I think we may feel reasonably confident that this is exactly what occurs in the wound. And at any rate we may be sure that neither in the earliest stage of the wound, where the tissues lie exposed; nor yet in the later stage, when the walls are infiltrated; have we in the wound, any more than we have here in this test-tube, anything in the nature of a membrane which could filter out albuminous substances.

Arising directly out of the physical properties of concentrated salt solutions is another point which has a very important bearing on the therapeutical action of these agents. We have seen in connexion with antiseptics that inasmuch as they have as good as no penetrative power, they will exert their effect only at the immediate point where they are applied; and, in the case where the antiseptic marches with an albuminous fluid, only on the face where the two fluids come in contact. In other words, the antiseptic will not diffuse into, and come into application in pus held up in the upper reaches or recesses of the wound, nor even in islands of pus encompassed by antiseptic fluid.

Now the exact contrary of this holds true of strong saline solutions introduced into the wound. No sooner are they introduced than the sodium chloride—for it is, of course, highly diffusible and is not quenched by antiseptics—will radiate out by diffusion through all the fluids of the wound. (In an experiment in which a tube full of water agar was inverted in a shallow receptacle of 4 per cent. salt solution we found that diffusion carried the salt up $4\frac{1}{2}$ centimetres in a night.) We may therefore picture in our mind's eye, in connexion with strong saline solution applied to the mouth of a wound, that the salt will very soon, in the lower reaches of the wound, attain a high concentration and act as a lymphagogue; and that afterwards it will come into operation in the upper reaches in a dilute, but perhaps still therapeutically valuable, form.

But let us note that this will apply only if the concentration of the saline solution is maintained throughout. Where the salt solution is applied in the form of a damp pad, and is then very rapidly diluted by the exudation, we shall get, but only very temporarily, a hypertonic solution in the lower reaches of the wound, and after that we should obtain only the same effects as with an isotonic salt solution.

Finally—and this is a point which may upon occasion have a practical interest—let us remember that 4 per cent. salt solutions have a specific gravity equivalent to that of the serum; and more concentrated solutions of course a higher specific gravity. It will therefore be theoretically possible, by availing ourselves of gravity, to get strong saline solutions directly to the bottom, not perhaps of a wound filled with pus, but certainly of a wound in which we have only blood clot and serum.

(To be continued.)

THE OPERATIVE TREATMENT OF GUNSHOT INJURIES OF NERVES.*

BY

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THE majority of the patients were in the section of the War Hospital at Croydon which the Surgeon-General of the Eastern Command has set aside for the treatment of injuries of the peripheral nerves and for stiff joints arising from wounds, and which he requested Dr. Woods and myself to organize. Other patients were in military or V.A.D. hospitals in other portions of the Eastern Command, and three in H.R.H. Princess Henry of Battenberg's Hospital for Officers.

The cases operated on by one of us (F. E.) numbered

28, of which 21 were due to bullets, and 6 to shrapnel or shell wounds. As regards the distribution of the lesions: 5 were injuries of the brachial plexus, 8 of the musculo-spiral nerve, 1 of the posterior interosseous nerve, 5 of the ulnar, 2 of the median and ulnar nerves together, and 7 of the sciatic or external and internal popliteal nerves. In 6 cases the injured nerve or nerves were completely divided. The sciatic nerve, as might be anticipated on account of its size, was divided three times; the other nerves divided were the median and ulnar together in one case, musculo-spiral and posterior interosseous once each. In one instance the sciatic nerve was perforated with incomplete division of the external popliteal portion. Many of the cases having been in V.A.D. hospitals before being transferred to Croydon, the period elapsing between the receipt of the wound and the operation was often considerable. This period in all but 4 cases was three months or over; in the remainder the shortest period was seven weeks. In the absence of evidence of improvement, and if the electrical reactions indicate a severe injury of the nerve, we are of opinion that an operation should be performed as soon as the condition of the wound permits of its being carried out aseptically. Excluding the 5 injuries of the brachial plexus, it was thought necessary in 8 cases out of the remaining 23 to resect the damaged portion of the nerve, or to refresh the ends if they were separated. In other cases the nerve was separated from adhesions and surrounded with Cargile's membrane. The various reasons determining the procedure adopted are given below in considering the electrical reactions. The smallest nerve operated on was the posterior interosseous. This was found to have been completely severed (the ends being separated) by a bullet which had comminuted the head of the radius. The nerve was exposed by an incision on the outer side of the forearm, just below the external condyle and on a plane corresponding with the palmar surface of the head of the radius. After dividing the muscles attached to the external condyle, the proximal end of the nerve was at once found. The ends were refreshed and the junction surrounded by a portion of the basilic vein. As regards the 8 cases of injuries of the musculo-spiral nerve, half of them were associated with fracture of the humerus.

