FACTORS AFFECTING THE PROGNOSIS OF BRACHIAL PLEXUS INJURIES

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The clinical results in a series of 131 patients with 134 brachial plexus injuries were analysed to determine the factors affecting prognosis. Isolated injuries to the upper trunk had the best prognosis, but the prognoses of isolated injuries to the cords, upper roots and lower trunk were not as good. Complete injuries of the plexus had the worst prognosis. Pain which persisted for more than six months was a bad prognostic sign for neurological recovery regardless of the location of the lesion. Horner's syndrome was not always accompanied by a bad prognosis. Operation did not affect the prognosis except in open lacerations. A pseudomeningocele detected by myelography usually precluded recovery in the root at the level of the pseudomeningocele.

The prognosis in patients with a brachial plexus injury is obscure for a variety of reasons. The injury frequently occurs after high velocity trauma as in that of multiple injuries and may be masked by other more serious injuries to the head or chest (Bonney 1959; Leffert 1974). The extent and severity of the brachial plexus injury is often doubtful until the physician is able to make an accurate examination of the arm. Sometimes a neurological deficit reported in the arm may be blamed on a co-existent head injury and it may be several weeks or months before the physician realises that the brachial plexus has been injured. The relationship between this deficit in the upper extremity and the anatomy of the brachial plexus makes accurate determination of the exact location of the lesion difficult or impossible. Nevertheless, when an accurate and complete neurological examination is performed, it should be possible in the majority of cases to localise the lesion to part or all of the brachial plexus, either supraclavicular or infraclavicular and preganglionic or postganglionic (Barnes 1949; Leffert and Seddon 1965). Failure to localise the lesion is usually the result of inadequate knowledge of the anatomy of the plexus or of an incomplete neurological examination. It is the purpose of this paper to determine the factors affecting prognosis in brachial plexus injuries and to propose guidelines for their diagnosis and treatment.

MATERIAL AND METHODS
This study was carried out over a period of 10 years from 1967 to 1977 during which 131 patients with 134 brachial plexus injuries were reviewed, three having bilateral injuries. One hundred and eighteen of these patients had at least one electromyogram and 70 had myelograms. One of us (CHR) examined 96 patients during an average follow-up of 5.2 years from the time of injury. Their ages ranged from 18 to 71 years with an average of 29 years. All patients in this group, which contained only four women, sustained their injuries in the course of their work: 32 were lumberjacks; 31 were construction workers; 12 were industrial workers; 10 were miners; and the remainder had other occupations.

Particular attention was paid to the anatomical location of the lesion, to pain, to any operation, to Horner's syndrome and to traction diverticulum to determine whether they were relevant in prognosis. The patients were classified into three groups according to the results. Full recovery implied no residual functional neurological deficit and the patients were able to return to their occupation. Incomplete recovery implied a persistent neurological deficit, but the patients were able to return to their occupation, or to pursue a slightly modified occupation. No recovery implied persistent neurological deficit of sufficient severity to preclude the return of the patients to their occupation. A pension for permanent disability was usually given to these patients.

RESULTS
Anatomical location of the lesion. In 112 of the 131 patients the lesion could be accurately localised by clinical examination supplemented with electromyography, nerve conduction studies and myelography (Table I). The term mixed was used for other neurological deficits in a heterogeneous group of injuries which were not localised. Isolated injuries to the upper roots (C5 and C6, postganglionic) were distinguished from injuries of the upper trunk by the absence of function of the serratus anterior, whose nerve comes from the roots of C5, C6 and C7. Thirteen patients in this series had isolated injuries of the upper roots, but only three of these made a full recovery which required an average of eight months (Table II). Thirty-four patients had...
injuries confined to the upper trunk with a functional serratus anterior. An analysis of the recovery of the patients in this group showed that 29 made a significant recovery. Those who recovered took an average of six months from the time of injury to do so.

**Table I.** Location of the brachial plexus injury

<table>
<thead>
<tr>
<th>Location</th>
<th>Number of Injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper roots</td>
<td>13</td>
</tr>
<tr>
<td>Upper trunk</td>
<td>34</td>
</tr>
<tr>
<td>Cords: lateral</td>
<td>6</td>
</tr>
<tr>
<td>medial</td>
<td>6</td>
</tr>
<tr>
<td>posterior</td>
<td>11</td>
</tr>
<tr>
<td>Lower trunk</td>
<td>18</td>
</tr>
<tr>
<td>Complete</td>
<td>24</td>
</tr>
<tr>
<td>Mixed</td>
<td>22</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>134</strong></td>
</tr>
</tbody>
</table>

**Table II.** Recovery of the brachial plexus injuries

<table>
<thead>
<tr>
<th>Injury</th>
<th>Full recovery</th>
<th>Partial recovery</th>
<th>No recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper roots</td>
<td>3</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Upper trunk</td>
<td>18</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>Lower trunk</td>
<td>3</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>Cords</td>
<td>6</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>Complete</td>
<td>0</td>
<td>6</td>
<td>18</td>
</tr>
</tbody>
</table>

Eighteen patients had isolated injuries to the lower roots or trunk (postganglionic) of whom only three made a full recovery. Recovery usually took up to 12 months from the time of injury. Thirteen of the 23 patients with isolated injuries of a cord were considered permanently disabled and most required further reconstructive operations to the extremity in the form of tendon transfers to restore function. Twenty-four patients had a complete brachial plexus injury with a flail upper extremity. All patients in this group had a myelogram performed; six patients with negative myelograms indicating no pseudomeningoceles subsequently made partial clinical recovery. The recovery was confined to the fifth and sixth cervical roots in all patients and occurred within two years from the time of injury.

