IN THE military service during war, injuries to peripheral nerves are amongst the most commonly observed in the wounded soldier that survives. This is easily understood when one realizes how multiple are the penetrating wounds that may be suffered by a single man, from the spraying of shell fragments. Because of the penetrating quality of, and multiplicity of fragments from highly explosive shells and land mines, nerves that are normally well-hidden and protected are just as vulnerable as are those near the surface. The purpose of this paper, therefore, is to review the most logical approaches for adequate exposure of the various nerves and to present new incisions developed on the Neuro-Surgical Service at Wakeman General Hospital.

These modifications are based on the study of 1567 peripheral nerve lesions.

In devising the new incisions, adherence to the following surgical principles was found to be of great advantage.

1. Adequate exposure of the injured nerve.
2. The approach to deeply lying nerves is made through fascial planes, rather than by penetrating through muscle substance.
3. If a muscle must be penetrated, it is always split in the direction of its fibers.
4. When a muscle must be divided, it is severed only at its point of fascial attachment, so that it may be easily repaired.
5. Shortening of a normal long bone, or resection of a clavicle are avoided when possible.
6. Skin incisions that are perpendicular to flexion creases must be avoided, since a traction scar will invariably result. Not only is the skin involved in the production of traction scars, but subcutaneous tissues and fascial layers as well.

The incisions of the extremities have for the most part been divided into three parts. This is especially true for incisions about the cubital and popliteal fossae. One part alone is usually sufficient for repair of the nerve, while two or all three parts may be used when rerouting as well as repair is necessary.

INCISIONS IN THE UPPER EXTREMITY

The Median Nerve. The median nerve in the arm, above the elbow joint, is easily explored through part 1, Fig. 1; this consists of a longitudinal incision over the mesial surface of the arm. It lies in the plane between the bor-
ders of the biceps and triceps muscles. The median nerve in the forearm is exposed through a longitudinal incision on the volar surface of the forearm. It is usually placed mesial to the border of the brachioradialis muscle (part 3, Fig. 1). Through this incision the pronator teres muscle is exposed and split in the direction of its fibers where deep within its substance the median nerve courses. Part 2 of the incision in Fig. 1 is a transverse incision following a flexion crease in the cubital fossa. When these incisions are united, a modi-

Fig. 1 (left). Incision for exploration of median nerve in arm and forearm.
Fig. 2 (right). Exposure of the median nerve in the arm and forearm accomplished by the use of the combined Z-shaped incision. (A) Median nerve. (B) Brachial artery. (C) Pronator teres muscle.

fied Z is formed, thus avoiding an incision crossing a flexion crease. The flaps, a and b, are now retracted and through this wide exposure the median nerve may be traced along its course in the arm and forearm (Fig. 2). A transplantation of this nerve may also be carried out. It is possible to explore the radial and ulnar nerve as well as the median nerve through this incision. Such an incision heals without distortion and avoids the flexion contractures shown in Figs. 3 and 4.

The Ulnar Nerve. The exposure of the ulnar nerve in the arm is accomplished through the same incision as for the median nerve as shown in part 1, Fig. 5. The ulnar nerve in the forearm is explored through part 3, Fig. 5.
Fig. 3 (left). Traction scar resulting from an incision perpendicular to flexion crease at the cubital fossa.

Fig. 4 (right). Extensive incision crossing the flexion crease at the cubital fossa.

This is a longitudinal incision following the margin of the flexor carpi ulnaris muscle. Part 2 of the incision in Fig. 5 is a 5 cm. curved incision over the region of the medial epicondyle. This is used to explore and transplant the

Fig. 5 (left). Incision for exposure of the ulnar nerve in the arm, at the ulnar notch, and in the forearm.

Fig. 6 (right). Incision for exposure of the ulnar nerve. Incision #1 was used for neurorrhaphy, after transplantation of nerve was performed through incision #2.
The ulnar nerve to the volar surface of the forearm. Parts 1, 2 and/or 3 of this incision may be used depending upon the need and location of the nerve injury as shown in Fig. 6.

The Radial Nerve. The radial nerve in the arm is exposed through part 1 of the incision in Fig. 7. This is a longitudinal or oblique incision over the lateral surface of the arm parallel to the radial groove. The radial nerve in the forearm, part 3 of Fig. 7, is exposed through a longitudinal incision over the volar surface of the forearm, being placed laterally over the border of the

![Fig. 7 (left). Incision for exposure of the radial nerve: (1) in the arm, (2) lateral to the cubital fossa, (3) in the forearm.](image)

Fig. 7 (right). Exploration of the brachial plexus. Transverse axillary incision.

The brachioradialis muscle. The radial nerve at the level of the cubital fossa is best exposed by a 5 or 6 cm. semi-circular flap incision as shown in part 2, Fig. 7. This incision is made laterally over the region of the lateral epicondyle in order to avoid crossing the flexion crease. When this flap is retracted medially, the nerve may be exposed as it lies between the biceps tendon and the brachioradialis muscle. From here it may be followed along its course beneath the brachioradialis muscle to its point of division into the deep and superficial radial nerves.

