INTRODUCTION

The brachial plexus is a network of nerves innervating the muscles of the shoulder, upper chest, and arm. The brachial plexus is formed by the anterior rami of C5 through T1 ***(Castillo, 2005)***. C5 and C6 nerve roots comprise the upper trunk, C7 continue to the middle trunk, and C8 and T1 comprise the lower trunk ***(Jin et al., 2007)***. The brachial plexus injury is the most severe nerve injury of the extremities, resulting in functional impairment of the upper limb ***(Yoshikawa et al., 2006).*** In general, abnormalities involving the brachial plexus can be divided into two broad categories for the purpose of imaging: traumatic and nontraumatic ***(Amrami and Port, 2005)***. The most common cause of traumatic brachial plexus lesions is traffic accidents, especially motorcycle accidents, with most of the victims being young males. The other common cause is birth palsy. The majority of obstetric brachial plexopathy involves the upper brachial plexus and is referred to as Erb's or Duchenne's palsy. Tumour, irradiation, and congenital anomalities, such as cervical ribs, account for nontraumatic causes of brachial plexopathy ***(Amrami and Port, 2005)***.

MRI is a non-invasive multiplanar technique that allows detailed assessment of the brachial plexus with no ionizing radiation ***(Medina et al., 2006).*** The brachial plexus is well depicted on MR imaging on coronal and sagittal view through its course ***(Jin et al., 2007)***.

AIM OF THE WORK

The aim of this work is to clarify the value of advanced magnetic resonance imaging techniques in diagnosis of brachial plexus lesions.

ANATOMY OF THE BRACHIAL PLEXUS

The brachial plexus is one of the major neural structures passing through the thoracic inlet ***(Reede,1997)***.

Thoracic Inlet:

The thoracic inlet or the root of the neck is a narrow space that serves as the junction between the neck and thorax. This space is wider from left- to- right than it is from front to back. Its boundaries are the manubrium anteriorly, the first thoracic vertebra posteriorly, and on each side the first rib laterally. This area is further delineated by Sibson's fascia, which extends on each side of the neck from the transverse process of the seventh cervical vertebra posteriorly to the medial border of the first rib ***(Reede, 1997)***.

Since the posterior attachment is more cranially located than the anterior aspect of the first rib, the plane of thoracic inlet is tilted downward anteriorly and on each side it is higher medially than it is laterally. Because of this orientation, when viewed in the sagittal plane, the lung apices are seen posteriorly and the structures at the base of the neck are located anteriorly. When axial images are obtained, the apices of the lungs are seen posteriorly, wherease the soft tissue structures of the inferior neck are visualised anterolaterally. Several major neural and

vascular structures are found in this region, and the key reference point for them is the anterior scalene muscle ***(Reede, 1997)***.

Major structures found in this region (thoracic inlet region) ***(Reede, 1997 and Bowen, 1999)*** *are* ***:***

A- Neural:

1- The vagus nerve (located in the carotid sheath).

2- The recurrent laryngeal nerve.

3- The sympathetic chain.

4- The pherenic nerve.

5- The brachial plexus.

B- Vascular:

1- The subclavian artery and vein.

2- The brachio cephalic artery and vein.

3- The common Carotid arteries and internal jugular veins (located in the carotid sheath).

C- Lymphatic:

1- The thoracic duct.

2- The right lymphatic duct.

D- Trachea.

E- Esophagus.

The location of the major neural and vascular structures in this region is easy to remember if the anterior scalene muscle is used as a point of reference ***(Reede, 1997)***.

The Brachial Plexus:

The anatomy of the brachial plexus is complex . It originates at the spinal cord and then courses through the neck, supraclavicular region, and axillary region. Along the course of the brachial plexus, numerous anatomic structures, mainly the scalene muscles related to its components ***(Higgin, 1997)***.

