The anatomy, investigations and management of adult brachial plexus injuries

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Abstract

Brachial plexus injuries have increased in numbers since the turn of the twentieth century in line with the increased use of motorcycles. Advances in microsurgical and tissue transfer techniques have seen the management of such injuries change dramatically during this time period. As a result, surgery for plexus injuries is now considered a legitimate option. Such injuries require extensive medical input in a multidisciplinary environment. All patients should be thoroughly investigated to establish the exact extent of the injury and managed on an individual basis. The options available are conservative or surgical. Conservative options include physiotherapy, orthotics and pain control. Surgical reconstruction of the plexus may involve neurolysis, nerve grafting, nerve transfer and late peripheral reconstruction including arthrodesis, tendon transfers, free muscle transfers and amputation. Despite many advances in the field, injuries still result in considerable disability and loss of working days.

Keywords anatomy; brachial plexus; management; nerve injury; neurophysiology

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Introduction

Brachial plexus injuries range from transient nerve dysfunction to a completely flail upper limb associated with life-threatening injuries. Significant injuries lead to physical disability in addition to psychological and financial hardship. The management of such cases is complicated by concurrent injuries that may delay or cloud the neurological assessment. In addition to this, anatomical variations within the brachial plexus make these injuries a considerable challenge to clinicians responsible for their care.

Traumatic lesions are most commonly the result of motorcycle accidents and typically affect young men.[1–3] Lesions can also occur following penetrating or sports related injuries, falls, industrial accidents, radiation therapy and iatrogenic causes (first rib resection, shoulder surgery, interventional radiology). The most common mechanism is a traction injury to the nerves secondary to forceful separation of the neck from the shoulder.[1]

History

Brachial plexus reconstruction began in earnest in the mid 20th century with work by Barnes, Brooks, Bonney, Seddon and Leffert and later Narakas. Despite their work the role of surgery was confined to exploration in order to determine prognosis, more complex interventions being associated with poor results.[1–4] The extent of this belief is highlighted by Seddon's comments in 1961 'The results of reconstructive operations have been so disappointing that we believe that this type of treatment should be abandoned'.[5] Towards the end of the 20th century advances in microsurgical techniques and tissue transfer procedures have improved the functional outcome of these injuries. However, many of these patients still require extensive medical input and a multidisciplinary approach to their care.

Assessment

A full assessment to establish the aetiology, and clearly define the level and severity of the injury must be performed. It is important to ascertain whether the lesion is pre- or post ganglionic, as this significantly affects both management and prognosis, and this may require supplementary tests such as electrophysiological or radiological investigations. Concurrent severe injuries occur in up to 80% of patients, and the attending clinician must be alert to this. Commonly associated injuries include dislocated shoulders, fractures of the proximal humerus, clavicle, scapula and cervical spine, in addition to major upper limb vascular injuries (subclavian or axillary artery). These injuries require management in their own right but can also provide vital clues to the extent and nature of the plexopathy.

A lesion can be classified using a variety of systems, which often differentiate between upper plexus and lower plexus injuries. Leffert's classification system[6] based on aetiology and level of the injury is commonly used (Table 1), but it must be remembered that lesions may occur at more then one level. Following a full evaluation the management plan should be tailored to an individual patient's needs and a time scale set out, with consideration given to both conservative measures and secondary reanimation of the limb.

Leffert classification of brachial plexus injuries

I	Open	
II	Closed	IIa Supraclavicular
		Preganglionic — nerve root avulsion
		Postganglionic — traction injuries
		IIb Infraclavicular
		IIc Combined
III	Radiotherapy induced	
IV	Obstetric	IVa Upper root (Erb's palsy)
		IVb Lower root (Klumpke's palsy)
		IVc Mixed

Table 1

Anatomy of the brachial plexus

The anatomy of the brachial plexus demonstrates a large degree of variability, both between individuals and between the left and right limbs of the same individual.[7] Most commonly the brachial plexus is formed by the confluence of the ventral rami of the spinal nerve roots from C5 to T1. Common variations include contributions to the plexus by the C4 nerve root (described as a pre-fixed plexus) or the T2 nerve root (a post-fixed plexus). The 5 roots normally contributing to the plexus merge into 3 trunks, each of which splits into anterior and posterior divisions. The divisions become 3 cords which give rise to the terminal branches (Figure 1).

