COMPUTERISED AXIAL TOMOGRAPHY IN TRACTION INJURIES OF THE BRACHIAL PLEXUS

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Severe traction injuries may damage the brachial plexus at any level from the spinal cord to the axillary outlet. Investigation aims to determine the level of the injury for each of the nerves, trunks or cords, with particular reference to obtaining firm evidence of any intradural (pre-ganglionic) damage.

We report the results of computerised axial tomography of the cervical spine in comparison with conventional myelography and with surgical exploration of the plexus. CT scanning with contrast enhancement greatly improves diagnostic accuracy, particularly at C5 and C6 root levels.

Closed traction injury of the brachial plexus is becoming more common because of the increasing number of motorcycle injuries. Seriously injured victims survive more often because the wearing of crash helmets is compulsory (Wynn Parry 1984). In our opinion, an exploratory operation is indicated in the first week after injury when there is clinical evidence of either a complete lesion of the brachial plexus or of a reparable lesion. An early operation is relatively easy, it provides an accurate prognosis and may give better results after nerve repair.

Early exploration may, however, be precluded by severe associated injuries and, in many cases, patients are referred some weeks or months after injury when exploration is very much more difficult because of fibrosis and distortion of the plexus.

Investigation then seeks to determine the level or levels of injury (that is, whether avulsions or distal injuries), the extent of the lesion (that is, which root or roots) and the depth of neural damage. The extent and depth of damage are indicated by the clinical features but the level of the damage is more difficult to determine and there is no reliable method of determining whether one or more roots have been avulsed from the spinal cord.

At present avulsion means permanent loss of function in the distribution of the affected root (Bonney 1977) and it is therefore important to establish whether there has been damage at this level. Existing diagnostic methods include:

1. Clinical assessment. Important factors are paralysis of proximal muscles, the pattern of sensory loss, the presence of crushing or burning pain in the insensitive hand and the presence of Horner’s syndrome. A positive Tinel sign may indicate possible rupture of a nerve trunk.

   The accuracy of clinical assessment is marred by inconstant innervation patterns in different individuals and by the difficulty of distinguishing between pre-ganglionic and post-ganglionic lesions.

2. Histamine testing, nerve conduction studies and somatosensory-evoked potentials. Bonney demonstrated in 1954 that demyelination of the sensory axons does not occur after pre-ganglionic lesions, so that axon reflexes are preserved, and Bonney and Gilliatt (1958) showed persistence of conduction in the sensory fibres passing to the posterior root ganglion of a spinal nerve avulsed from the spinal cord. These two methods are difficult to interpret in areas where innervation patterns are very variable and in skin which is hairy or very thick as in the palm of the hand.

   After stimulation of the median nerve at the wrist, somatosensory-evoked potentials can be recorded from the brachial plexus, spinal cord, brainstem and sensory cortex (Jones 1977). The value of somatosensory-evoked potentials in localising the site of the lesion has been assessed; there was good correlation with the findings at operation (Jones 1979).

3. Myelography. The value of myelography in assessing brachial plexus injuries was first recognised by Murphey, Hartung and Kirklin in 1947, and later confirmed by other workers (White and Hanelin 1954; Davies, Sutton and Bligh 1966; Yeoman 1968). Unfortunately, myelography often underestimates the extent of the lesion (Wynn Parry 1984). The myelographic findings in cases with intradural damage may include: meningocele, obliteration of a root pouch, an absent or smaller root shadow, and cystic accumulation of cerebrospinal fluid in the spinal canal (Fig. 1).

4. Exploration. Operation remains the ultimate diagno-
Myelogram after traction injury. Small diverticula are seen at C6 and C7. A meningocele is seen at C8, T1 is normal.

Appearance of roots at hemi-laminectomy and intradural exploration. Figure 2 - Normal. Figure 3 - A case in which the roots have been avulsed.

