BRITISH MEDICAL JOURNAL

LONDON SATURDAY JULY 1 1944

PENICILLIN IN BATTLE CASUALTIES

BY

J. S. JEFFREY, M.D., F.R.C.S.Ed.
Lieut.-Col., R.A.M.C.

AND

SCOTT THOMSON, M.D.
Major, R.A.M.C.

After the report to the War Office by Prof. H. W. Florey and Brigadier Hugh Cairns which indicated the value of penicillin in war wounds, the Army Medical Services decided to give the benefit of this new drug to as many of the wounded as possible. At that time—Sept., 1943—the main fighting in which the British Army was engaged was in Italy, and after agreement with the M.R.C. Penicillin Committee it was arranged that the bulk of British penicillin production would be sent there. An additional benefit was that by concentrating most penicillin in one area the maximum information should become available, since shortage of supply in any planned investigation could be avoided. Thereupon the War Office formed a "Penicillin Control Unit," consisting of surgeon, pathologist, and laboratory technicians, whose function it was to distribute the drug among the Army, instruct surgeons in its properties and demonstrate its use, instigate special investigations, and collect results.

We arrived in Italy in Dec., 1943, and set up our laboratory in a forward base hospital at Bari. This was convenient, because the main fighting at that time was on the Eighth Army front in Eastern Italy. Later on, the laboratory was moved to Western Italy to cope with the fighting around Cassino and beyond. The laboratory was equipped with apparatus from the Base Depot Medical Stores, and no special apparatus not in current use was sought. It was pleasing to note the absence of contamination in the bacteriological laboratory, which functioned successively in a small room with rough-cast floor and walls, in a tent, and in a mobile laboratory van.

Supplies of penicillin were flown out to us regularly from the War Office. They were products of three British firms—Therapeutics Research Corporation, Kemball, Bishop and Co., and Imperial Chemical Industries; and two American firms—Pfizer, and Merck. Samples of all batches of penicillin received were assayed before the bulk was distributed, and only three early specimens were found not to possess the activity stated. In these three the deterioration was of an extreme degree, but from their general appearance it was immediately obvious that there had been some radical change. The loss of activity was attributed to the presence of moisture in the container of the sodium salt. In connexion with the stability of penicillin, it was of interest to note that small amounts remaining of two preparations brought from England to North Africa in May, 1943, were found to have retained their activity and were used in Jan., 1944. These preparations had been carried among our personal kit for a period of four months.

The initial distribution of the drug we did personally among the 80 operating centres dealing with the casualties—General Hospitals, Casualty Clearing Stations, Field Surgical Units, and special units such as Mobile Neurosurgical and Maxillo-Facial Units. Our penicillin came to us mostly as the sodium salt, for systemic use and for local solutions. The calcium penicillin we mixed with sulphathiazole as a diluent, in the strength of 5,000 units of penicillin per gramme of sulphathiazole. This made a satisfactory powder, which, along with an efficient insufflator (R.A.F. type—D. Rose), was distributed

largely among the forward operating centres. Most of the sodium salt was sent to base hospitals, for they alone can hold on to fractures and other casualties long enough to give an adequate course of penicillin systemically. We let the forward units have small stocks of sodium penicillin for use in gas gangrene and penetrating chest wounds. By May, 1944, the penicillin supply position in Italy was so satisfactory that practically all the more serious casualties were able to get penicillin if it was indicated; and the distribution of the drug was taken over by the Army Blood Transfusion Unit (Major G. W. Wolstenholme, O.C.). This is a most efficient service, and its refrigerating vans are constantly visiting the operating centres.

