Nerve-suturing, neurorrhaphy, nerve-grafting / by De Forest Willard.

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NERVE-SUTURING.

THE operation of nerve-suturing may be performed primarily or secondarily. Primary suture is performed immediately after or within a few days of the division of the nerve. Secondary suture is done at any time thereafter, even years later—the hope of success diminishing with the length of time, the loss of nerve-substance, etc. These operations have now been sufficiently numerous to show that the fear of tetanus is ungrounded, no deaths being reported from this cause. Suture of a divided nerve would certainly result in tetanus if division of a nerve, inflammatory conditions, and the presence of foreign bodies were causes of tetanus. Practical experience shows that with cleanliness of person and of instruments the operation is a safe one.

It is best performed after wounds by squaring the divided ends with a very sharp knife, not with scissors, and suturing in such a manner as to prevent any twisting or infolding of filaments. Catgut, very fine, chromicized or made thoroughly aseptic in boiling alcohol, should be employed. Fine sterilized silk is equally good. A round needle is better than a cutting one. The suture should pass directly through the body of the

[1] One of the Mütter Course of Lectures delivered before the College of Physicians of Philadelphia.

nerve and include both sheath and fibers. A second suture at right angles to the first is often desirable.

Secondary suturing is performed by freeing the imprisoned nerve from all its surrounding cicatricial connective tissue, stretching it freely, and removing a small section, so as to give good opposing surfaces.

It is not well to remove successive sections from the end of a nerve to secure good nerve-filaments and tissue, as the gap may be made very wide before good tissue is reached. It is better, after getting rid of the dense central connective tissue, to draw moderately good ends together and unite them. A nerve will stretch very considerably if it is thoroughly cleared for some distance from the surrounding tissues.

The most serious obstacle to successful nerve-suturing is the loss of nerve-substance, occasioned either by a wound or by the extirpation of a neuroma or other tumor. Frequently an inch can be gained by clearing the nerve for a considerable distance, but when this fails the gap must be bridged either by flaps cut from the nerve by longitudinal splitting and turned over from either end or by the device of Bruns (see Figs. 1, 2, and 3), or by grafting.

Gleiss[1] reports thirteen instances of nerve-suturing in eleven patients in Bruns' clinic at Tübingen from 1882 to 1891. Four were primary operations, seven secondary. Union was secured in all but one case. The median nerve was sutured five times, the ulnar three, the radial four, and the peroneal once. The most rigid asepsis was adopted.

Bruns does not freshen the nerve-ends in primary wounds, but in secondary ones the ends are cut off and the intermediate cicatricial tissue is removed. He gives two new plans for approximation in old cases in which there is union by a connective-tissue bridge. While

[1] Beit. zur klin. Chirurgie, Band x, Heft 2, 1893, and Annals of Surgery, August, 1893.

these are ingenious they do not seem to offer a good end-to-end approximation; not so good as is secured by

FIG. 1.

FIG. 2.

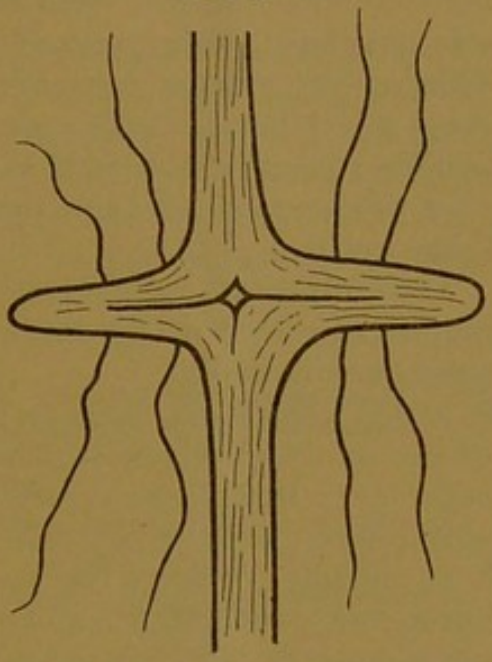
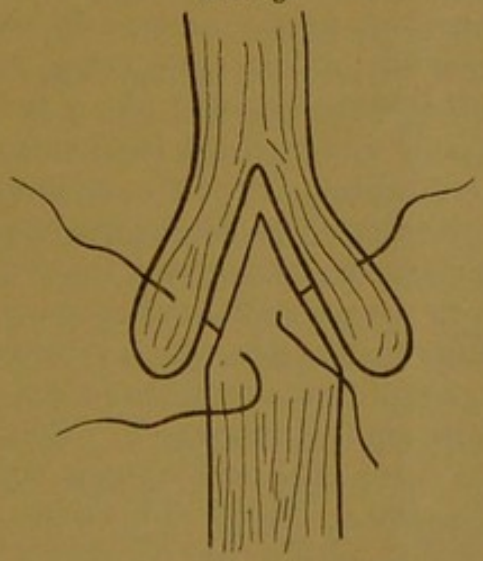


FIG. 3.



cutting off the ends and simply suturing them, Figs. 1, 2, 3.

