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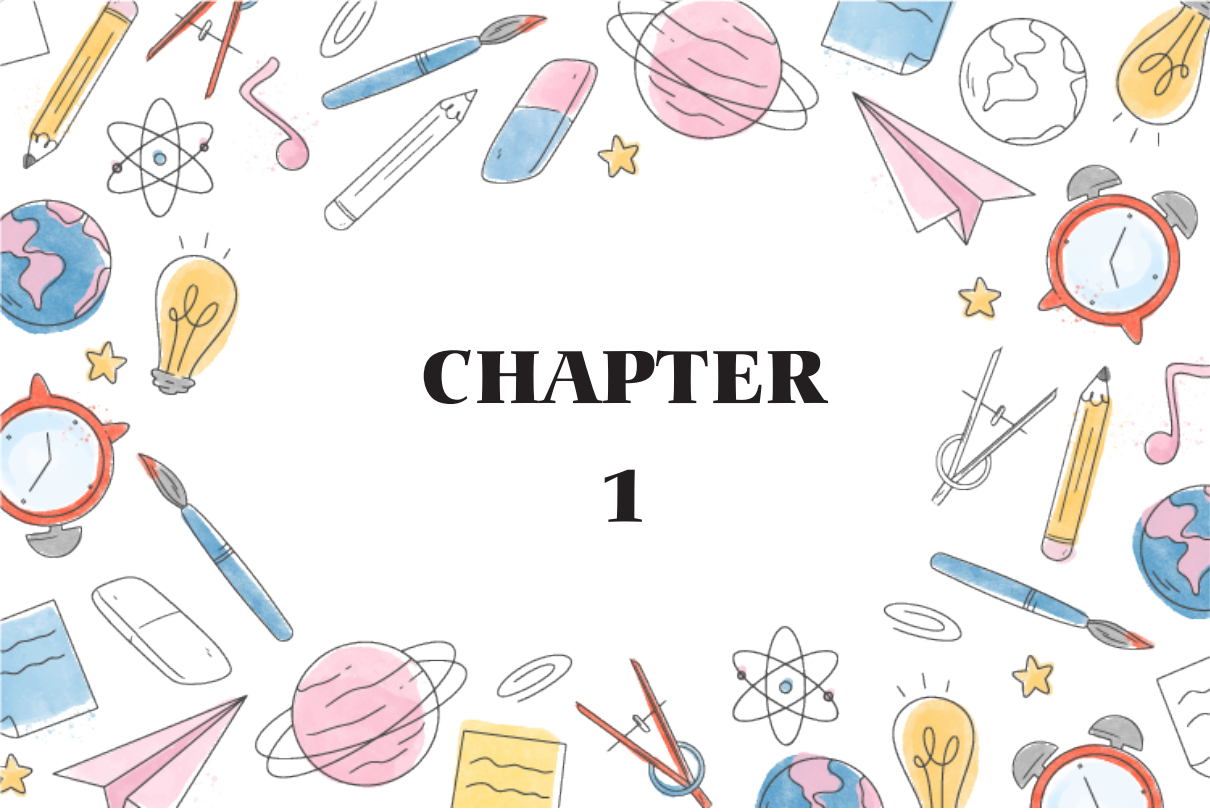

CHAPTER 1

ANATOMY AND EMBRYOLOGY OF THE SUPERFICIAL BRANCH OF THE RADIAL NERVE

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1. PERIPHERAL NERVOUS SYSTEM

1.1. Embryology of the Nervous System

All nervous system structures are of ectodermal origin (1). In the third week concerning the embryonic period, the ectoderm over the dorsal side of the chorda dorsalis thickens to create the neural plate. The lateral sides of the neural plate then rise for the creation of the neural fold (1). The groove that develops between the neural fold is called neural groove (1). This groove takes the shape of a cylinder as the neural fold rise further, approach each other in the midline and fuse (1). This cylinder is called the neural tube (Figure 1) (2). The neural tube, which stretches from the head to the caudal, develops into the central nervous system, comprising the spinal cord and the encephalon (3). In the fourth week, the upper part of the neural tube is referred to as the cranial part, while the lower part is referred the spinal part (3). Three swellings occur in the cranial part (3). These structures, also known as the primary brain vesicles, are called prosencephalon, mesencephalon and rhombencephalon from front to back (4). These three structures and the brain parts that will develop from them are collectively called the encephalon (4). Spinal cord develops from spinal part (4). The part of the neural fold that do not contribute to the formation of the neural tube give rise to the neural crest (1,3). Neural crest cells then migrate from the neuroectoderm and transform into mesenchymal cells within the underlying mesoderm layer (1,3). The neural crest migrates to the dorsolateral side of the neural tube, forming the ganglia of the cranial and spinal nerves; it migrates ventrolaterally, forming the nerve sensory cells in the spinal ganglion, and migrating ventrally, forming the nerve cells in the truncus symphaticus, the chromaffin cells in the medulla of the adrenal gland, and the vegetative plexus in the gastrointestinal tract, thus forming the source of many formations of the peripheral nervous system (1,3).