The brachial plexus is a complex network of nerves which extends from the neck to the axilla and which supplies motor, sensory, and sympathetic fibers to the upper extremity. Generally it is formed by the union of the ventral primary rami of the spinal nerves, C5–C8 and T1,the so-called ‘‘roots’’ of the brachial plexus. (This is not the same as the dorsal and ventral spinal roots that join to form a spinal nerve.) The roots of the brachial plexus lie between the scalenus anterior and medius muscles. The plexus is divided topographically into two parts:

1) **The supraclavicular part**, located in the posterior cervical triangle.
2) **The infraclavicular part**, located in the axilla **(Johnson E. O. ,2006)**

The roots of the brachial plexus combine to form trunks:

1. **Upper trunk**, from C5 and C6
2. **Middle trunk**, from C7
3. **Lower trunk**, from C8 and T1

In relation to surrounding structures, the C5 to C7 roots pass inferiorly, laterally, and anteriorly between the anterior and middle scalene muscles ***(Bowen, 1994)***. The C5 and C6 roots unite along the lateral border of the anterior scalene to form the upper trunk, and C7 becomes the middle trunk. The C8 and T1 roots, which have a more horizontal course posterior to the anterior scalene and subclavian artery, unite to form the lower trunk behind the anterior scalene or just lateral to it. The anterior and posterior divisions of the plexus are formed in the retroclavicular region lateral to the anterior scalene and medial to the lateral margin of the first rib. The divisions of the lower trunk may be formed more laterally than those of the upper and middle trunks ***(Bowen, 1999)***.

The trunks separate into anterior and posterior divisions that then form three cords:

1. **Lateral cord,** from the anterior divisions of the upper and middle trunks
2. **Medial cord,** from the anterior division of the lower trunk.

3. **Posterior cord,** from the posterior divisions of all three trunks.

Each cord gives off one or more branches and then ends by dividing into two terminal branches in the axilla.

The branches of the lateral and medial cords (from the anterior divisions of the plexus) innervate the anterior muscles of the upper limb. The major branches are the ulnar, median, musculocutaneous, and pectoral.

The branches of the posterior cord (formed from the posterior divisions of the plexus) innervate the posterior muscles and include the subscapular and axillary, as well as the radial branches.

The upper branches of the plexus, which arise in the neck rather than the axilla, include the dorsal scapular, suprascapular, long thoracic, and nerve to the subclavius ***(Williams et al., 1989).***

The Scalene Muscles:

1- The anterior scalene muscle:

Arises from the transverse processes of the third through the seventh cervical vertebrae and extends inferior laterally to insert into the first rib ***(El-Khoury et al., 1995)***.

This muscle is considered the key reference point used to locate the major neural and vascular structures in

this region. The subclavian vein is located anterior to the anterior scalene muscle and a portion of the subclavian artery posterior to it ***(Valvasori, 1995)***.

2- The middle scalene muscle:

It is larger and arises from the posterior aspect of the transverse processes of the second to the seventh cervical vertebrae. It has a broad insertion a long the first rib ***(El-Khoury et al., 1995)*** .There is a groove in the first rib between the insertion of the anterior and middle scalene muscles through which pass the subclavian artery and brachial plexus ***(Clement, 1985).***