Selection of Cases

Infection and its prevention are such important factors in the open wounds of warfare that we advised that certain types of case should receive penicillin as a routine. At first treatment was strictly confined to battle casualties, but with increasing supplies we broadened the scheme to include other casualties and some medical conditions. At all times the treatment was extended alike to British, New Zealand, Indian, Canadian, and Colonial soldiers, sailors, and airmen; and latterly we were able to include our Polish, Yugoslav, and French allies. Our American allies always had their own supply, and were putting it to good use. The general selection of cases was:

Systemic Penicillin (I.M. or I.V.).—(a) All fractured femurs, the worst-fractured tibiae; fractures of shoulder and upper humerus; other severe fractures (e.g., pelvis); amputations; severe hand injuries; multiple severe soft-tissue wounds. It was advised that such cases should be given a systemic course of penicillin prophylactically as soon as they reached a base hospital. (b) Gas gangrene. (c) Late cases with established sepsis—in selected cases. (d) Septicaemias—waiting for a positive blood culture in medical cases but not in battle casualties.

Local Penicillin.—Wounds of chest, head, eyes, face, and soft tissue.

Technique of Systemic Administration

The administration of the drug throws a big extra strain on the hospital staff, particularly when more than 20 patients are being treated simultaneously. We entrusted the work principally to the transfusion officer of the hospital and his orderlies. For day work they made up bottles of 18 c.cm. aq. dest. containing 90,000 units—i.e., 6 doses of 15,000 units in 3-c.cm. doses—and they did the injections (intramuscular) themselves. A screw-cap laboratory specimen bottle holds 18 c.cm. conveniently. The smaller specimen bottle holds 3 c.cm., and for night work the 3-c.cm. doses were put up in the requisite number of bottles and left with the night sister for her to inject. It was easier for her at night to suck up the whole contents of the bottle rather than measure out exact amounts. Occasionally the administration was by continuous intravenous drip, 5,000 units an hour in glucose-saline, plasma, or blood. On the whole the intramuscular route proved more foolproof and satisfactory.

Reactions.—Untoward reactions were negligible apart from *thrombophlebitis* on continuous intravenous drip. The vein usually thrombosed after 48 hours, and the onset of thrombosis

was not delayed by increasing the rate of infusion from 4 pints to 6 pints in 24 hours. Pain on intramuscular injection was fleeting. We saw only one urticarial reaction in 200 cases treated systemically. It developed on the third day of treatment. There were widespread wheals over the body, and it disappeared spontaneously in two days though the treatment was continuing. Pyrexia sometimes occurred on intravenous therapy, but there were no rigors. We tried intramuscular injections of calcium salt in three patients, and there were no local ill effects even after 36 consecutive injections. If the fear that injection of calcium penicillin will cause necrosis is allayed, then manufacturers can concentrate on producing the calcium salt, which has two advantages over the sodium salt: (a) it is not affected by moisture and can be prepared as a powder for local use; and (b) it can be manufactured in greater concentration than the sodium salt.

Clinical Results

The results which are summarized below cover the period from January to June, 1944, and much of the work was experimental, with searching for the proper technique. We had at our disposal about 700,000,000 units of penicillin. It is not possible yet to state the number of wounded men who received treatment with penicillin, but it must run into several thousands. Of the over-all benefit that ensued there can be no doubt. Apart from the general diminution in the infection rate, and the probable effect of that on subsequent mortality, we can recall many instances where the man's life was beyond question saved solely because this drug was available. Detailed reports of some of the investigations are being prepared by the surgeons concerned, and will be published soon.

Soft-tissue Wounds

There was general agreement among surgeons that the wounds in Italy became more quickly infected than did those in the Middle East, and an untreated 24-hour-old wound might already show pus formation. Nevertheless, provided proper surgery had been performed at the C.C.S., the wounds looked clean when they arrived back at the forward base hospitals. On the other hand, it is possible that they would not have stood up to the longer line of evacuation we used to have to contend with. *Staphylococcus aureus* was the predominant organism.