The motor nerve fibers that arise from the spinal cord are generated by nerve cells situated in the basal plate portion of the spinal cord during the fourth week of development (1). These fibers, which develop in bundles, direct themselves to a specific muscle group and form the ventral nerve roots (radix anterior) (1). The dorsal nerve roots (radix posterior) originate from the cells in the spinal ganglia of the spinal nerves (1). The central extensions of these cells develop into the alar plate of the spinal cord (1). At the same time, the distal extensions of the cells in the spinal ganglia join with the ventral nerve roots to create the spinal nerve (1). The distal extensions of the cells in the spinal ganglia merge with the ventral nerve roots to create the spinal nerve (1). Immediately after the spinal nerve is formed, it divides into branches called anterior and posterior branch (1). Posterior branch; innervates dorsal axial muscles, vertebral joints, part of the derm of the back (1). Anterior branch; provides innervation to the thoracic regi-

on, anterior abdominal wall and extremities and forms the cervical plexus, brachial plexus and lumbosacral plexus (1,3).

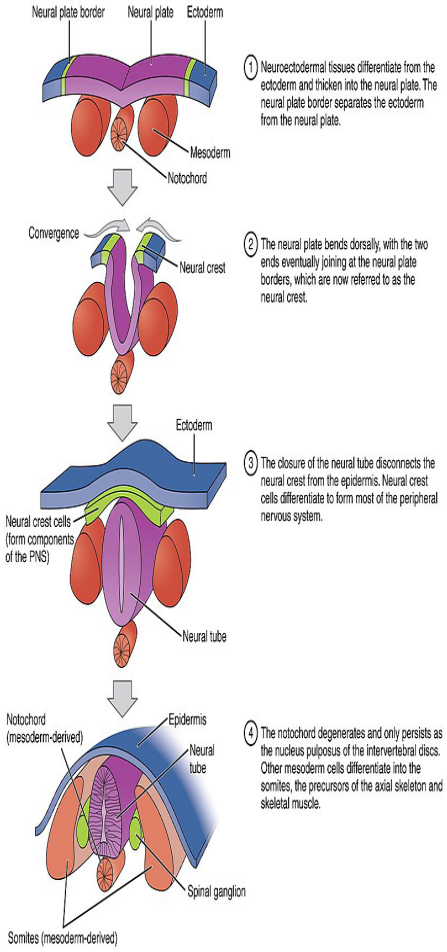

Figure 1. Neurulation (5)

1.2. Development of the Peripheral Nervous System and Dermatome Areas

In the fifth week, motor axons out of the spinal cord extend into the limb buds and differentiate into the dorsal and ventral muscle masses. After the motor axons, sensory axons that use them as guides also enter the limb buds (3). At the same time, precursor Schwann cells of neural crest origin wrap motor and sensory nerve fibers in the extremities, forming neurolemma and myelin sheath (1,3). In the fifth week, peripheral nerves are formed from nerve plexuses (cervical plexus, brachial plexus, etc.) that

