

Chapter 1

Anatomy of the peripheral nervous system

Overview

This chapter is about the different components and functions of the peripheral nervous system which links the central nervous system (brain and spinal cord) to muscles and to sensory receptors for activation of muscle contraction and perception of sensation. The anatomy, motor and sensory territories supplied by plexuses and nerve trunks, and cranial nerves are detailed. The anatomy and function of the sympathetic and parasympathetic nervous systems are also outlined. Microscopic anatomy details the morphology and role of myelinated and unmyelinated nerve fibres.

Introduction

The peripheral nervous system (PNS) has two components: the somatic peripheral nervous system which includes sensory and motor neurons and nerve fibres, and the autonomic nervous system which comprises the sympathetic and parasympathetic systems ¹. The somatic peripheral nervous system controls muscle contraction and perception of sensation, while the autonomic nervous system works automatically without conscious control.

Somatic peripheral nervous system

Each spinal nerve results from the fusion of two roots. The ventral root is formed by the aggregation of spinal motor rootlets (motor neuron

axons). The cell body, or perikaryon, of the motor fibre is located in the anterior horn of the spinal cord. The dorsal root contains the dorsal root ganglion, where cell bodies of all sensory neurons of the PNS are found. These two roots unite to form the mixed spinal nerve. There are eight pairs of cervical spinal nerves, twelve pairs of thoracic spinal nerves, five pairs of lumbar spinal nerves, five pairs of sacral spinal nerves and a few pairs of coccygeal nerves.

Cervical plexus

The motor fibre endings of the cervical plexus innervate cervical muscles and the diaphragm. Sympathetic sudomotor and vasomotor fibres pass through this plexus to blood vessels and glands.

Brachial plexus

The brachial plexus is formed by the assembly of C5, C6, C7, C8 and T1 ventral roots. Three trunks (superior, middle and inferior) originate from the brachial plexus. Each of these trunks divides into a ventral and a dorsal branch and three cords are formed (lateral, posterior and medial), which finally lead to the spinal nerves of the upper limbs. The superior brachial plexus is very vulnerable during birth trauma with subsequent deltoid, biceps, brachialis and brachioradialis paralysis. Lower plexus compression by a cervical rib (C8, T1), or infiltration by cells originating from a breast or pulmonary cancer, may cause paralysis of the small hand muscles.

Nerves of the upper limbs

The nerves of the upper limbs are as follows:

- the musculocutaneous nerve (C5, C6) innervates muscles predominantly involved in flexion of the arm;
- the scapular nerve (C5) innervates muscles for elevation and adduction of the scapula;

- the suprascapular nerve (C5-C6) innervates the supraspinatus and infraspinatus muscles for lift and outward rotation of the arm, resulting in abduction of 15° and external rotation of the arm;
- the axillary nerve (C5-C6) innervates the deltoid and teres minor muscles for abduction of the arm to the horizontal and outward rotation of the arm;
- the radial nerve (C6-C8) innervates the triceps, anconeus, brachioradialis, extensor carpi radialis, extensor digitorum and supinator muscles for extension and flexion of the elbow and supination of the forearm; muscles for the extension and flexion of the elbow, supination of the forearm, extension of the wrist and fingers, and abduction of the thumb. Sensory innervation is to the posterior upper arm and forearm, and the posterior thumb and lateral 2½ fingers;
- the median nerve (C5-T1) innervates muscles involved in flexion of the fingers, abduction and opposition of the thumb, and pronation of the forearm. Sensory innervation is to the palm and fingers 1 to 3 and the lateral half of the fourth finger;
- the ulnar nerve (C8-T1) innervates muscles controlling abduction and adduction of the fingers and wrist flexion; sensory innervation supplies the dorsal and palmar medial faces of the hand, and half of fingers 4 and 5.

Thoracic nerves

The 12 pairs of thoracic nerves give rise to the cutaneous innervation of the thoracic dermatomes. Motor fibres supply innervation of the muscles of the thoracic and abdominal walls.

Lumbosacral plexus

The lumbar plexus is composed of primary branches of the anterior roots L1, L2, L3 and L4. Iliogastric, ilioinguinal and genitofemoral nerves originate from the L1 root and innervate transverse and oblique abdominal muscles. Femoral, obturator and lateral femoral cutaneous nerves are formed from the remaining roots. These nerves are responsible for flexion

and adduction of the thigh, leg extension, and sensory innervation of the anterior thigh and leg.

The sacral and coccygeal plexuses are formed from roots coming from L4 to S4. Their main terminal branches are the superior (L4-S1) and inferior gluteal nerves (L5-S2), the posterior femoral cutaneous nerve (S1-S3), the sciatic nerve (L4-S3) and its division into the tibial and common peroneal nerves, and to the pudendal nerve. They result in extension of the thigh, leg and foot, and help to close the bladder and rectal sphincters, and supply sensory innervation of the thigh and perianal region.