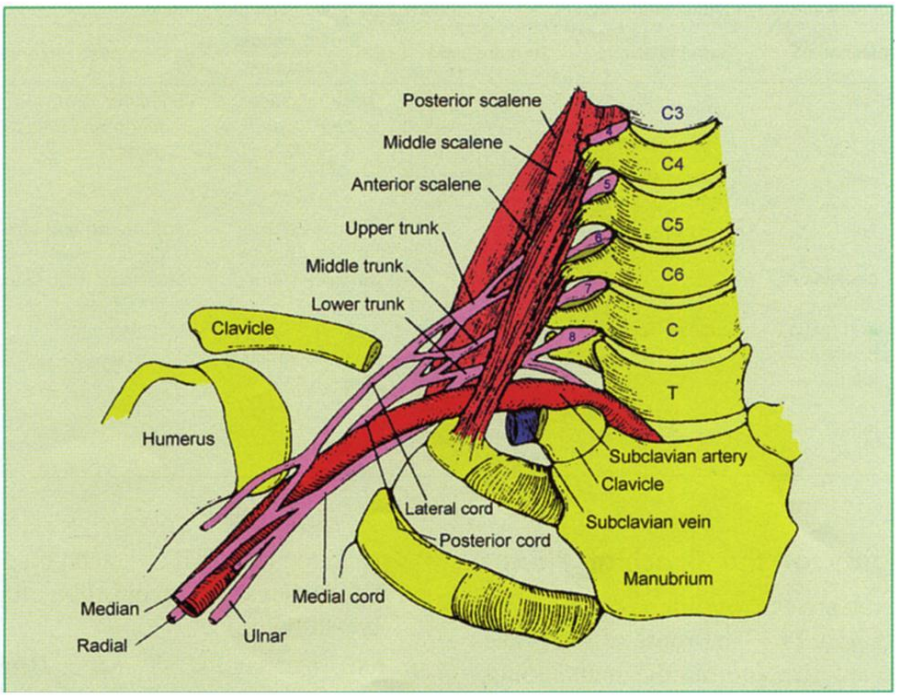

Fig. (1): Normal anatomy of the brachial plexus.Note the close relationship between the brachial plexus, the brachial vessels, and the surrounding anatomic structures ***(Quoted from Kichari, 2003)***.

3- The posterior scalene muscle:

It arises from the transverse processes of the fifth to the seventh cervical vertebrae and insert on the outer surface of the second rib. This muscle is frequently in separable form the middle scalene muscle ***(Clemente, 1985)***.

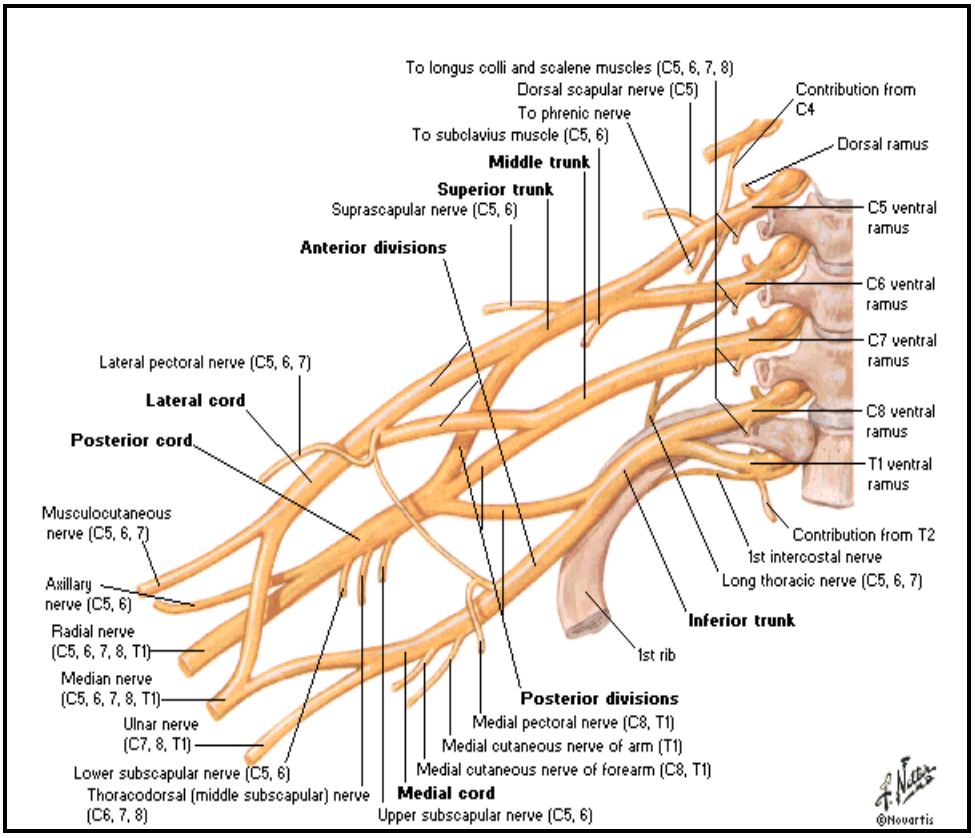

Fig. (2): Schematical presentation of the right brachial plexus ***(Quoted from Netter, 1991)***.