Penicillin was not used routinely in the forward areas in soft-tissue wounds because the supplies were reserved for more serious casualties; but when it was used there was no alteration in the existing technique of wound treatment, except that, in place of sulphanilamide powder, penicillin-sulphathiazole powder was insufflated throughout the wound like a hoar-frost (5,000 units per gramme; average amount, 2 g.). Prior to this the wound was carefully trimmed or excised and left open; and there was fortunately no tendency on the part of surgeons to neglect surgery and rely too much on penicillin. If this is appreciated by surgeons then there is everything to be gained by making use of the proper combination of surgery and penicillin, for the knife alone cannot get rid of infection. We have no concrete evidence from Italy to show that on arrival at the base those wounds which had been previously insufflated with penicillin-sulphathiazole powder were cleaner than any others, though favourable impressions were formed by many surgeons. (In a previous series of battle casualties during the Sicilian campaign we found that of the wounds excised and insufflated with penicillin at the C.C.S. level exactly 50% showed no growth on culture when they arrived with dressings undisturbed at the forward base hospital five days later.)

At the base hospitals early secondary suture was performed as a routine, and this was made possible by the short line of evacuation, whereby in less than 10 days from wounding the case arrived at a base hospital where he could be retained. The first dressing was usually done in the operating theatre, and if the wound was suitable for suture the patient was forthwith given pentothal anaesthesia and operation was performed.

The technique of penicillin administration in secondary suture became fairly standardized: (1) for superficial wounds, if clean—a single insufflation of penicillin-sulphathiazole powder and suture; (2) for dirty superficial wounds—preliminary insufflations once daily for two days, then suture over a third

insufflation; (3) for sinuses, and perforating wounds where the powder could not reach—suture with fine rubber tubes and instillations of 3 c.cm. (250 units per c.cm.) down each tube daily for 4 days. In all three types practically no excision was done except to freshen the skin edge and remove a loose tag. The powder was at a strength of 5,000 units per gramme, but latterly equally good results seemed procurable at base hospitals using 2,000 units per gramme. While the powder method was simple and almost always successful, there was a tendency, as the surgeon became more experienced, to use tubes and instillations if he wanted to make assurance doubly sure in a difficult case. On the other hand, tubes and instillations were often followed by Gram-negative pus, which seemed to become more common as the weather got hotter. Gram-negative pus was not noticeable with powder alone.

Here are three examples of series of suture at general hospitals:

1. *Lieut.-Col. J. J. M. Brown*.—68 superficial wounds were sutured with sulphanilamide with 23% of failure. 110 comparable wounds were sutured, with one insufflation of penicillin-sulphathiazole powder; there were no failures. 108 wounds regarded as unsuitable for suture by pre-penicillin standards were sutured with penicillin with 17% of failures.

2. *Lieut.-Col. R. W. Hendry*.—"Insufflation:—170 cases of soft-tissue wounds capable of secondary suture or skin-graft were treated with penicillin-sulphathiazole powder. In practically all these cases a 100% wound-healing was obtained. Instillation:—25 cases were treated by instillation—mostly large shell-wounds of buttock or thigh. Some 70% were healed in 10 days, the remainder being left after 10 days with superficial healing wounds. The average stay in hospital of these cases before being sent to convalescent depot or discharged to duty with healed wounds was 40 days. Without penicillin these would have been '90 days + ' cases."

3. *Lieut.-Col. F. H. Bentley*.—256 wounds sutured or grafted with local penicillin with 95% success. The average stay in hospital of 61 penicillin cases was 21 days; the average stay of 200 contrasts was 34 days. In wounds with skin loss, 10 to 14 days old and bacteriologically infected, Thiersch grafts were applied successfully after 2 to 3 days' preliminary insufflation. In two cases rotation flaps were swung down to cover large defects into the knee-joint. A useful technique with skin defect was to do partial suturing with tubes and instillations: after 4 days there was less oedema and tension, and the wound could then be sutured complete or grafted.