In a case of tearing of a radial nerve complicated with fracture there was no restoration of function at the end of five months. The nerve was thoroughly liberated from compression and from the connective tissue, and was enveloped in a graft of skin, after the method of Thiersch, to prevent restrangulation. Without having given this latter method a practical trial, it strikes me that the squamous epithelial skin-cells would more probably produce compression than would the connective-tissue cells.

The limb should be fixed after the operation, to prevent motion and tension. Massage and electricity should be subsequently used.

Etzold reports six cases of nerve-injury in the region of the axilla in which restoration of function did not occur, even though the nerves were sutured. He attributes this result to the fact that in high injuries like these it is difficult to restore the nerves. This was, perhaps, not so much due to the height of the injury as to the complications that existed in the axillæ, as the brachial veins had to be ligated; and this, in addition to the injury of the surrounding soft parts, must have interfered with nutrition. Etzold found, as have other observers, that cerebral impulses are conducted along the nerve at an earlier period than those arising from electric impulses. Motion was established in one case fourteen months after suturing, yet there was no electric response.

That sensation seems to require a lower degree of conducting-power in the nerve than does motion is demonstrated in another instance in which return of sensibility was much more rapid than that of motion.

Wolberg[1] has made a number of experiments to decide whether a nerve can heal without degeneration of the peripheral segment. In all of his cases degeneration did take place, and in all of my experiments undoubted

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[1] Deutsche Zeitschr. fur Chirurgie, Band xix.

degeneration has occurred. In Bruns' four cases of primary suture there was immediate restoration of function.[1]

NERVE-GRAFTING AND NEUROPLASTY.

The suturing of one end of a widely separated nerve-trunk to the freshened surface of a neighboring nerve or muscle is sometimes advantageous. Splitting the nerve and turning down the fragments endangers the vitality of the nerve. Fig. 4.[2] I have practised this method in cases in which the ends could not be brought together by other

FIG. 4.

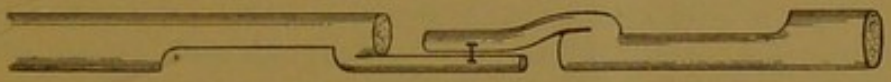
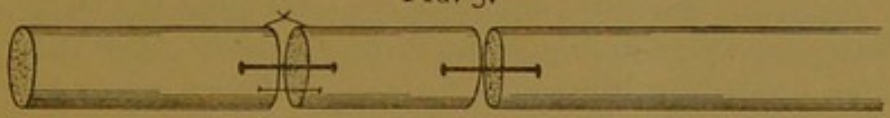


FIG. 5.



means, but the results have been only partially satisfactory. Splitting a nerve interferes very seriously with its transmitting-power and subjects it to the risk of inflammation. Microscopic examination, however, in a number of my experiments, shows that even though the injured flap degenerates, it forms a skeleton or basis for regeneration of nerve-filaments.[3] The split halves can, however, sometimes be brought into close end-to-end union; but if torn loose from its attachments the flap becomes a transplanted nerve. If its sources of supply are gone, this procedure possesses but slight advantage over the transplantation of an entirely new piece of nerve from an individual or an animal. The best possible insertion for a fresh graft is a nerve taken from an ampu-

[1] See Gleiss' tables, Annals of Surgery, August, 1893, p. 233.

[2] In Fig. 4, the flaps should have been sutured end to end, instead of overlapping.

[3] International Medical Magazine, April, 1894.

tated human limb and immediately introduced into the gap. (Fig. 5.)

To freshen a neighboring trunk and apply the cut end to its side may be helpful, but this is attended with the risk arising from irritation of the trunk, which may result in pain and other trophic symptoms.

Numerous operations for transplantation of nerves have been described. One of these is by Tillemanns,[1] in which a section four and one-half centimeters long, from a nerve of a rabbit, was inserted in the median and ulnar nerves. Sensation returned in four weeks and motion in nine. Another case is Kaufmann's,[2] in which after an injury to the musculo-spiral nerve a gap of four centimeters was filled with the transplanted sciatic of a dog. The result was doubtful three months later.

