studied and confirmed the findings of Richter and Shaw.7 It was noted that the areas of high resistance, or sympathetic levels, did not always coincide with the sensory levels. Artificial diaphoresis was necessary to bring out clear lines of demarcation in all of these patients, since all skin areas showed a uniformly high resistance without this stimulation of sweat gland activity. Observations on three cases of postoperative sympathectomies were similar to those described
by Richter, Smithwick, and Richter and Levine. In two cases the findings were shown to coincide with those obtained by the starch-iodine test of Minor. Again artificial diaphoresis was necessary to bring out the true differences, and furmethide proved very helpful.

Furmethide provided by far the most satisfactory means of artificial diaphoresis. It was effective in about five minutes following subcutaneous injections of 2 to 5 milligrams. Sweat gland activity in normal skin areas was increased, often with visible perspiration and pilomotor activity, while denervated areas were unaffected. No serious side effects were encountered. Most patients expressed an urgent desire to void. One patient showed an erythematous eruption limited to a partially denervated area on the back of his forearm. It was of interest that the E.S.R. remained very high in this denervated area in spite of the marked erythema. The local erythema was probably due to the absence of sympathetic vasoconstrictor effects, allowing an exaggerated response to the parasympathomimetic drug.

CONCLUSIONS

1. Denervated skin shows a marked increase in electrical resistance a few minutes following nerve section and remains at a relatively high level until neurotization takes place. It can be demonstrated more clearly when the sweat glands of surrounding areas are active. In the cat there is an extreme rise in resistance during the second and third week following denervation, after which it falls to a steady level, still many times higher than that of the normal skin.

2. Richter’s skin resistance method is an objective, practical, and precise
test for the diagnosis of peripheral nerve injuries involving the sympathetic supply to the skin.

3. Furmethide is a simple, effective and rapid diaphoretic agent for skin resistance tests and eliminates the necessity of other time-consuming and cumbersome procedures.

4. The new dermohmmeter has made possible the testing of more patients without artificial diaphoresis. It is simple and "fool proof" in operation and enables one to make quantitative measurements of skin resistance when desired.

5. The interpretation of the results of clinical skin resistance examinations would be greatly facilitated if previous examinations, made shortly after injury, were available for comparison.

REFERENCES