**Pain.** Thirty patients had significant causalgic-like pain in the injured extremity which was noted on admission, or shortly after. Six months after their original injury, 13 patients still had significant causalgia but only four of these 13 subsequently manifested incomplete recovery in the injured area of the plexus (Table III). In the other 17 patients, the pain gradually disappeared over a period of six months and in most of these patients clinical recovery occurred.

**Operation.** Despite the large number of patients in this review, only 14 of the 131 underwent surgical exploration of the brachial plexus. Four of these 14 patients had open injuries of their plexus and all were surgically explored and repaired. The remaining 10 patients had closed injuries and were explored between 6 and 29 months from the time of injury, the average time to exploration being 11.5 months. The results of the operations performed in these patients are given in Table III. Ten patients underwent an exploration of the brachial plexus only and although no treatment was given at the time of operation, four of these 10 patients made an incomplete recovery distal to the injury. If recovery occurred it was always evident within one year of the operation.

**Horner’s syndrome.** On admission 14 patients were found to have a well documented Horner’s syndrome. Eleven of these patients did not recover from Horner’s syndrome and recovery was not found in the first thoracic root. All 11 patients demonstrated a pseudomeningocele at the point of emergence of the first thoracic root. Three patients with Horner’s syndrome demonstrated signs of clinical recovery: two patients with negative myelograms made some degree of recovery in the T1 root; and the third patient with a positive myelogram recovered function in the motor distribution of T1.

**Pseudomeningocele.** The presence of a pseudomeningocele or traction meningocele on myelography was assessed with regard to prognosis of the root at the level of the pseudomeningocele (Murphey, Hartung and Kirklin 1947). The pseudomeningocele occurred as a result of tearing the dura and this has been said to preclude recovery in the root involved (Yeoman 1968; Leffert 1974). Seventy patients in this study group underwent myelography and 34 were found to have at least one pseudomeningocele. Thirty-one of the 34 positive myelograms did not recover any function in the root at the level of the pseudomeningocele. Three patients did make some recovery: one with a traction diverticulum of T1 and Horner’s syndrome had partial

**Table III.** Summary of the results

<table>
<thead>
<tr>
<th></th>
<th>Full recovery</th>
<th>Partial recovery</th>
<th>No recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain disappeared by 6 months</td>
<td>6</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Pain persistent after 6 months</td>
<td>0</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Operation: exploration</td>
<td>0</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>neurolysis</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>suture</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Pseudomeningocele</td>
<td>0</td>
<td>3</td>
<td>31</td>
</tr>
</tbody>
</table>
recovery of function in the T1 root; another recovered limited function at the C5 level despite myelographic
evidence of root avulsion at C5 and C6; and a third
patient with evidence of a pseudomeningocele at C7, C8
and T1 with complete intrinsic paralysis regained some
function of the first dorsal interosseous muscle 15
months after injury.

DISCUSSION
It is important to determine the anatomical location of
the lesion to assist with the prognosis. Barnes (1949)
noted that patients with injuries of the upper trunk had a
better prognosis than those with injuries of the lower
trunk. Bonney (1959) concluded that the prognosis for
return of function to the intrinsic muscles of the hand
was dismal in a complete brachial plexus injury.
However, six of the 29 patients in his series regained
some function in the region of the upper trunk. Most
authors have reported that supraclavicular injuries have
a less favourable prognosis than infracavicular injuries
(Bonney 1959; Leffert and Seddon 1965; Leffert 1970,
1974). The reason for this difference was shown by the
axon reflex test in patients with brachial plexus injuries
(Lewis, Harris and Grant 1927; Bonney 1954). Bonney
(1954) noted that a triple response seen after injection of
a one per cent histamine solution into anaesthetised
skin implied an adverse prognosis for recovery in the
root examined. If the triple response was absent the
injury was most likely to be postganglionic and therefore
the prognosis for recovery was better. Other authors
have confirmed these findings (Barnes 1949; Leffert
1974).

Leffert and Seddon (1965) found that infracavicular
lesions had a relatively good prognosis and that most
patients with such injuries regained motor function in
the injured cord or terminal branch. A useful adjunct to
the location of the lesion in a patient with a brachial
plexus injury is electromyography (Bufalini and
Pescatori 1969). They reported that the presence of
denervation potentials on the posterior cervical muscu-
lature implied a preganglionic lesion and hence a bad
prognosis. They also noted that the return of voluntary
motor unit potentials to a muscle supplied by an injured
root, trunk or cord will precede clinical evidence of
recovery.