Robson [3] inserted two-and-a-quarter inches of a human posterior tibial nerve (secured from a fresh amputation) into a gap in the median, forty-eight hours after an injury. Four months later sensation was almost entirely restored, and although trophic changes were present, the case was very hopeful.

Hoffmann inserted the sciatic of a dog into the radial without benefit; and White, replacing the musculo-spiral by the sciatic of a dog, met with a like result. Albert grafted a section of human nerve into the median and the ulnar in separate cases, but without benefit. Gunn attached the ulnar to the uninjured median, and one month later reported the finger as strong.

Ward inserted two and a half inches of median nerve, just amputated, into a median injured four months before. Seventeen months later there was slight sensation of touch and a fair amount of power, an improvement upon the previous condition.

In another case two inches of a sciatic nerve from a

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[1] Berliner klinische Wochenschrift, June, 1883.

[2] Revue de Sci. Méd., 1884, vol. xxiv, p. 305.

[3] Clinical Society, London, 1889.

rabbit were placed between the split ends of an ulnar. Sensation returned upon the eighteenth and motion upon the twenty-fifth day. The use of the hand, with marked grasping-power, completely returned.

It will be noticed that sensation antedates motion, and in all these cases it was proved that atrophy of the peripheral end certainly was marked.

Atkinson sutured the median nerve and inserted the sciatic of a rabbit between the extremities of the ulnar. Sensation returned before motion.

Harrison[1] reports eight cases of nerve-grafting. In one case he inserted two-and-one-quarter inches of the sciatic nerve of a freshly killed kitten into a median nerve, two inches of which had been destroyed, suturing with catgut. The wound healed by first intention, and sensibility returned in forty-eight hours; nutrition improved. After five months motion returned in the fingers. In another case four inches of the sacral nerve of a dog were inserted into an ulnar, with a return of sensation in thirty-six hours.

Primary grafting is, of course, much more certain than secondary, as trophic changes naturally interfere greatly with the success, although nerve-function is not impossible after a long period of time.

A ferrule of decalcified bone stitched in the gap after invaginating the ends, is recommended by Vaulair,[2] but such isolation of a nerve from surrounding supporting tissues may result in sloughing. In my experience the bone tube disappears so quickly that it is of no use either in guiding the two ends in reaching each other, or in protecting them from subsequent cicatricial contractions.[3]

Another method of splicing consists in splitting longi-

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[1] British Med. Journ., 1892, vol. i, p. 602.
[2] Archives de Physiologie, 1882, vol. x, 595.
[3] Internat. Med. Magazine, April, 1894, Experiment No. XII.

tudinally the nerve through its center for the necessary length, say, one inch, then cutting out one side and reflecting the flap upon its base. The opposing end is then treated in the same way, the flap being made upon the opposite side so as to fit against the corresponding flap. The two can then be sutured.

MacCormac exposed a nerve and attached it by two loops of kangaroo tendon to the inner edge of the triceps, and sutured the fascia with catgut. Decided improvement took place. By the same method Pearce reduced a dislocation forward of an ulnar nerve.

Croft exposed and sutured a nerve to its sheath. Gould also performed a similar operation.

Bergmann adopted another course, viz., resection of the humerus, in order to shorten the arm so that the divided nerve-ends could be brought together, but this seems an unnecessary procedure.

Dittel reports a case in which the ulnar nerve was split for seven centimeters. Flaps were turned up and united end to end, with the result of a restoration of sensation and of movement under prolonged electric treatment.

Vucetic reports an injury to the ulnar nerve attended with loss of substance. Flaps were cut from each end, and catgut sutures employed. Suppuration took place, but the final results were good.

In all cases of nerve-grafting it is vitally important that the animal furnishing the nerve should be young, as the regenerative power is much greater at an early period of life, and in cases of nerve-suture it has been noted that young patients are more hopeful than older ones. The direct method of suturing is usually employed, although the indirect plan has been used in a number of instances.

Pain and stiffness may follow either primary or secondary suturing, but the functions return to a remarkable degree. Sometimes the first evidence of returning sensa-

tion is a feeling of tingling or of numbness, followed by a recognition of the fact that certain sensations are being received. This increases until finally restoration more or less complete takes place. There is at first a sense of confusion in regard to sensations, as it is impossible to join filament to filament. A filament of a nerve that primarily brought intelligence from a toe may have been united with a filament presiding over a leg-area; hence, reëducation is necessary, and this is entirely a question of time. It is well known that after an amputation many years are not sufficient for the reëducation of the brain in regard to the area from which new impressions are received.