Topogram showing scanning level and scanning angle.

tic method, although in late cases extensive fibrosis can make interpretation of the findings difficult. Exploration is usually performed anteriorly through a supraclavicular incision, extending from the spinal foramen to behind or even below the clavicle and it is imperative that a nerve stimulator is used during the operation.

Some surgeons have explored within the dura through a hemi-laminectomy (Bonney, personal communication 1985) (Figs 2 and 3). This is obviously the most certain method of diagnosing avulsions of the roots or rootlets, but is a major operation. Somatosensory-evoked potential tests have been found useful during operation to detect proximal root damage (Landi et al. 1980; Sugioka 1984).

Contrast-enhanced computerised axial tomography has been used at St Mary's Hospital since 1983 and we have studied the accuracy of the technique.

MATERIAL AND METHODS

During two years from January 1983 to January 1985, 27 patients with brachial plexus injuries were investigated at least one month after injury by CT scans with enhancement in addition to clinical assessment and myelography. In two cases the contrast material was injected by a lateral puncture between the first and second cervical vertebrae, but in all others 8 ml of either Iopamidol 300 or Amipaque 240 were injected by lumbar
puncture and screened into the cervical region. Prone anteroposterior, oblique and lateral views were obtained on a conventional screening unit with under-couch and lateral x-ray tubes.

CT scanning was performed between 30 minutes and two hours later, using a Siemens Somaton 2000 scanner and taking 4 mm slices at 4 mm intervals. The slice level was determined using a topogram facility and the scanning angle was in the plane of the intervertebral disc (Fig. 4). Slices began one or two segments above and ended one or two segments below the clinically and myelographically abnormal levels.

Sixteen of the 27 cases had an exploratory operation through a supraclavicular incision which was extended as required. Scarring often made identification of nerve tissue difficult and a nerve stimulator was invaluable. Nerve root avulsion was diagnosed if the whole nerve was found lying free or if no muscle contraction was seen despite stimulation of the nerve root as close to the spinal foramen as possible. The clinical features, myelograms and the enhanced CT scans have been compared and correlated with the findings at operation in these 16 cases.

RESULTS

The patients were all men or boys with ages ranging from 13 to 31 years (mean, 21 years) who were investigated from 1 to 14 months after injury (mean, 5 months).

Clinical features. The distribution of sensory loss and muscle weakness proved useful in estimating the extent and degree of damage, but did not help to identify the level of damage. Important features were severe pain in the affected limb and the presence of Horner’s syndrome.

Of 10 patients with severe limb pain, nine had avulsions of at least two roots. Of six patients who had no pain, one had avulsion of all roots, two had avulsion of two roots, two had a single root avulsion each and one had no root avulsions. Horner’s syndrome was found in 10 patients, six of whom proved to have avulsion of the first thoracic nerve. The first thoracic nerve was intact in all six cases in which there was no Horner’s syndrome.

Myelography. In six of 16 cases, the correlation between myelographic and operative findings was complete. Of these six, one showed normal appearances, one showed avulsion of the fifth to sixth cervical nerves with an intact first thoracic nerve, one showed avulsion of the fifth, sixth and seventh cervical nerves, one showed an isolated seventh cervical nerve avulsion, one showed avulsion of the eighth cervical and first thoracic nerve and one showed an isolated avulsion of the first thoracic nerve.

In the other 10 of the 16 cases, myelography failed to indicate intradural damage. In seven cases the fifth cervical nerve was involved, in eight the sixth cervical nerve, in four the seventh cervical nerve, in two the eighth cervical nerve and in two the first thoracic nerve.

Diagnostic accuracy was only 37.5% overall, though for the eighth cervical and first thoracic nerve it was 75%. Myelography was least accurate in assessing the uppermost two nerves (Fig. 5).