develop within the mesenchyme of the limb bud (1,3). A dermatome refers to the region of derm innervated by a spinal nerve (6). The spinal nerves are distributed in segments to provide nerve function to the dorsal and ventral surfaces of the limb buds (6). The spinal nerves originating from adjacent segments are usually adjacent to each other in dermatome regions (6). A dermatome may also receive branches from the spinal nerves that innervate the adjacent dermatome (6). Therefore, if a spinal nerve is cut, no clinically significant sensory loss is observed in the dermatome of that spinal nerve (6). However, in some regions, the nerves that innervate adjacent dermatome areas do not originate from adjacent segments (6). In such cases, the nerve fibers innervating two adjacent dermatomes do not pass to the dermatome on the other side (6). An example of this situation is that in the upper extremity, the regions innervated by the fifth cervical (C5) nerve and the sixth cervical (C6) nerve are adjacent to the regions innervated by the second thoracic (T2) nerve; the first thoracic (T1) nerve and the eighth cervical (C8) nerve, but they rarely overlap in dermatome areas (1). Dermatome areas can be followed out of proximal to distal throughout the lateral aspect of the upper extremity and out of distal to proximal along the medial side (7). As the extremities lengthen and move distally, they carry their nerves with them (7). Developmental stages are determined according to the Carnegie embryo staging system, an internationally used system (7). According to Carnegie's staging system, development occurs in twenty-three stages (7). The stage the embryo is in depends on the length of the embryo in millimeters (mm) and the number of somites (7). The early development of the upper extremity nerves of the human embryo takes place between the thirteenth and twenty-first stages (7). At the thirteenth stage (4-6 mm, thirty or more somites, approximately twenty eight days old); the upper extremity nerves emerge from the C5-T1 levels of the spinal cord (7). In the fourteenth stage (5-7 mm, approximately thirty two days old); the spinal nerves begin to unite and form the brachial plexus (7). At the sixteenth stage (11-14 mm, approximately thirty seven days old) and the seventeenth stage (11-14 mm, approximately forty one days old); the median nerve, ulnaris nerve and radialis nerve extend towards the palmar aspect (7). In the twentieth stage (21-23 mm, approximately fifty - fifty one days old) and the twenty-first stage (22-24 mm, approximately fifty two days old); the appearance of the upper extremity nerves is similar to the nerve structure of adult individuals (7).

1.3. Anatomy of the Peripheral Nervous System

The nervous system is examined topographically under two primary categories: the peripheral nervous system and the central nervous system (4). The central nervous system is the largest section of the nervous sys-

tem that receives and evaluates the stimuli brought by afferent nerves and sends the necessary responses via efferent nerves (4). It is composed of two distinct parts: the encephalon, found within the cranial cavity, and the spinal cord, found within the vertebral canal (4). The peripheral nervous system consists of all the nerve tissues except the central nervous system, and its role is to convey signals out of the body tissues to the central nervous system or to deliver instructions out of the central nervous system to the final organs (4). The peripheral nervous system occurs nerve fibers and ganglia (6). There are two types of fibers in peripheral nerves: afferent and efferent fibers (4). Afferent fibers (sensory) transmit sensations received from the periphery by nerve endings to the central nervous system (4,6). The somatic afferent fibers are related to bone, skeletal muscles and skin and are known as general somatic afferents (4,6). The visceral afferent fibers are related to internal organs, vessels and mucous membranes (6). Efferent (motor) fibers originate from the central nervous system and undertake motor functions related to the operation of muscles (somatomotor) or organs (visceromotor) (6). The peripheral nervous system is examined in three main sections: the autonomic nervous system (related ganglia and special senses of taste, smell, balance, hearing, vision), twelve pairs of cranial nerves that are distinct out of the encephalon, and thirty-one pairs of spinal nerves which come out of the spinal cord (4). The autonomic nervous system maintains the organism's homeostasis via innervating organs that work outside our control, such as the heart, lungs, organs containing smooth muscle fibers, and glands (6). Cranial nerves are twelve pairs and originate from the brain and brainstem (4). They generally provide exocrine secretion function through voluntary and involuntary muscle movements in an area extending from the head and neck region to the abdominal cavity (4). Cranial nerves also have functions to perceive special and general senses (4). Spinal nerves originate out of the spinal cord, travel through the intervertebral foramen of the vertebral column, and distribute to peripheral structures (4). These nerves contain fibers that convey sensory stimulus out of the periphery into the central nervous system, convey motor stimulus out of the central nervous system into the periphery (4).

2. RADIAL NERVE

2.1. Anatomy of the Spinal Nerves

The spinal nerve forms through the merging of the axons originating from the lateral and anterior cornu of the spinal cord (anterior root-radix motoria) and the peripheral extensions of the axons in the spinal ganglion (dorsal root ganglion) at the level of the intervertebral foramen (Figure 2) (4,6). Contains pseudounipolar neurons within the spinal ganglion (4,6). The distal extensions of these neurons participate in the structure of the

spinal nerve, while their fibers extending to the center transmit the sensations received from the periphery to the spinal cord (4,6). A spinal nerve icludes somatic afferent-efferent fibers and visceral afferent fibers (4,6). In addition, some of the spinal nerves also contain preganglionic autonomic fibers (4,6). The spinal nerve departs out of the vertebral canal via the intervertebral foramen (comprising sensory, motor, autonomic fibers) (4,6).