In those cases in which resection was performed the fibrotic tissue, or bulbous end, was removed on the proximal side until the section showed well-defined nerve bundles; and the distal end was refreshed. The ends were pierced with a round shafted needle, and united with one or, in the case of large trunks, two sutures of twenty day chromic catgut (0 or 1 size). It was always found possible to get the ends together by freeing the nerve above and below, and flexing the nearest joint or adducting the upper arm. Where a portion of the nerve was thickened and appeared to be "hidebound," chiefly from thickening of the perineurium, an incision was made into the thickened tissue.

The five cases of injuries to the brachial plexus furnished many points of interest. One was due to a bullet smashing the centre of the clavicle. The clavicle was divided, and fragments of bone were found pressing upon the anterior divisions of the fifth, sixth, and seventh nerves, which were enveloped by dense scar tissue. This was removed, the nerves were surrounded with Cargile's membrane, and the clavicle wired. In another case the injury was by a bullet at the root of the neck. At an operation, two months after the injury, the trunks of the fifth, sixth, and seventh cervical nerves were found thickened and more or less adherent. The condenser reaction of the paralysed muscles read from 1 to 4 micro-farads charged at 70 volts. The thickened nerves were separated from adhesions and surrounded with Cargile's membrane. Five months after the operation there was a good return of movement in the paralysed muscles. In the other cases the injuries were below the clavicle, and in two instances were of a most extensive character. The difficulty in dealing with these cases is increased by the fact that the axillary artery and vein are usually involved in the scar tissue and require careful separation. In one case it was found necessary to ligature the artery and vein above and below the lesion. No trouble occurred as regards the circulation of the limb, probably because the anastomotic circulation had been enlarged owing to partial occlusion of the axillary artery. A dense mass of

* A paper read before the Medical Society of London on November 1st, 1915.

cicatricial tissue had matted together all the cords of the brachial plexus and was adherent to the anterior aspect of the subscapularis muscle.

When confronted for the first time with this condition of things surgical interference appears hopeless, but it was found that by cutting combined with teasing by blunt dissection the various strands of the cords could finally be separated out and the cicatricial tissue removed. In the case above referred to, a rounded mass of fibro-neuromatous tissue the size of a thrush's egg was removed from the posterior cord; and a portion of the inner cord, three-eighths of an inch in length, was resected and the nerve united. In another case the cords were matted together by a dense scar behind the pectoralis minor, just above the point where the internal circumflex is given off. The bullet had entered on the posterior surface of the root of the neck through the outer part of the trapezius, had passed under the clavicle, and made its exit behind the anterior axillary fold. The site of the lesion of the plexus was fixed as just below the point where the musculocutaneous is given off, by the fact that the muscles on the front of the arm were the only ones giving normal reactions. It was found possible to separate the median nerve from the cicatrix, but half an inch of the posterior cord and three-eighths of an inch of the internal cord were excised, and end-to-end union effected. Dr. Panton kindly examined the portion excised from the posterior cord: it consisted solely of dense fibrous tissue, and contained no nerve fibres.

In a third case the median and ulnar trunks were matted together below the lower edge of the pectoralis minor, but were separated and surrounded with Cargile's membrane.