Enhanced CT scans. In good quality scans, the cervical cord and dura were clearly seen and the sensory rootlets and motor roots could be seen as filling defects in the column of contrast material (Figs 6 and 7). Accurate correlation at all levels between CT scans and operative findings was obtained in 12 of the 16 cases – a diagnostic accuracy of 75%. The indications of intradural damage were absent roots or rootlets, small diverticula (Fig. 8), moderate diverticula and meningoceles with leakage of contrast medium beyond the spinal foramen (Fig. 9). Roots and rootlets were not consistently visualised.

Small diverticula were seen on the scans at 18 levels, but avulsion was confirmed at operation in only 11 of these. The seven small “diverticula” whose association with avulsion was not confirmed were seen in three patients. In one patient, operation had to be abandoned because of bleeding before confirmation of the association of four small diverticula seen on the CT scan at levels C5–8 could be obtained; in two patients, three small bulges thought to be indicative of root avulsions, at C6 in one patient and C6 and C8 in the other, probably represented leaks of contrast from meningoceles at adjacent levels (Fig. 10).

In only one case was no definite abnormality shown on a very poor quality CT scan but avulsion was diagnosed at operation. There was 100% correlation between the presence of either diverticula of moderate size or frank meningoceles and root avulsion diagnosed at operation.

Relative accuracy of CT scanning and myelography. The relative merits of myelography and CT scanning with enhancement are shown in Figure 5. The pre-ganglionic
lesions of root avulsion were diagnosed more frequently by CT scans and at operation than by myelography. This confirms that myelography underestimates the extent of the neural lesion. CT scanning may sometimes overestimate the extent of intradural damage, especially when contrast medium leaks from an adjacent meningocele.

Enhanced CT scanning is more accurate than myelography at all levels, but most strikingly so at the fifth and sixth cervical levels. This finding is of particular significance as the fifth and sixth cervical nerves are those most commonly susceptible to traction injuries of the brachial plexus and diagnosis at these levels is difficult clinically, by myelography, and even at operation. They are also the levels most amenable to repair, and in which repair gives the best results.

CONCLUSIONS
The prognosis after traction injuries of the brachial plexus depends upon whether the nerves have been avulsed from the spinal cord. Although re-implantation of avulsed nerve roots remains a theoretical possibility (Jamieson and Eames 1980), avulsion at present results in permanent loss of function. An accurate assessment of the level, extent and depth of injury is essential for planning management and achieving successful repair. It is useless to repair a rupture of the fifth cervical nerve root if in addition it has been pulled out of the spinal cord. The cut face of an avulsed fifth cervical root may appear to be full of healthy bundles if the proximal damage has been pre-ganglionic. The extent and depth of injury are usually clear from the clinical findings, but the difficulty of establishing the diagnosis of avulsion remains, especially at the fifth and sixth cervical levels where the potential for surgical repair of distal roots and nerve is the most rewarding. The methods used at present – clinical, physiological, electrophysiological, myelographic – are all unreliable and even late anterior surgical exploration may fail to give firm evidence. Only exploration by hemi-laminectomy can give undeniable evidence of nerve avulsion and this is a major undertaking (Figs 2 and 3). This was originally done by Bonney, when myelography was even less reliable and less safe, to establish the diagnosis and to ascertain the cause of pain (Bonney, personal communication 1985). The next best method is probably early anterior exploration, when irrefutable evidence of avulsion may be found, although even then the fate of the first thoracic root may be difficult to determine.

CT scanning with contrast enhancement, with increasing experience and technical improvements, can
provide good visualisation of the cervical nerve roots. There are problems caused by the increasing obliquity of the lower cervical roots (Fig. 2), but the important fifth and sixth cervical roots are shown well by CT scans, while conventional myelography is least reliable at these levels.

We believe that the accuracy of diagnosis shown in this series makes CT scanning the preferred method of investigation of traction injuries of the brachial plexus and that further improvements in resolution will make diagnosis even more accurate. Magnetic resonance imaging may, in future, also prove valuable in the management of these injuries.

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REFERENCES