Although at the time of secondary suturing, degeneration has progressed, yet the speedy restoration of nerver function after injury shows that by some method transmission of nerve-force is brought about; the prognosis, therefore, is very favorable, and no case should be allowed to suffer for want of the attempt to secure union. We may give this class of patients a large degree of hope as to prognosis, as even without operation great improvement has been found to take place, showing that we may have return of sensation in a divided nerve without actual reunion. The functions of motion and sensation both return if continuity of the axis-cylinder has been restored. The symptoms of nerve-regeneration to be expected then will be active muscular contractions, improvement of atrophy and faradic irritability of muscles that have been previously paralyzed.[1]

The question of age materially affects the rapidity of regeneration; this I have proved personally by experimentation, and find that union takes place much more quickly in the pup than in the older dog. Bowlby thinks that the musculo-spiral particularly presents great energy of union, even more than other nerves.

[1] A most satisfactory study of nerve-regeneration is contained in Howell and Huber's admirable article in the Journal of Physiology, 1892, vol. xiii, No. 5.

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In one case reported at St. Bartholomew's Hospital, in which the ulnar was operated upon by Mr. Marsh, twelve years after the injury, there was decided gain of motion and sensation. No patient, therefore, should despair, but it is well to warn against the expectation of too immediate results. Improvement is sometimes decided only two years after an operation. Of course, the cases operated upon years after an accident are not as hopeful as early ones, yet they are worth the attempt. Whenever improvement fails to take place it is probable that a change has occurred not only in the nerve but also in the central cells. When there has been sloughing and suppuration the amount of dense cicatrix will have much to do not only with preventing union but also with secondary results. If, however, each nerve is freed from surrounding compression this danger is lessened, although a wide line of reunion will certainly interfere with nerve-transmission.

The fact that degeneration occurs in the motor cells of the spinal cord, which are the trophic centers of the muscles, probably explains why in some cases motor power cannot be restored. Sensation may return when operations are done years after the nerve has been severed, but motion may not so often be restored. Within a year good results may be looked for; the difference of a few weeks or a few months is not believed to affect materially the chances of success. After this time there is a smaller ratio of cures.

I had recently an opportunity of observing a lad upon whom I operated nearly ten years ago for a glass division of the ulnar, which was united and sutured almost immediately after the accident. While able to use the little finger, and while the ring-finger has slight sensation, there is atrophy of all the muscles of the small digit, and that portion of the hand, while useful, is feeble.

In many cases in which no improvement has at first

occurred, gradual gain for some months has taken place at a later period.

As regards the errors in reporting various nerve-results after operation the observations of Zander[1] are interesting. His reports tend to show that surface-manifestations are unreliable even as regards such distinct tracts as the divisions of the median into the ulnar and radial. The facts of the case probably are that divisions are uncertain, and that irregularity of distribution and free anastomoses are frequent. Arloing and Tripier have shown that in order to secure absolute loss of sensibility in the foot of a dog, it is necessary to divide every nerve leading to the part.

It is possible that some of the immediate excellent results may have been due to the fact that a region (for instance, the hand) is supplied with nerves from a number of sources, and other vicarious or substitutive nerves may have been brought into play, thus deceiving the surgeon, who may unwittingly report a return of sensation early. A number of these cases are cited by Weir Mitchell,[2] showing that sources of error are common, and Létiévant has forcibly called attention to the same subject.

In many cases of rapid return of function, especially in primary suture, it should be remembered that the supplementary activity of other nerves may give rise to a series of remarkable results, not because a nerve has been sutured, but because the patient has recovered from the shock of the injury, which previous to the operation may have temporarily annulled both sensation and motion. This vicarious action of nerves has been well demonstrated by Mitchell, Savory and others, and errors in observation have been carefully depicted. Errors may occur, as in the case of Pirogoff, quoted by

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[1] Berliner klinische Wochenschrift, 1891, Feb. 24.

[2] Injuries of the Nerves. Mitchell, Morehouse, and Keen.

Weir Mitchell, in which case it is possible that the surgeon labored under the same mistake that happened to myself in one of the experiments already alluded to.[1] In this case I was probably as certain as Pirogoff that the nerve had been completely divided, as it was distinctly before my eyes, and yet subsequent examination proved that a large bundle of fibers had escaped section. Naudorfer and Schuh had a similar experience. In Pirogoff's case sensation was normal, but he had *not* sutured the nerve.