Nerves of the lower limbs

The nerves of the lower limbs are as follows:

- the femoral nerve (L2-L4) motor fibres supply the iliopsoas, sartorius and quadriceps femoris muscles resulting in flexion and outward rotation of the lower leg and extension of the lower leg over the thigh; sensory innervation is to the anterior thigh and anterior and medial surfaces of the leg and foot;
- the lateral femoral cutaneous nerve is purely sensory and innervates the anterior and lateral surfaces of the thigh;
- the obturator nerve (L2-L4) controls adduction and rotation of the thigh; cutaneous innervation is on the internal thigh;
- the superior gluteal nerve (L4-S1) controls abduction and inward rotation of the thigh and flexion of the upper leg to the hip;
- the inferior gluteal nerve (L4-S1) motor fibres command extension of the thigh at the hip and outward rotation of the thigh;
- the sciatic nerve (L4-S3) motor fibres supply the biceps femoris, semitendinosus and semimembranosus muscles resulting in flexion of the lower leg, and also muscles dependent upon the tibial and peroneal branches that are terminal branches of the sciatic nerve;
- the posterior femoral cutaneous nerve (S1-S3) supplies sensory innervation of the posterior thigh, lateral perineum and lower buttock;
- the tibial nerve (L4-S2) motor fibres control plantar flexion, inversion of the foot and toe flexion. Sensory innervation is devoted to the lateral calf, foot, heel and small toe;

- the common peroneal nerve (L4-S1) branches to the deep peroneal nerve which gives rise to motor fibres supplying the tibialis anterior, extensor hallucis longus, extensor digitorum longus, extensor digitorum brevis muscles, and to the superficial peroneal nerve, which gives rise to motor fibres supplying the peroneus longus and brevis muscles resulting in foot dorsiflexion and toe extension. Sensory innervation comprises the lateral part of the leg and the dorsal aspect of the foot.

Cranial nerves

The first two pairs of cranial nerves are derived from the cerebrum, while the other ten originate from the brain stem. Cranial nerve I — the olfactory nerve — and cranial nerve II — the optic nerve — do not belong to the PNS. They are actually expansions of the central nervous system (CNS). The other ten cranial nerves enter the PNS after leaving their nuclei in the brainstem.

Oculomotor nerves — cranial nerves III, IV and VI

Cranial nerves IV and VI innervate extraocular muscles only. The third cranial nerve innervates extraocular muscles, the levator palpebrae superioris muscle and pupil constrictor muscle. Complete paralysis of the third cranial nerve induces ptosis, which may totally hide the affected eye, and areactive pupil dilatation (mydriasis).

Cranial nerve IV supplies the superior oblique muscle, allowing the eye to look down and inwards, especially when climbing stairs or reading a book in bed. Cranial nerve VI innervates the lateral rectus muscle, which directs the ipsilateral external gaze.

The trigeminal nerve — cranial nerve V

The trigeminal nerve conveys the sensibility of the face, sinuses, teeth and the anterior part of the oral cavity. It is divided into:

- the ophthalmic branch — pure sensory innervation;

- the maxillary branch — pure sensory innervation; and
- the mandibular branch — sensory and motor innervation of mastication and the tensor tympani muscles.

The sensory part of the ophthalmic division of the cranial nerve V (V1) innervates the cornea and eyeball and forms the afferent limb of the corneal reflex. The maxillary branch innervates the mid-part of the face and the mandibular branch of the lower face.

The facial nerve — cranial nerve VII

The motor fibres of the facial nerve are distributed to the muscles that contribute to facial expression, muscles of the scalp and all facial muscles, and the orbicularis of the eye. Parasympathetic fibres innervate the lacrimal gland and salivary glands. Sensory taste fibres come from the anterior two thirds of the tongue and the soft palate.

The vestibulocochlear nerve — cranial nerve VIII

The utricle, saccule and semicircular canals trigger signals necessary for coordination, balance and movement of the head and neck, which are conveyed through the vestibular component. Expansions of the peripheral spiral ganglion innervate the hair cells along the cochlear duct of the Corti organ. Hearing information from the Corti organ is conveyed to the cochlear nuclei through the cochlear component of the eighth cranial nerve.

The glossopharyngeal nerve — cranial nerve IX

The glossopharyngeal nerve innervates the stylopharyngeus muscle and participates in the innervation of the pharyngeal muscles for swallowing. Sensory fibres convey taste sensitivity of the posterior third of the tongue and posterior part of the soft palate.

The vagus nerve — cranial nerve X

The peripheral motor neurons of the vagus nerve innervate the muscles of the soft palate, pharynx and larynx, allowing speech and swallowing. Preganglionic parasympathetic axons ensure the autonomic parasympathetic innervation of the heart, lung and gastrointestinal tract to the descending colon.

The accessory nerve — cranial nerve XI

The course of the cranial part of the eleventh cranial nerve runs alongside the laryngeal and pharyngeal branches of the vagus nerve and the nerves to the soft palate. The spinal part is formed of spinal motor neurons from the lateral first four or five segments of the cervical spinal cord. The spinal accessory nerve innervates the sternocleidomastoid and the upper two thirds of the trapezius muscles, resulting in the rotation of the head and shoulder elevation.

The hypoglossal nerve — cranial nerve XII

The hypoglossal nerve innervates all the tongue muscles.

Autonomic nervous system

The autonomic nervous system (ANS) consists of efferent fibres that innervate organs such as the heart, smooth muscle, exocrine and endocrine glands, and metabolic tissues, immune cells, etc.; this innervation involves a two-neuron pathway. Afferent activity may travel via the cranial PNS (e.g. vagus nerve) controlled by neurons in the brainstem, or along the somatic PNS (e.g. neurons conveying finger nociception) controlled by neurons of the spinal cord. Thus, sympathetic and parasympathetic preganglionic neurons, which are the first part of the efferent pathway, are activated through interneurons and will synapse with postganglionic neurons that will in turn produce a reflex response (e.g. contraction of vascular smooth muscle in the regulation of blood pressure).