Boldness is justifiable in operating on these severe lesions, as one knows that the limb must remain useless unless restoration of conduction in the nerves can be effected by surgical measures. There is the less hesitation in operating freely since it has been established by the experiments of Professor Robert Kennedy¹ that the junction of the peripheral end of a divided nerve to the corresponding proximal portion of the same nerve is not necessary for the re-establishment of function. He writes: "In *Macacus* the paralysis resulting from section of the fifth and sixth nerves may be largely restored by anastomosis of the peripheral segments of the two roots to the seventh cervical nerve, or to the spinal accessory." Two cases of partial paralysis of the brachial plexus as a result of arterio-venous aneurysm in the axilla have been met with. At the operation in one case pressure was found on the median, ulnar, and musculo-spiral nerves in the lower part of the axilla. The other case is an example of an arterio-venous aneurysm involving the lower part of the axillary artery with paralysis of the musculo-spiral nerve. After keeping the patient under observation, it has been found that the aneurysm is increasing and the condenser shows that the paralysis is not improving, in spite of the treatment. An operation will therefore be performed.

All the cases except one have been tested electrically by Dr. Woods. In practically all instances the paralysed muscles did not react to faradization. We found the Lewis Jones condenser of great assistance, as it furnished a numerical equivalent indicating the degree of interruption to conduction through the nerve and the condition of the muscle; for example, in 6 cases in which there was evidence of complete division of a nerve, in one instance there was no response with the condenser, while in 4 the numbers ranged from 2 to 4 m.f. charged at 70 to 100 volts.* In these cases operation was performed three to five months after the infliction of the wound. The period elapsing after the infliction of the wound must be taken into consideration, for in the remaining case, in which operation was performed for complete division of the internal popliteal nerve seven weeks after the wound, the muscles responded to a 1 m.f. capacity at 70 volts. There could be no doubt as to the nature of the lesion, since the ends of the nerve were widely separated. This patient had received massage and electrical treatment from an early date, and the consequent state of nutrition of his

muscles probably had an effect as regards the electrical reactions.

As showing the effect of time on the reactions obtained by the condenser, it may be noted that in the case of division of the posterior interosseous nerve operated on five months after the injury, the muscles at the back of the forearm, except the extensor carpi radialis longior, gave no response to testing with the condenser.

The chief point in the operative treatment of these nerve lesions is to determine whether simply to separate the injured nerve from the surrounding tissues or to resect it; and this is of greater importance owing to the fact that anatomical division is comparatively rare. A definite indication is usually afforded by inspection. There may be evidence of complete division with union by a band of fibrous tissue, and in this case an enlargement of the proximal end will be present; or the site of division, which may be partial or complete, is indicated only by a well-defined bulbous enlargement. In less severe injuries there is often a fusiform thickening of some extent involving the nerve trunk. In other cases, especially in injuries to the musculo-spiral nerve associated with fractures of the humerus, the nerve may be embedded in callus. In one case it was stretched round a spicule of bone. The musculo-spiral nerve may be generally thickened and enlarged for some length; it was in a case of fracture of the humerus as thick as the end of a little finger. The condenser required for the extensors of the wrist and digits was of 2 m.f. capacity at 70 volts; nevertheless, after freeing the nerve voluntary movement returned rapidly, and in two and a half months there was almost complete restoration of function.

Not infrequently the affected nerve is evidently constricted by cicatricial tissue surrounding it, or by the pressure of a dense cicatrix of the integuments. Where doubt exists as to the advisability of resection, an indication of the amount of damage is sometimes furnished by blunt dissection of the nerve bundles from above into the cicatrix to ascertain if they are continuous across it.

The condenser also furnishes important indications of the site and severity of the lesion. In a case of wound of the thigh at its middle third by a portion of shell the sciatic nerve had been perforated. The condenser required was of 4 m.f. at 120 volts for the muscles on the front of the leg, 1 m.f. at 70 volts for the peronei and 0.25 for the calf, showing that the damage was to a portion of the external popliteal nerve. At the operation the internal popliteal nerve was separated from the external nerve by blunt section, and a dense nodule or neuroma was found involving the inner half of the external popliteal. This was excised without interfering with the outer strands of the external popliteal, and the gap was united with catgut.

Further, the condenser gives reliable and easily recognized indications as to when cases of nerve injury are improving under treatment. The two following cases may be quoted:

CASE I.