The Brachial Plexus. Transverse axillary incision. Exposure of the entire brachial plexus in the axilla can be easily accomplished by a transverse incision following a flexion crease across the entire axilla as shown in Fig. 8. This is the incision of choice, especially for exposing the radial nerve since it lies posteriorly in the axilla. Such an incision avoids the deformity and dis-
ability of a contraction scar which follows an incision perpendicular to the flexion creases in the axilla as shown in Fig. 9.

**Supraclavicular incision.** This is a 4 cm. transverse incision 2 cm. above and parallel to the clavicle as shown in Fig. 10. This incision is used to expose the brachial plexus in the neck. It is also used for exposure of the anterior scalene muscle.²

**Infraclavicular exposure of the brachial plexus.** This is the accepted approach for exposure of the brachial plexus beneath the pectoralis major muscle.

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**Fig. 9 (left).** Traction scar resulting from an incision perpendicular to flexion crease at the axilla.

**Fig. 10 (right).** Exploration of the brachial plexus. Supraclavicular incision for exposure of the brachial plexus in the neck.

**Fig. 11 (left).** Exploration of the brachial plexus. Infraclavicular incision for exposure of the brachial plexus beneath the pectoralis major muscle.

**Fig. 12 (right).** Traction scar resulting from erroneously planned infraclavicular incision crossing the anterior axillary fold.
Fig. 13. Exploration of the brachial plexus. Transclavicular approach for exposure of the brachial plexus above, below, and beneath the clavicle.

Transclavicular approach to brachial plexus (incision of Stone). By this approach the brachial plexus may be exposed above, below, and beneath the clavicle, without sacrificing the clavicle or without injury to the fibers of the pectoralis major muscle. A modified semi-circular incision is made beginning

Fig. 14 (left). Traction scars resulting from incisions perpendicular to the flexion crease at the wrist.

Fig. 15 (right). Incision for exposure of the median and ulnar nerves at the wrist.
above the clavicle near its sternal attachment, and continuing upward and lateralward to the border of the deltoid muscle (part 1, Fig. 13). The incision now curves downwards and crosses the clavicle at its outer third (part 2, Fig. 13); it is now continued downward toward the axilla (part 3, Fig. 13). When the skin flap is retracted the fascial plane between the deltoid and pectoralis major muscle is clearly discernible. The clavicle is divided at this point; the lateral portion is retracted upwards and the medial portion with

the pectoralis major attached is retracted downwards and outwards. The pectoral muscle is in this way separated from the deltoid in their normal plane of cleavage, bringing the entire brachial plexus clearly into view. At the termination of the surgical procedure, the clavicle is wired together. This procedure surpasses all other clavicular approaches to the brachial plexus in that the integrity of the shoulder girdle is more easily maintained.

**INCISIONS IN THE HAND AND WRIST FOR EXPOSURE OF MEDIAN AND ULNAR NERVES**

The most severe and disabling contracture scars are caused by longitudinal incisions crossing the flexion crease and transverse carpal ligament at
the wrist and into the hand (Fig. 14). The median and ulnar nerves on the volar surface of the wrist may be easily exposed by using a transverse incision, in a flexion crease at the wrist as shown in Fig. 15. When using this incision the transverse carpal ligament is also divided in the direction of its fibers. This is an exploratory incision, and should mobilization or transposition be required, the incision is then continued at right angles as far proximally as indicated.  

A combined incision for exposing and following the median nerve from the forearm into the hand, consists of two parts as shown in Figs. 16 and 17.

![Fig. 18 (left). Traction scar at the wrist produced by continuation of forearm incision into the hand. Fig. 19 (right). Incision for exploring the tibial and peroneal nerves in the region of the popliteal fossa.](image)

Part a, Fig. 16 follows a flexion crease in the hand, and is used for exploring the median nerve in the hand. Part b, Fig. 16, a longitudinal incision in the forearm ending at the wrinkle lines in the wrist, is used for mobilization of the nerve in the forearm when necessary. Part b may be continued as far proximally as is found necessary. The small intact area of skin between these two incisions may be easily undermined and the nerve exposed beneath it. A comparable incision is made for exposing the ulnar nerve in the forearm and hand. Adherence to this type of incision would have prevented the contracture scar at the wrist noted in Fig. 18.
PERIPHERAL NERVE SURGERY

Fig. 20 (left). Retraction of skin flaps in the region of the popliteal space to show the operative exposure obtained by use of the Z-shaped incision.

Fig. 21. (right). Exposure of the sciatic nerve with its division into the tibial and peroneal in the region of the popliteal fossa. (A) Sciatic nerve. (B) Peroneal nerve. (C) Tibial nerve.