Variations of the brachial plexus

The fourth cervical nerve occasionally gives a branch to the fifth cervical nerve, and the first thoracic nerve occasionally receives a branch from the second thoracic nerve. These contributions from C4 & T2 nerves are subject to frequent variation. When the branch from C4 is large, the branch from T2 is usually absent, and the T1 contribution is reduced in size. **This constitutes the prefixed type of plexus**. On the other hand, the branch from C4 may be very small, or entirely absent. In that event, the contribution from C5 is reduced in size, and that from T1 is larger. **This constitutes the postfixed type of plexus *(Williams et al., 1996).***

Relations of the brachial plexus

In general, the main components of the brachial plexus are located as follows; the roots between the scalene muscles, the trunks in the posterior triangle of the neck, the divisions behind the clavicle and the cords in the axilla.

(1) In the vertebral foramen:

Opposite the foramen, each pair of anterior and posterior nerve roots invaginate the dura and arachnoid to form a funnel shaped depression at the bottom of which each perforates the meninges independently carrying with it an individual and separate bilaminar sleeve of dura and

arachnoid. The extension of the subarachnoid space formed in this way is continuing along the nerve roots usually as far as the ganglion. The dural layer is continued for a short distance along the nerve roots to become continuous with the perineural sheath of the single bundle of the nerve fibre. The somewhat condensed tissue on the surface of the dura is continuous with the epineurium of the spinal nerve ***(Williams et al., 1989)***.

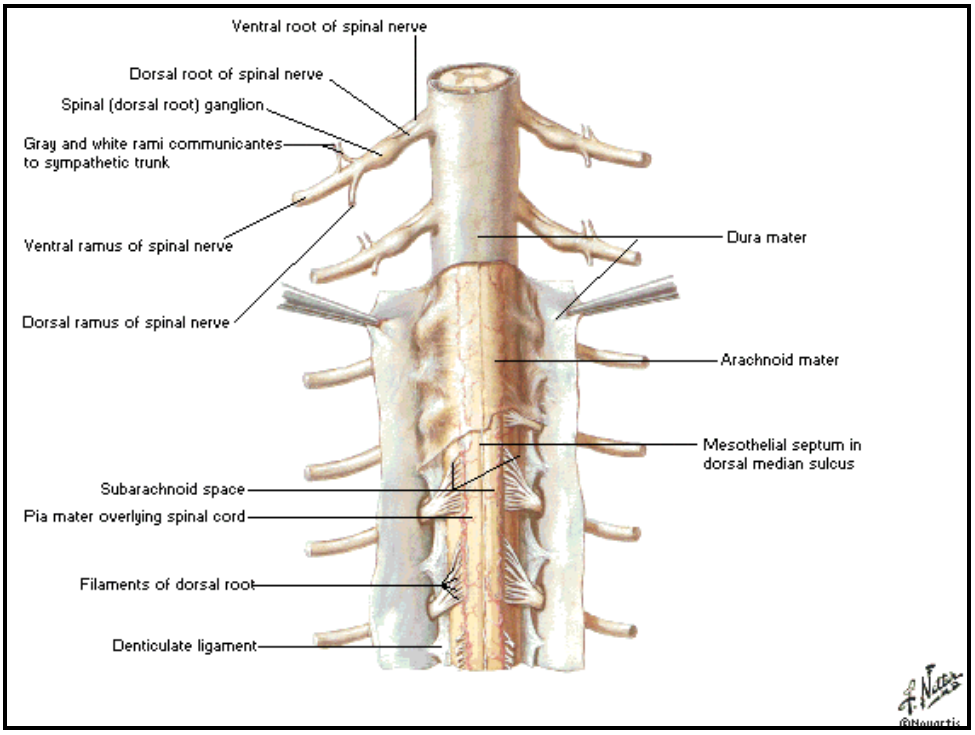

Fig. (3): Diagram showing relation of the nerve rootlets with the spinal membranes (posterior view) ***(Quoted from Netter, 1991)***.