1% *Neutral Proflavine-Sulphathiazole Powder*.—A trial of this powder was made in soft-tissue wounds, and the general impression of surgeons was favourable—"not quite as good as penicillin-sulphathiazole powder, but definitely better than sulphanilamide powder." It took 4 to 5 days' insufflation to prepare an infected wound for suturing, as against 2 to 3 days with penicillin. Its main place is in superficial wounds; and it has also been found effective in clearing up Gram-negative infection. There is evidence that this powder can necrose on a fresh surface (as against a granulating surface). Four wounds were seen covered with a thin black film, giving rather a mummified appearance. With calcium penicillin in short supply it seems reasonable to encourage surgeons at base hospitals to use proflavine-sulphathiazole for surface wounds and sodium penicillin solution for deep wounds; and to reserve calcium penicillin for fresh wounds at the C.C.S. level.

Chest Wounds

In the ordinary way about 33% of penetrating chest wounds go on to empyema formation, through infection of the haemothorax. Penicillin has a big place in the management of the haemothorax or the established empyema, but to obtain the results it can give demands the greatest skill in getting the drug to the right part. Local instillation into the pleural cavity is the method of choice, and is combined with systemic therapy only when the patient has a large empyema and is very toxic. Systemic therapy alone is not enough, as the drug does not get through the barrier on the pleura in sufficient concentration. The principal difficulties of getting the drug to the part are due to loculation and clotted haemothorax, so that patient aspiration is always, and open operation sometimes, necessary.

In the forward areas, after closing the sucking wound, the surgeons sometimes instilled 15,000 units of sodium penicillin in 15 c.cm. aq. dest. At the base hospital (*Lieut.-Col. A. L. d'Abreu* and *Major J. Litchfield*) 60,000 units were instilled

after every aspiration, which was usually every 2 to 3 days. The 60,000 units were dissolved in 30 to 60 c.cm., depending on the size of the cavity. If operation was necessary the drug was instilled down the drainage-tube, which was then clipped off for 6 hours. The intrapleural instillation of penicillin produced a high concentration, which persisted for 48 to 72 hours, and there was no doubt that the instillations had a dramatic effect on the bacteria in the pleural cavity. In established sepsis, rib-resection and drainage were often rendered unnecessary, even in staphylococcal empyema. A certain number still required rib-resection or intercostal drainage, though the convalescence was made easier. The worst complication was the broncho-pleural fistula which kept reinfecting the cavity and usually ended fatally. A lesser complication was the anticipated one of Gram-negative pus; staphylococci, streptococci, pneumococci, and clostridia were eradicated, but Gram-negative pus from *pyocyaneus* and coliform organisms remained in the cavity. Among the most satisfactory cases to treat were the huge chest-wall wounds, which were safely sutured even in the presence of infection.

Open Fractures

The aim with all severe fractures was to get them set up and started on a course of penicillin within 14 days of wounding and before infection had become firmly established. In the forward areas the wounds were excised and penicillin-sulphathiazole powder insufflated. At the base the patient was started at once on a systemic course, and after being "penicillinized" for 24 hours the wound was trimmed again, when necessary, and partially sutured. Fractures of femur were treated by skeletal traction and Thomas splint; other fractures by closed plaster. The course of penicillin extended from 5 to 10 days (500,000 to 1,000,000 units): 15,000 units 3-hourly intramuscularly for the first three days; thereafter at 4-hourly intervals. The wounds were left undisturbed for 21 days, and the decision whether to continue penicillin after the 5-day course depended on memory of the degree of wound inflammation at the time of operation, and the patient's general condition. After 3 weeks, if the case was not going well, the organism present was tested for sensitivity to penicillin, the wound reassessed and drainage improved, and further penicillin given.