INCISIONS IN THE LOWER EXTREMITY

The Tibial and Peroneal Nerves in the Popliteal Fossa. Here again the incision is divided in three parts as shown in Fig. 19; a longitudinal incision is made along the posterior surface of the thigh, lower third. This incision is carried down to, but not through the flexion crease in the popliteal fossa (part 1, Fig. 19). This incision is used for exposure of the sciatic nerve at the point of division into the tibial and common peroneal nerves. The incision is now carried transversely, at the flexion crease in the popliteal fossa, lateralwards to the border of the head of the

Fig. 22. Traction scar resulting from an incision perpendicular to the flexion crease at the popliteal fossa.
fibula (part 2, Fig. 19); now it is curved downwards lying between the bellies of the gastrocnemius and soleus muscle (part 3, Fig. 19). In this fashion the two flaps are retracted, as shown in Fig. 20, and the tibial nerve may be followed into the calf while the peroneal nerve may be exposed on the lateral surface of the leg at the head of the fibula (Fig. 21). For the exposure of the common peroneal nerve alone, the lower third of the incision alone may be used. To omit the modified Z across the popliteal fossa produces the result pictured in Fig. 22.

![Anatomical drawing](image-url)

**Fig. 23 (left).** An anatomical drawing to show the relationship of the sciatic nerve to the biceps femoris muscle. (From Gray's *Textbook of anatomy*. Philadelphia: Lea & Febiger, 1930, 22nd ed., p. 958.)

**Fig. 24 (right).** Incision for lateral approach to the sciatic nerve in the thigh, in (C) plane of division between (B) vastus lateralis and (A) biceps femoris muscle. (From Sobotta's *Atlas of human anatomy*. New York: G. E. Stechert & Co., 1932, 3rd ed., p. 608.)

**THE LATERAL APPROACH FOR EXPOSING THE SCIATIC NERVE IN THE THIGH**

A review of the anatomy of the sciatic nerve in the thigh (Fig. 23) reveals that the massive biceps femoris muscle crosses the sciatic nerve in the middle third of the thigh from mesialward to lateralward. This is easily understood since the muscle originates from the ischial tuberosity, while the insertion is over the head of the fibula and lateral condyle of the tibia as shown in Fig. 23. The sciatic nerve below the level of the gluteal fold lies
beneath the lateral border of the biceps femoris muscle in the upper two-thirds of the posterior thigh, rather than in the midline between the biceps and semitendinosus muscle. When the accepted midline incision is used along the posterior surface of the thigh, the biceps femoris muscle must be separated from both the semimembranosus and semitendinosus muscles, before the nerve can be exposed, and in addition it will often be necessary to sever part of the attachment of the biceps muscle from the ischial tuberosity before the upper portion of the sciatic near the gluteal fold is adequately exposed. The lateral incision, therefore, is a longitudinal incision placed in the plane of division between the vastus lateralis and biceps femoris muscle,

Fig. 25. Exposure of the sciatic nerve in the thigh by the use of the “lateral approach.” (S.N.) Sciatic nerve. (B.M.) Biceps femoris muscle.

as shown in Fig. 24. By gently elevating the biceps femoris muscle the sciatic nerve is easily exposed, as shown in Fig. 25.

EXPOSURE OF THE SCIATIC NERVE BENEATH THE GLUTEUS MUSCLES

The “question mark” or sickle-shaped incision of Stookey is used for exploration of the sciatic nerve from its exit at the sciatic notch to the gluteal fold. A curved incision is made beginning in the mid-gluteal region at the level of the sacro-iliac joint and continuing downward and outward over the region of the greater trochanter of the femur. The incision is now curved downward and then inward along the gluteal fold, to the mid-thigh and continued down along the mid-thigh for about 5 cm. as shown in Fig. 26. The gluteus maximus muscle is split along the course of its fibers, all the way to the fascial and tendinous insertion at the iliotibial band over the greater trochanter. Great care is now used to sever the gluteus maximus muscle at its fascial insertion. The entire muscle is now reflected medialwards.

For convenience the Stookey incision is divided into three parts. The first (part I, Fig. 26) may be used alone to expose the sciatic nerve at the
sciatic notch, especially when a neurolysis alone is indicated. The lower third (part III, Fig. 26) may be used alone for sciatic nerve exposure near the gluteal fold. When the lower incision alone is used (Fig. 27), only a small portion of the gluteus muscle insertion is severed.

**EXPOSURE OF THE TIBIAL NERVE**

The tibial nerve lies beneath the calf muscles, the gastrocnemius and soleus and adjacent to the posterior tibial muscle. It may best be reached by a longitudinal incision over the mesial surface of the leg and approached beneath the fascial plane of the soleus muscle as shown in Fig. 28 (incision of Clifton). This incision may be continued proximally when it is found necessary to reflect the soleus muscle in the presence of a very extensive tibial nerve defect.

It must never be approached through the calf by a posterior incision as shown in recent literature since the muscles are so constructed that they cannot be split in the direction of their fibers. The trauma
produced by penetrating the calf muscle results in a severe postoperative reaction as well as severe disabling adhesions between the calf muscles, and definitely impedes plantar flexion of the foot. Fig. 29 is a cross section of the leg in its upper 3rd showing the anatomy of the tibial nerve and the new approach.

Fig. 29. Cross section of the leg in its upper third showing the relationships of the tibial nerve, and the surgical approach.

REFERENCES