Two anatomical triangles contain the proximal plexus. The interscalene triangle is formed between the anterior and middle scalene muscles superiorly and the first rib inferiorly and contains the roots of the plexus. The posterior triangle of the neck contains the trunks of the plexus and is formed by the sternocleidomastoid muscle anteriorly, trapezius laterally and the clavicle inferiorly.

Dorsal (sensory) and ventral (motor) rootlets arise from the spinal cord and merge to form a root as they pass through the vertebral foramen. Just prior to the formation of the root the sensory rootlet enlarges in diameter forming the dorsal root ganglia (DRG). The DRG contains the cell bodies of the sensory nerves (motor nerve cell bodies are within the spinal cord). An injury proximal to the DRG is described as pre-ganglionic. This may be avulsion of the rootlets from the spinal cord or an injury, which is still intradural, but just proximal to the DRG. The rootlets have no connective tissue or meningeal covering as they originate from the spinal cord; this contributes to their susceptibility to avulsion from the cord. The roots have a protective layer formed by the dura and are able to move freely within the foramen. As the C4, C5, C6 and C7 roots emerge from the foramen they are tethered to the transverse processes of their respective vertebrae. C8 and T1 are not tethered in this way, which leads to a higher incidence of root avulsion from the spinal cord being seen at these levels compared to the upper plexus.

The roots enter the scalene triangle, being found between anterior and middle scalene muscles. The first terminal nerves to arise from the plexus do so at this level. The C5 root has 3 branches at this point: contributions to the phrenic, long thoracic and dorsal scapular nerves. The roots descend and move laterally into the posterior triangle of the neck.

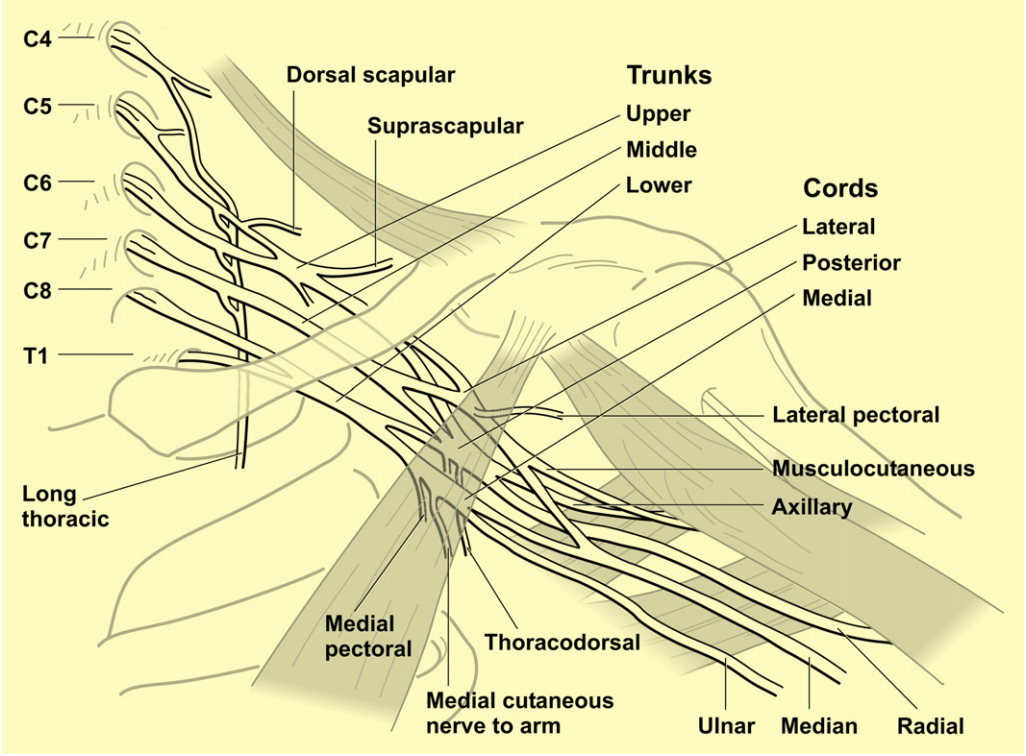

Figure 1 Diagrammatic representation of the Brachial Plexus.