Howell and Huber's[2] tables on secondary suturing show that, as a rule, secondary suturing is more hopeful soon after an injury, although results have been excellent even after a long period of time; the average time for the return of motor power is about six months, and for the return of sensation three months—a peculiar fact that shows itself in all nerve-experiments.

Their summary includes 80 cases of nerve-suturing secondarily, with 38 per cent. of successes and 50 per cent. of improvements, making 88 per cent., with only 12 per cent. of failures.

They have presented the profession with most valuable deductions from the recorded cases of suture, and conclude that in primary nerve-suture the nerve-function will in all probability be restored either completely or partially, that young patients are more hopeful than older ones, and that clinical as well as physiologic evidence is against the possibility of immediate union.

In primary suturing the prognosis is exceedingly good, and improvement may be expected in nearly all cases.

Rapid return of motion, and more particularly of sensation, has been frequently noted, but the errors of interpretation have been already noted, and it seems to be

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[1] International Medical Magazine, April, 1894.

[2] Journal of Physiology, 1893, vol. xiv, No. 1.

definitely proved that the transmission of a nerve-impulse requires a continuous axis-cylinder. Nerve force is a vital force, and though resembling electricity is entirely distinct.

The natural inference from cases of the kind related is obviously that in all cases in which nerves are accidentally divided union should be aided by suturing; and in the majority of cases their function will be restored if the attempt is made within a reasonable period of time.

The prognosis of recovery of function after primary and secondary suture of nerves is very much better now than formerly. Even in secondary suture great improvement is almost certain to follow, and complete success is to be expected in the majority of instances.

Primary suture. Of 117 cases of primary suture collected for me by Dr. John H. Rhein the following summary is made:

The median nerve was sutured 41 times; the ulnar, 38; the median and ulnar, 30; the median, ulnar, and radial, 3; the radial, 4; the musculo-spiral, 3; the sciatic, 1; the external popliteal, 1; the posterior tibial, 1; the anterior tibial, 1.

It will thus be seen that the nerves of the upper extremity have been subjected to this operation in 113 cases, and also that the nerves of the forearm suffer injury more frequently than those of the upper arm. This may be accounted for by the fact that many of the wounds were due to glass, and caused by the effort of the individual to save himself by extending his hand. Knife-cuts are also much more frequent in this region.

The *nature of the injury* was as follows:

From sharp instruments in 62 among 81 cases; from dull instruments in 8; from nerve-injury during operation, 14.

Sex. As might be expected, males are in excess of females, as accidents are much more frequent in men

than in women. In the cases recorded, 86 males were injured and 20 females.

Age. Under ten years (the youngest being two years) there were 8 cases; from ten to twenty, 34; from twenty to thirty, 31; from thirty to forty, 15; from forty to fifty, 18; from fifty to sixty, 3.

The exact time after injury is recorded in only a few instances, but it is fair to assume that the majority of operations were performed on the first or second day, and that these were all primary sutures.

Material used. Catgut was employed in 72 cases; silver wire in 5; silk in 7; kangaroo-tendon in 1.

Distance of separation of ends. This unfortunately is recorded in only a few instances. The smallest distance given is 1 cm., and occurred six times; 2 cm., three times; 3 cm., once; 4 cm., once; 2 inches, once.

Return of sensation. The record covers only 39 cases. Sensibility returned on the same day as the causative accident in 7; on the next day in 2; within a few days in 17; after one week in 13; after two weeks in 6; after four weeks in 7; after six weeks in 2; after two months in 3; after six months in 4; after one year in 1; after one and one-half years in 1.

Return of motion. This occurred on the day of the injury in 1; on the next day in 1; after several days in 4; after one week in 6; after two weeks in 2; after three weeks in 5; after four weeks in 3; after two months in 5; after three months in 1; after six months in 1; after one year in 4. One "cure" was reported in seventeen days.

Results. Among 123 cases, one death is reported a few weeks afterward (the cause was not stated), and another took place from gangrene sixty-five days after operation. Improvement in one day is reported in 6 cases; complete return of motion and sensation, one year later, in 10 cases; slight improvement at the end of this time in 10 cases; partial improvement at the end

of one year in 3 cases. Slight improvement is also noted in several cases at the end of two and three months, and in other cases complete return of motion and sensation is recorded at the end of one week, eighteen days, two months, three months, six months, ten months, and one year respectively.

Negative results are given in 2 cases.