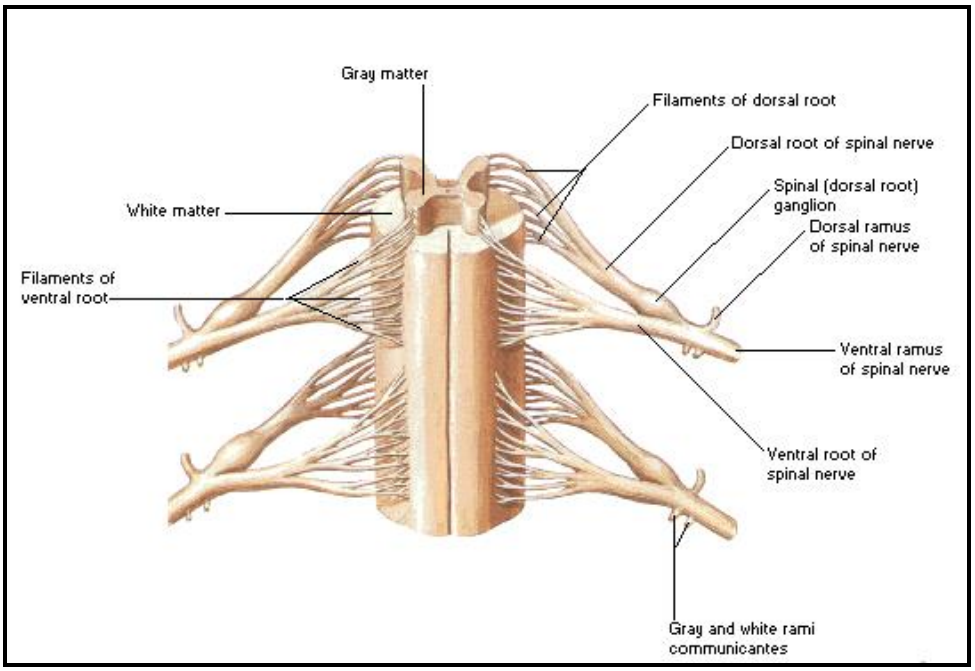

Fig. (4): Diagram showing exit anterior and posterior roots from the spinal cord (Anterior view) ***(Quoted from Netter, 1991)***