Among battle casualties the commonest serious problem from the point of view of infection is fracture of the femur. We were anxious to know what proportion of fractured femurs became chronically infected under conditions existing in Italy, and for this reason studied 70 open fractures of the femur being treated by standard methods at an orthopaedic centre (Major R. J. Furlong and Major J. M. P. Clark). Estimating that a sinus down to bone was the best indication of some degree of infection, it was found that at 8 weeks after wounding 36% were still open fractures, and that by 12 weeks the figure had come down to 23%. These are figures of patients who survived or did not require amputation (see below). At the same time a similar number of femurs were treated by the same surgeons with penicillin and partial suture (average 800,000 units), and the figures at 8 weeks and 12 weeks were no better than the contrasts. This rather disappointing result was due to difficulty in maintaining adequate drainage of the Gram-negative pus and autolytic products, and to occasional internal manipulations that penicillin seemed to justify. However, there was no doubt that major sepsis was prevented, as shown in the following Table.

140 Open Fractures of Femur

	No.	Deaths	Amputations
Contrasts	70	6 (8.6%)	6 (8.6%)
Penicillin	70	1 (1.4%)	2 (3%)
		(Due to concomitant cerebral lesion)	(Both for useless legs and not for sepsis)

A certain number of femurs will always require amputation when the defect is such that an artificial leg is a better proposition and when there is a major vascular injury. But certainly few of these patients, if any, should die from infection if the organisms they are harbouring are sensitive to penicillin. At another orthopaedic centre, which was able to concentrate

attention on a smaller number of cases, Major R. J. B. McEwan and Capt. J. G. Bickerton treated 12 femurs by partial suture and conservative fracture methods, and an average of 540,000 units of penicillin. Nine were firmly closed and epithelized by 12 weeks, and three showed minor residual infection. All were united.

Many open fractures of other bones were treated with penicillin, but the results were not studied systematically. Suture was usually not attempted in the fractured tibia, but most of the others healed well when partially sutured. The systemic course of penicillin seemed beneficial in most cases. A trial has been begun of instilling large doses locally to the fracture site, with promising results.

Knee-joints

Penetrating wounds of the knee-joint do extremely well if treated conservatively, with or without penicillin. Seventeen were treated in the forward areas by insufflation of penicillin-sulphathiazole powder, and 17 with sulphanilamide powder. One in each series ultimately became septic. In contrast to this good prognosis in knee wounds as a whole, it may be said that when the joint does develop an acute arthritis it is an extremely serious condition and there is a place for penicillin.

Eight grossly infected knee-joints settled down most satisfactorily, in three cases with already actively functioning joints at the time of writing (8 weeks). We believe that local instillation is the method of choice in lesions confined to the knee-joint or with minor associated fracturing of femur, tibia, or patella. The joint is opened, washed out with saline, and the capsule closed round a thin rubber tube. The skin is partially sutured. Five to ten c.cm. of penicillin solution—250 units per c.cm.—are instilled twice daily for about four days, and the tube is then removed. Alternatively, the joint can be washed out and then closed completely, being filled with penicillin solution before final closure. In a few days it can be aspirated and refilled if necessary. Systemic therapy, or the combination, is indicated if there is gross fracturing round the knee, and when the toxæmia is profound.

Amputations

Twelve infected amputation stumps healed fairly well when treated with tubes and instillations. Better results were obtained in eight stumps when the patient was given a short systemic course. We advised 24 hours' systemic penicillin before performing a deliberate operation, followed by a further 2 to 4 days' therapy. In the case of the lower leg, when the decision is made to amputate for a septic or crushed foot it is the practice in war surgery to amputate through the lower third as a precautionary measure. Later on, the leg has to be re-amputated at the site of election. With penicillin controlling infection it proved possible to perform definitive amputations, though this treatment was entrusted only to experienced surgeons.

Gas Gangrene

Encouraging results were obtained in this condition, which hitherto has carried a mortality of 50% in Italy. The treatment we recommended was threefold:

- (1) Radical surgery—excision of muscle, or amputation if necessary.
- (2) Gas-gangrene antiserum—49,500 units I.V. at operation (polyvalent antiserum, 27,000 *welchii*, 13,500 *septicum*, 9,000 *oedematiens*), followed in 6 to 8 hours by a further 49,500 units if no clinical improvement, and repeated again when necessary.
- (3) Penicillin systemically—25,000 units of sodium penicillin at operation, and a 3- to 5-day course of 15,000 units I.M. 3-hourly—i.e., 120,000 units a day. (Average 380,000 units.)