Sensation is reported normal at the end of two years in 3 cases; in 1 case at the end of four months. Four cases are reported as well in two years, 5 at the end of five years, and 5 at the end of three years. In 14 cases motion and sensation are noted as good.

Secondary suture. A review of the extensive and valuable tables made for me by the indefatigable efforts of Dr. John H. Rhein shows that of 130 cases of secondary suture the median nerve was involved 35 times; the ulnar, 34; the median and ulnar, 20; the musculospiral, 10; the brachial plexus, 1; the fifth cervical, 1; the radial, 29; the sciatic, 6; the popliteal, 1; the external popliteal, 2; the posterior tibial, 1; the perineal, 1; the posterior inter-osseous, 1.

As might be expected, there is a preponderance of males, as they are much more subject to accident. There are noted of males 98, of females 31.

The character of the accidents is as follows: from sharp instruments, 96; from dull ones, 5; from gunshot-wounds, 6; as a result of nerve-injury during operation, 3.

The character of the suturing material used was catgut in 47 cases; kangaroo-tendon in 14; silk in 10; horsehair in 6; silver wire in 2; decalcified bone in 1.

The time of operation after injury was fifteen days in 12; one month in 15; two months in 19; three months in 14; six months in 19; nine months in 20; two years in 10; six years in 1; nine years in 1.

The return of sensation is definitely recorded only in a few cases. This was noted on the next day after operation in 12; several days afterward in 17; within the first two weeks in 21; after one month in 19; after three months

in 2; within six months in 12; after one year in 1; after two years in 1.

Motion returned on the next day in 1 case; after several days in 3; within the next two weeks in 9; within a month in 18; after six weeks in 1; within six months in 13; after one year in 3; after two years in 1; after three years in 2. In 1 case it was reported that motion had not returned at the end of a year.

The amount of separation was one-half cm. in 18 cases; one cm. in 9; two cm. in 4; three cm. in 7; four cm. in 9; seven cm. in 1; ten cm. in 2; one inch in 1; two inches in 8.

The results are given as follows: One death from hydatids. Improvement within the first month was noted in 6 cases; "motion and sensation improved in six months in 11 cases." Complete return of motion and sensation took place in from one week to six months in 17 cases. A similar result is reported as having occurred in one month in 7; in six months in 14; in one year in 25; in two years in 18; in four years in 2. Fourteen cases are reported as cured; 3 as completely cured in five years. Other cases are reported as showing a slight improvement in one, two, and three years respectively. These should be put down as unsuccessful cases. The total number of cases slightly improved is 10; either greatly improved in motion and sensation or absolutely cured, 102; very slightly improved, or not improved at the end of a year, 15; 1 death resulted from hydatids; thus giving 80 per cent. improved by operation, with practically no risk to life.

CONCLUSIONS.

1. Immediate suturing of a divided nerve should never be neglected, as the result is eminently successful as regards restoration both of sensation and of motion.

2. Clean end-to-end suture should be secured if possible. In wounds inflicted by a sharp instrument this is easily attained; in torn wounds it is wiser not to remove

more of the nerve than is imperative, as a nerve continuously stretched unites less readily than one which lies loosely. Whenever a portion is necessarily sacrificed better union will be secured by clearing the nerve for a considerable distance, stretching it thoroughly so as to obtain end-to-end suture if possible, and then stitching. When it is impossible to join the ends other material may be grafted into the gap, or the nerve may be spliced by flaps cut from its own substance.

3. The best suturing-material is fine chromicized catgut inserted by means of a small, round needle directly through the sheath and body of the nerve. Two sutures are usually advisable, crossing each other at right angles.

4. Secondary suturing offers good hope of success, and should be attempted even if years have elapsed since the accident. Repeated operations may ultimately succeed if the nerve is thoroughly cleared, stretched, and brought together.

5. When the loss of nerve-substance has been large, a nerve-graft, or a section taken preferably from a freshly amputated limb or from an animal, should be inserted in the gap. This usually gives better results than the splicing-operation of splitting the nerve and turning the flaps into the gap.

6. Decalcified bone-tube, which has been employed for guiding the ends toward each other, is so rapidly absorbed that it is of but little service.

7. Restoration of function often takes place many months after the operation.

8. My own experiments agree with those of other operators and prove that the distal portion of a severed nerve rapidly degenerates, as does also an interposed graft; yet that transmission of function is possible and that subsequent regeneration may take place as regards both sensation and motion.

9. During the healing-process the part should be placed absolutely at rest, and the nerve slightly relaxed if possible.