An officer received a bullet wound at close range which carried away the internal condyle and paralysed his ulnar nerve; very definite improvement occurred. Three weeks after the injury the muscles supplied by the ulnar nerve required a condenser of 2 m.f. capacity, the charging voltage being 75. Nine months later the reactions were precisely the same and the improvement as regards sensation and voluntary power had remained stationary for some time. Operation was therefore decided on. The nerve was constricted, and just above the injured part was a small, bulbous enlargement. Seeing that there had been considerable restoration of function the nerve was freed and surrounded with Cargile's membrane. Treatment by massage and electricity was continued. At the end of two months the condenser test was exactly the same as before the operation. The patient was therefore advised to submit to resection of the injured portion of the nerve.

CASE II.

A patient was admitted to Croydon War Hospital with a shrapnel wound behind and above the head of the fibula and paralysis of the muscles of the front and back of the leg. On August 25th the condenser required for the peronei muscles was of 0.25 m.f. capacity at 70 volts. After continuous treatment the condenser capacity for the peronei, seven weeks later, was 4 m.f. at 80 volts. Operation showed that the external popliteal nerve was definitely thinned at a point corresponding to pressure by a very indurated cicatrix of the integument.

The disappointing feature of the treatment of nerve injuries is the long period required for the completion of

* Normal muscles give, with a condenser, a reading of 0.025 to 0.075 micro-farads capacity charged at 70 volts. In a moderately severe lesion of a nerve the muscle gives 0.75 to 1 micro-farads charged at 70 volts, and a severe lesion 1 to 4 micro-farads charged at 70 to 100 volts.

the reparative processes, and so far we can give very little information as regards the ultimate results of our work in respect of restoration of function, most of the cases having been operated on after the beginning of August.

REFERENCE.

¹ *Proc. Roy. Soc.*, Series B, vol. lxxxix, No. B, 610.

Memoranda: MEDICAL, SURGICAL, OBSTETRICAL.

MAGNETIC PROPERTY OF GERMAN BULLETS.

It does not appear to be generally known that German rifle bullets are strongly attracted by an ordinary magnet, whereas the English bullet is quite devoid of this quality. The difference is due to the composition of the casings. The English bullet has a casing of 80 per cent. copper and 20 per cent. nickel, and although nickel and many of its alloys possess magnetic qualities, the alloy of nickel and copper in the above proportions is non-magnetic.

At my request, Mr. Leslie Aitchison, M.Met., of the Sheffield University, very kindly made an analysis of a German bullet, with the following result:

The casing is a steel containing 3.36 per cent. nickel and low in carbon. The body of the bullet contains 96.92 per cent. lead and 2.95 per cent. antimony.

With the highly successful methods now available for localizing war missiles in the body by x rays, magnetic tests are no longer of any value for this purpose, but the magnetic attraction possessed by the German bullet may, under certain circumstances, be utilized to assist in its removal from the body. The following notes of a case will explain what I have in mind:

I. W., aged 38 years, a sergeant in the 6th Sherwood Foresters, was standing up in a trench with his hands in his greatcoat pockets when he was struck by a bullet in the right arm, just below the insertion of the deltoid muscle. The bullet passed upwards and inwards until it encountered the first rib, which it fractured. The resistance so offered was sufficient to arrest its momentum, and it fell into the pleural space and gravitated to the base of the right lung.

Examinations with the x -ray screen demonstrated that it was freely movable in the pleura in response to alterations in the patient's posture, and, as it was causing discomfort, it was decided to attempt its removal by a giant magnet which my ophthalmic colleague, Major Pooley, kindly placed at my disposal.

The idea was to employ intratracheal ether anaesthesia, and under the positive intrapulmonary pressure thus secured to make an opening into the pleura and extract the bullet by means of a soft iron probe connected at one end to the magnet. Tests showed that the attractive force so available would be amply sufficient for the purpose. But "the best laid schemes o' mice and men gang aft a-gley." On the eve of the day selected for the attempt the intratracheal apparatus was unfortunately broken, and the delay caused thereby led to the bullet being extracted in the ordinary way. The case had an ironic aspect. The bullet turned out to be an English one, and was, of course, unresponsive to a magnet.