It is advisable to have the antiserum and penicillin circulating in the blood before operation, but in the event this was seldom done.

Thirty-three cases were treated on the above lines and 12 died (36%); 5 of the 33 patients were adjudged too ill for surgery, and all died quickly. The other 28 patients had the full treatment of surgery, antiserum, and penicillin, and 7 died (25%). The deaths of these seven men were due in three cases to fulminating toxæmia for which our resuscitation, antiserum, and penicillin were inadequate, and in four cases to late secondary effects such as bronchopneumonia and renal failure. All of these 33 cases were examples of true gas gangrene (clostridial myositis) with massive involvement

of muscle, and the predominant pathogen was *Cl. welchii*. They provided convincing evidence that penicillin can arrest the progressive myositis, but that, nevertheless, radical surgery is still the main factor in treating the disease.

Penetrating Wound of Abdomen

It was not felt that there was any special indication for penicillin in penetrating abdominal wounds, for it seemed to us that the deaths were due to physiological reasons rather than to sepsis. Infection of the abdominal wall is an indication of an infective element, and is also a bad prognostic sign as regards late deaths (14 to 28 days). A few such cases were treated by a short systemic course with decided improvement.

Head Wounds

The percentage of scalp and brain wounds that heal by primary union has always been a high one when operation is performed at special neurosurgical units. In Italy, with greater infectivity of the terrain, this standard tended to deteriorate whenever penicillin was in short supply, but was maintained when penicillin-sulphathiazole powder (5,000 units per gramme) was insufflated to surface wounds and into depths of brain. In brain abscesses tubes and instillations formed the method of choice.

Maxillo-facial Wounds ; Eyes ; Burns

Wounds of the face have hitherto been allowed to heal spontaneously, and at a later date the scar was excised. With the use of penicillin-sulphathiazole powder many face wounds have had primary suture. The resulting scars were admirable, and even if they were not the men were enabled to return to duty and to have cosmetic surgery performed at leisure.

Satisfactory results were obtained in cases of corneal ulcers and abrasions, and conjunctivitis, by 2-hourly drops of sodium penicillin, 1,000 units per c.cm. aq. dest. In 50 cases no staphylococcal, streptococcal, pneumococcal, or gonococcal infection remained after 48 hours of instillations. Infected eye-sockets were treated by local penicillin; panophthalmitis by a systemic course. Blepharitis responded to an ointment of 500 units per gramme of soft lanette wax (25% lanette wax in water).

Penicillin-sulphathiazole powder insufflated on to the burned area and covered with tulle gras proved a most excellent dressing for burns. It was not employed frequently, because it used up too much powder.

This was the basis of a report submitted to the D.G.A.M.S. by the Penicillin Control Unit, Central Mediterranean Force. We wish to thank the Director-General for permission to publish this report. We are also grateful to Major-Gen. L. T. Poole (Director of Pathology), Major-Gen. D. C. Monro (Consultant Surgeon), Brigadier Hugh Cairns (Consultant in Neurosurgery), and Sir Howard Florey (Honorary Adviser in Pathology to the Army) for advice and help in our investigation; and to the administrative and medical officers of the R.A.M.C. for their full co-operation.

EARLY DIAGNOSIS OF PERIPHERAL NERVE INJURIES IN BATTLE CASUALTIES

BY

W. RITCHIE RUSSELL, M.D., F.R.C.P.Ed. and Lond.

Brigadier; Consultant in Neurology to M.E.F.