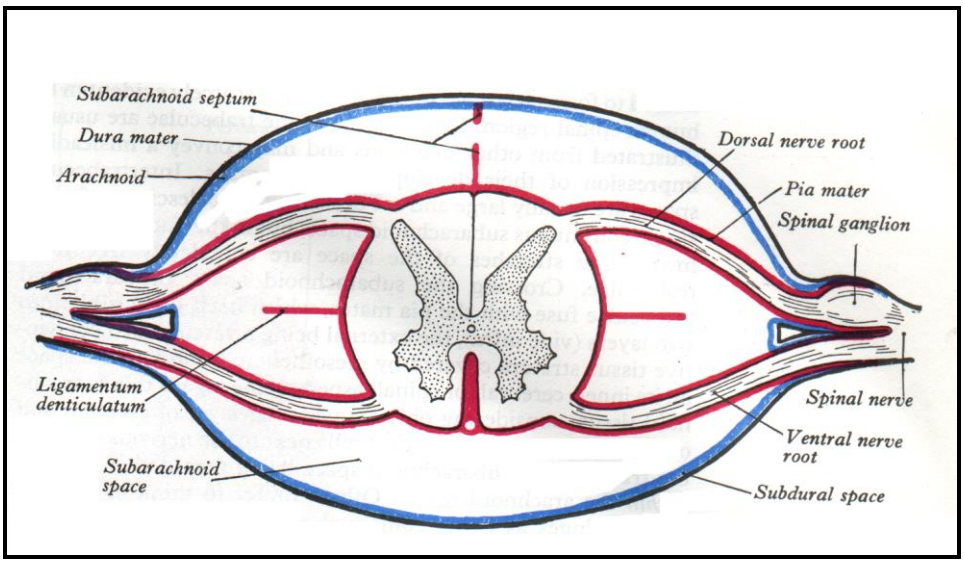

Fig. (5): A trasverse section through the spinal cord and its membranes black=dura, blue=arachnoid, red=pia mater ***(Quoted from Williams et al., 1989).***

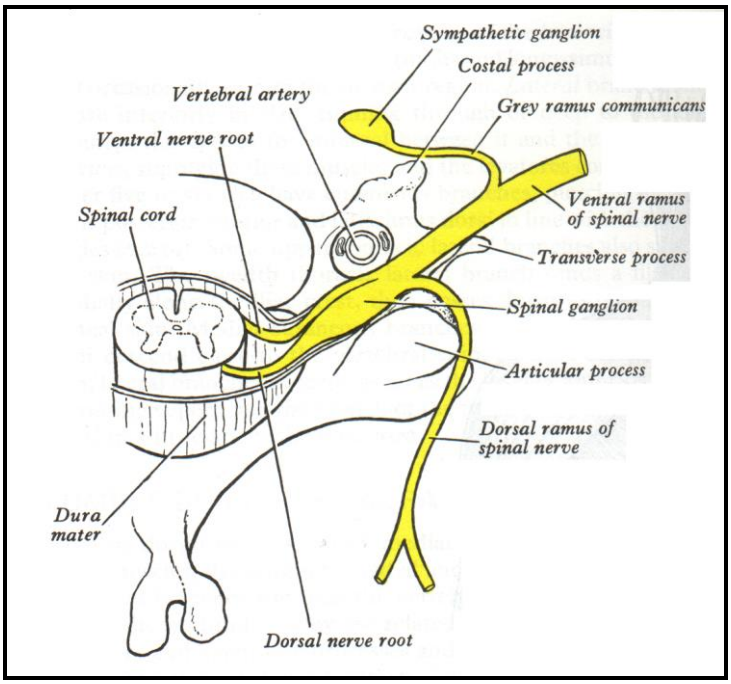

Fig. (6): Diagram showing relation of the cervical nerve and its ganglion to a cervical vertebra ***(Quoted from Williams et al., 1989).***

(2) Just outside the vertebral foramen:

The fifth, sixth and seventh cervical nerves are securely attached to the vertebral column. Each one leaving its foramen is immediately lodged in the gutter of the transverse process to which it is securely bound by its epineural sheath, by reflections of the prevertebral fascia, by slips from the musculotendinous attachments to the transverse processes and by fibrous slips that descend from the transverse process above to blend with the epineurium of the nerve below. The nerve is also held backwards against the transverse process by the vertebral artery whose adventitial coat blends with the sheath of the nerve. The

eighth cervical and first thoracic nerves lack these attachments as they leave their intervertebral foramina ***(Williams et al., 1989). Herzberg et al. (1989),*** described the transverse radicular ligaments that are well formed at the C5, 6, and 7 roots, but are absent at C8 and TI. All these factors plus the presence of proximal branches at the C*5*,6,*7* roots and their absence at the C8 and T1 roots make the lower roots more vulnerable to avulsion injury ***(Williams et al., 1989).***

(3) In the neck:

The brachial plexus lies in the posterior triangle in the angle between the clavicle and the lower posterior border of sternomastoid muscle ***(William, 1995).*** So the upper most parts of the plexus (the upper roots and trunks) can be felt in the angle between the clavicle and sternocleidornastoid ***(McMinn, 1994)***.