My excuse for sending this note for publication is that I have not come across any reference to the matter in the literature within my reach.

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COMPOUND DISLOCATION OF THE KNEE: RECOVERY WITH A USEFUL LIMB.

A STATEMENT in Major Robert Jones's recent work on *Injuries of Joints* leads me to record a case which I treated at Nablous some few years ago.

An Arab aged about 60 was brought to the C.M.S. Hospital at Nablous, Palestine, in 1903 or 1904 one morning, on the back of a fellow-workman, a distance of fully half a mile. He had bled considerably on the way, and the femur was not only dislocated but had ruptured the skin posteriorly and was protruding therefrom.

The history of the case was interesting because, from the account of the English nurses at the above hospital, he

had been treated twice before at intervals of two years, once for fracture of the same thigh, and also, I was told, for dislocation. In spite of the weakness of the joint he was still following his avocation of a porter, and whilst so engaged and carrying a heavy load the knee gave way under him, with the result stated.

It was found absolutely impossible to reduce the dislocation without further enlarging the rent in the skin, which tightly grasped the femur above the condyles. This was possibly a blessing in disguise.

After reduction the limb was put up on a side splint and a large-sized drainage tube inserted; after a daily or almost daily syringing with mercury perchloride 1 in 2,000 for about a month, the wound closed without infection of the joint or rise of temperature; there was very free discharge of synovia.

The patient left the hospital with a weak but not a useless limb. I am sorry not to have further details, since I was only in temporary charge of the hospital.

Chepstow.

JOHN CROPPER, M.D., B.C.Cantab.

Reports of Societies.

DISCUSSION ON GUNSHOT WOUNDS OF PERIPHERAL NERVES.

THE discussion on this subject was resumed at a meeting of the Medical Society of London on November 1st, when Sir FREDERIC EVE made the communication which is published in full at page 676.

Dr. E. F. BUZZARD said that information was required concerning three points especially: (1) Which cases should be operated upon; (2) what should be done at the operation; (3) how could pain be relieved? With regard to the first point, it was difficult to lay down any rule, but he thought it wise to explore in cases of doubt. Whether operation should be performed or not depended upon whether the local conditions were favourable to return of function. He was sceptical as to the value of the electrical reaction of degeneration, as it was influenced by the treatment applied. It was difficult to decide what should be done at the operation when a fusiform swelling was found consisting largely of scar tissue, but carrying many nerve fibres. In peripheral nerve lesions he advised that the nerve should be examined carefully both with the eye and with the finger. In the case of partially divided nerves, whether the nerve were excised or merely sutured, incomplete recovery would follow. Pain and hyperaesthesia of a most severe type might continue for months. In such cases operative treatment was required, and excision might be necessary, although the injury was only partial. Injection of alcohol into the proximal end of the nerve was of great value as a means of abolishing pain.

Mr. JOCELYN SWAN gave his experiences of 63 cases of nerve injury: 38 had been operated upon, 41 nerves being explored, and 25 were not operated upon. Of these, 6 had refused operation; in 3 it had been deemed inadvisable; 4 had been deferred, and in the remaining 12 improvement and recovery of function had occurred in from two to four weeks after the injury. Those cases which thus recovered had been ascribed to "nerve concussion," and in such it was difficult to say whether any actual damage had been done to the nerve or not. In them a strong faradic current produced a reaction, and this provided a valuable prognostic guide. He thought that no operation should be undertaken until the surface wounds had firmly healed, and there was no evidence of an underlying focus of infection. If there were paralysis of muscles, a corresponding area of anaesthesia, and an absence of faradic reaction, he advised exploration. In some cases with partial injury to a nerve some muscles escaped and anaesthesia was imperfect. Of the 41 nerves explored complete division was found in 13, and in the remaining 28 scar tissue had to be dealt with to free the nerve. In 2 cases metallic fragments were buried in the nerve, and in another a fragment of bone. There was no means of distinguishing between complete division of the nerve and its binding by scar tissue. When the latter had been encountered the result had been more satisfactory when both nerve and scar had been excised. Voluntary movements often returned long before even a feeble reaction was obtained to a strong faradic current. He had