AND

A. B. HARRINGTON, M.B.Aberd.

Captain, R.A.M.C.; Graded Physician

It is the experience of all Nerve Injury Centres that cases are admitted in which there have been delay in diagnosis and errors in early treatment that have gravely prejudiced the subsequent usefulness of the limbs affected. One of us (A. B. H.), for example, has been responsible for the records of cases admitted to a Nerve Injury Centre in the Middle East; the interval after wounding before an associated nerve injury was recognized is given in the accompanying Table. From these figures it is obvious that the methods commonly used in investigating limb injuries soon after wounding often fail to indicate paralysis of one or more of the principal nerves to limbs.

Interval after Injury at which the Presence of a Nerve Lesion was recognized

Nerve	Interval in Weeks after Injury			
	Under 1 Week	1 to 4 Weeks	Over 4 Weeks	Totals
Arm				
Radial	11	8	4	23
Median	15	5	6	26
Ulnar	29	12	5	46
Two or more nerves	15	2	1	18
Other lesions	1	—	1	2
Leg				
Sciatic	15	2	1	18
Lateral popliteal and branches	12	4	11	27
Medial popliteal and branches	6	3	2	11
Other lesions	—	1	—	1
Totals	104	37	31	172

The importance of stressing the need for paying special attention to the early treatment of nerve injuries is indicated by the observation that of 132 cases of nerve injury in the upper limb 61 showed a varying degree of contracture or stiffness of the joints of the fingers. In most of these this disability was due to the effects of nerve injury only and not to associated injury of muscles in the forearm. As will be mentioned later, the maintenance of full range of movement of joints and tendons is the first consideration in the treatment of cases of nerve injury in the upper limb.

The methods of examining cases of nerve injury have been fully described in the M.R.C. War Memorandum No. 7, 1942—"Aids to the Investigation of Peripheral Nerve Injuries"; but surgeons who have to treat battle casualties in forward areas may find useful a description of a few selected tests which they can apply quickly to cases of limb injury while the patient is lying on a stretcher. The most common trick movements are also given.

Rapid Methods of Examination Suitable for Use in Forward Battle Areas

In most instances the tests needed to demonstrate the integrity of the principal nerves of a wounded limb take less than 60 seconds to apply, and the expert can do the essential tests in less than 30 seconds. When there is nerve injury, however, the tests to locate the lesion may take a further few minutes. If the injuries have caused severe loss of consciousness or profound shock it may be necessary to postpone the examination.

Muscle Tests.—The examination of voluntary action of the muscles is the most accurate method of quick diagnosis, as a few of the muscles supplied by each nerve can be tested in a very short time. The patient is asked to carry out specific movements against resistance or to maintain posture against resistance (which need be only slight), while, where possible, the muscles contracting or their tendons are observed and palpated to confirm beyond all doubt that the muscles are contracting. The latter part of the test prevents deception by trick movements. Wasting of denervated muscles is a useful guide in chronic cases only. Testing the electrical reactions is of no value in early cases, and is seldom necessary for diagnosis in chronic cases.

Sensory Tests.—The examination of sensation provides valuable confirmatory evidence of the muscle tests, but takes more time, is difficult to carry out in a severely wounded patient, and as a rough preliminary test is less reliable than the motor examination. It is obvious that only the simplest sensory tests can be used in severely injured patients. In this connexion the following principles are worthy of note:

(a) In the majority of cases testing of sensation in the peripheral portion of the limb, in the hand or foot, is the essential part of the examination.

(b) The patient can often himself accurately describe and map out any area of anaesthesia.

(c) Sensory tests should be directed first towards demonstrating the integrity of the main nerves. For example, in the upper limb attention to the palmar aspect of the index and little fingers will test the median and ulnar nerves, while in the lower limb sensation over the dorsum and sole of the foot depends on the lateral and medial popliteal nerves (or their branches) respectively.

(d) Testing with the point of a pin is usually the most useful method, but the stimulus must be vigorous when testing over the thick skin of the palm and sole. Testing for light touch is often best done by stroking the skin lightly with the finger, as a wisp of cotton-wool is useless on thickened skin.