The brachial plexus at this region is covered by platysma, deep fascia and skin. It is crossed by the supraclavicular nerves, the nerve to subclavius, the inferior belly of omohyoid, the external jugular vein and the superficial branch of the transverse cervical artery ***(Williams, 1995)***.

The roots of the brachial plexus enter the posterior triangle of the neck by emerging through the interval between the scalenus anterior and scalenus medius.

Together with the subclavian artery, the plexus acquires a sheath; the axillary sheath which is derived from the prevertebral layer of the deep cervical fascia ***(Snell, 1995)***.

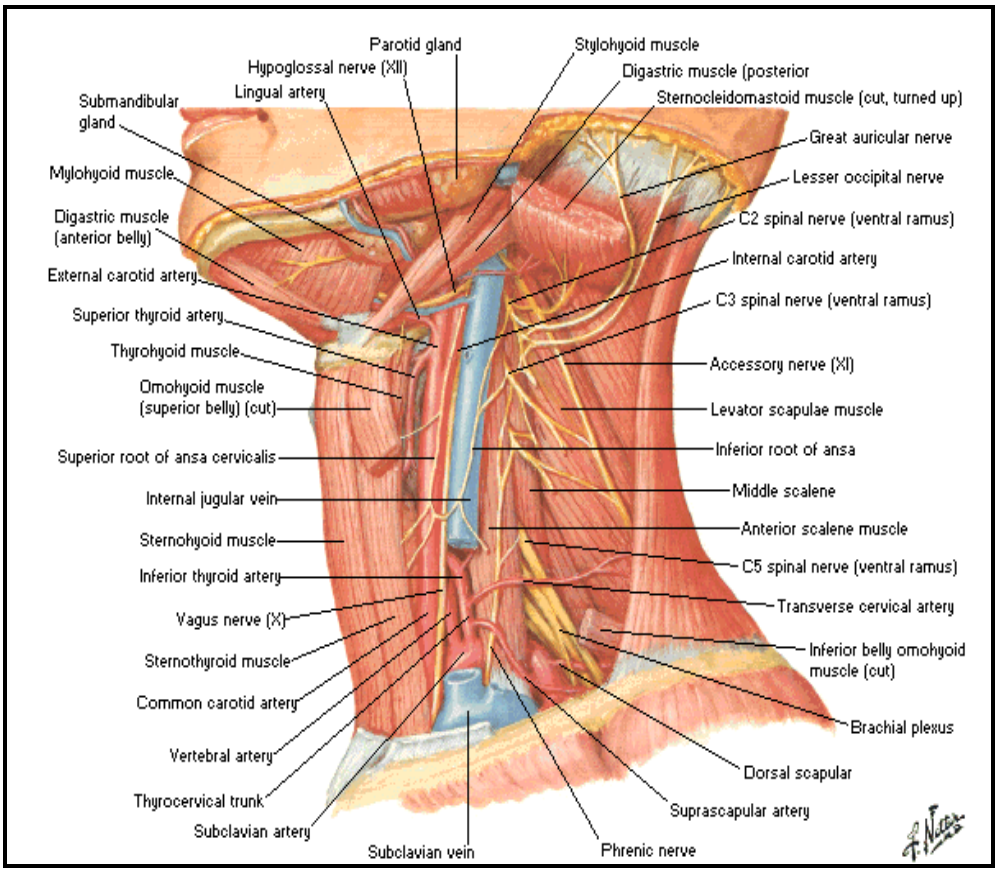

Fig. (7): Diagram showing the superficial relations of the brachial plexus in the posterior triangle of the neck ***(Quoted from Netter, 1991).***

(4) In the axilla:

The lateral and posterior cords are lateral to the first part of the axillary artery, the medial cord being behind it. The cords surround the second part of the artery and related to it according to their names.