On the basis of our review it is desirable to
determine the location of the lesion before assessing the
prognosis. Our study has demonstrated that isolated
injuries to the upper trunk have the best prognosis with
full recovery when compared with other types of
brachial plexus injuries. Other authors have noted
similar results (Barnes 1949; Bonney 1959; Leffert and
Seddon 1965). In contrast isolated injuries of the upper
root with a normal myelogram do not do as well. The
reason for this difference is not entirely apparent as the
distance from the point of injury to the motor end-plates
supplied by these nerves is approximately the same for
both injuries.

This review has confirmed the observation of
Leffert (1974) which showed that lesions of the lower
trunk of the brachial plexus are rare. The prognosis for
recovery of this injury is poor, as only seven of 18
patients made useful clinical recovery. This poor
prognosis is undoubtedly related to the great distance
from the point of injury to the motor end-plate supplied
by the lower trunk. This review does not support the
findings of Leffert and Seddon (1965) who found that
infracavicular injuries have a good prognosis. However,
the 17 patients in our series sustained their cord injury as
a direct result of an anterior dislocation of the shoulder.
Delay in relocation of the shoulder may have accounted
for the poor prognosis seen in our patients.

Persistent pain in the presence of a brachial plexus
injury regardless of the location of the lesion is a bad
prognostic sign. Frequently, pain is present immediately
after the injury but occasionally it may not develop for
several weeks or months (Leffert 1974). Pain which
persisted for more than six months after injury implied a
poor prognosis for the return of neurological function.
Similar observations have been reported by other
authors (Barnes 1949; Bonney 1959). Amputation
occasionally gave relief of pain if it was performed within
one year of injury; however, the results were not
predictable (Rorabeck 1980).

The indications for surgical exploration of closed
brachial plexus injuries remains confusing. Bonney
(1959) suggested that all postganglionic injuries should
be explored after eight weeks providing no recovery had
occurred. Seddon (1963) reported the use of a cable
graft which he used to restore partial function to an
upper trunk. Millesi, Meissl and Berger (1972) and
Luskin, Campbell and Thompson (1973) have reported
favourable results with cable grafts after resection of the
damaged portion of the plexus. Most of their good
results were confined to restoration of function in the
motor territory of C5 and C6. The experience of Bonney
in World War II (1954) and the experience of Nelson,
Jolly and Thomas in Vietnam (1968) suggested that
early exploration of an open brachial plexus injury
should not be carried out unless there was a concomit-
ant injury to the brachial artery or vein. On the basis of
our review and reports by others, operation may be
indicated in the following patients: those who have
sustained a laceration to a trunk or cord; those with a
postganglionic injury to the upper or lower trunk in
whom no recovery has occurred within six and eight
months of the injury respectively; and those with closed
cord injuries in whom no recovery has occurred within
eight months of injury. Operation is contraindicated in
patients with a blast injury or gun-shot wounds to the
brachial plexus and in patients with two or more
pseudomeningoceles.

This study has confirmed reports by other authors
(Barnes 1949; Leffert and Seddon 1965; Leffert 1974)
that Horner's syndrome is usually a bad prognostic sign.
Brooks (1954) made the observation that Horner’s syndrome does not always occur at the time of admission but may become evident several weeks later. Our study has demonstrated conclusively that Horner’s syndrome found on admission is not always accompanied by irreparable damage to the first thoracic root. In three patients with Horner’s syndrome some recovery in function of the first thoracic root occurred. Two patients had a normal myelogram and one patient had a fracture of the first rib causing trauma to the stellate ganglion or to the white rami communicantes. It is imperative in patients with Horner’s syndrome that a good quality radiograph of the cervical spine and first two ribs is obtained. Myelography must be performed in all cases of Horner’s syndrome seen in conjunction with the brachial plexus injury. Only then can the prognostic significance of Horner’s syndrome be determined.

Yeoman (1968) demonstrated the value of myelography and the prognosis in brachial plexus injuries. He noted a correlation between the pseudomeningocele seen after myelography and the presence of a positive axon response to histamine in the root injured at the level of the pseudomeningocele. Other authors have reported that the presence of a pseudomeningocele after myelography implies irreversible damage to the root (Leffert 1974). This was the case in 31 of the 34 patients in our study with at least one pseudomeningocele indicated by myelography. However, three patients did recover some function in the territory of the root supposedly irreparably damaged as indicated by the pseudomeningocele. A prefixed plexus would seem to explain the apparent anomaly in one of these three patients in this group who afterwards regained function at the C5 level despite the presence of a pseudomeningocele. In the other two patients, in whom motor recovery of the first thoracic root was reported, a postfixed plexus would seem to be the most likely explanation. Thus, it should be remembered that anatomical variations can occur in the brachial plexus and that a pseudomeningocele observed by myelography can occasionally cause confusion in predicting the prognosis.

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REFERENCES


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