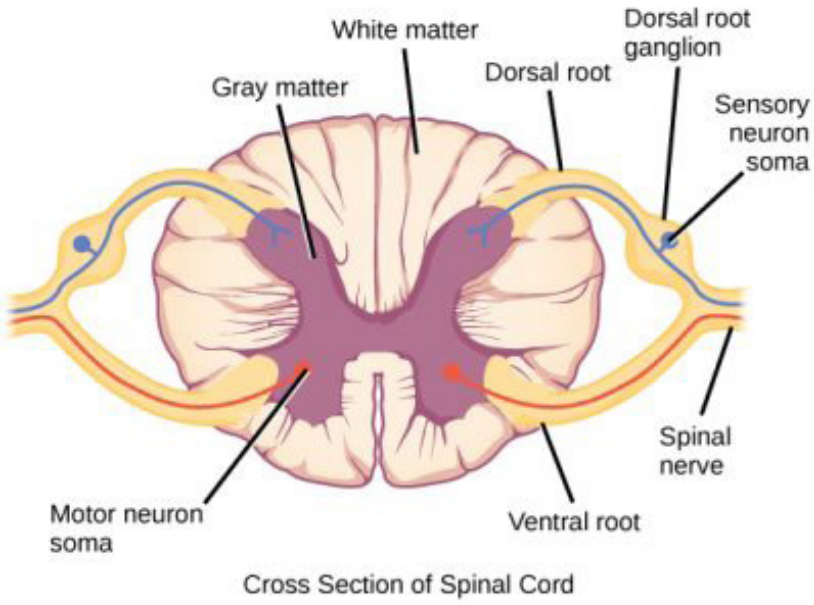

Figure 2. Spinal nerve formation (8)

Although the spinal cord has thirty-three segments, the number of spinal nerves is thirty-one pairs. This is because the last two of the three coccygeal segments remain rudimentary and there is no spinal nerve exit in this region. The distribution of thirty-one pairs of spinal nerves is as follows; one pair of coccygeal nerve (Co1), five pairs of sacral nerves (S1-5), five pairs of lumbar nerves (L1-5), twelve pairs of thoracic nerves (T1-12), and eight pairs of cervical nerves (C1-8) (4,6). Once it passes through the intervertebral foramen, every spinal nerve splits toward a ventral branch and a dorsal branch. The ventral branch can also be called the anterior branch. The dorsal branch can also be called the posterior branch (4,6). Of these branches, which carry fibers from both roots (except C1, C2), the posterior branches are thinner than the anterior branches (4,6). The meningeal branch, which branches off from the posterior branch, receives sensory impulses from the vertebrae and their related ligaments, while providing innervation to the blood vessels and membranes of the spinal cord with the postganglionic sympathetic fibers it carries (4,6). Other fi-

bers from the posterior branches provide innervation to the back muscles and the derm on the back. The anterior branches (except for the anterior branches of thoracic nerves) innervate the front and side parts of the body and the extremities through the plexuses they form (4,6).

2.2. Anatomy of the Brachial Plexus

The brachial plexus forms when the anterior branches of the C5-T1 nerves combine (Figure 3). Variationally, some fibers coming from the anterior branches of C4 and T2 may also participate in this formation. Compared to other plexuses in the peripheral nervous system, the most complex structured nerve network is observed to be the brachial plexus (6). Its formation begins amid the scalenus anterior and scalenus medius and continues to the axillary fossa. Branches distributed especially in the upper extremity contain sensory, somatomotor and sympathetic fibers (4,6). The brachial plexus consists of four groups of nerve elements, from proximal to distal: branches, trunks, divisions, and cords. The supraclavicular part of the brachial plexus, consisting of branches and trunks, is situated in the lateral cervical region; the infraclavicular part, consisting of the fasciculus and the proximal parts of the nerves originating from them, is located in the axillary fossa (6). The long thoracic nerve (C5-7) and the dorsal scapular nerve (C5) arise from the branches (4). Branches emerge out of the outer lateral edge of the scalenus anterior to form the trunks (4,6). In the most common organization, the inferior trunk is created when the anterior branches of the C8,T1 nerves; the middle trunk is created when the anterior branch of the C7 nerve only; and the superior trunk is created when the anterior branches of the C5,6 nerves (4). While the inferior and middle trunks fail to produce any nerves, the suprascapular and subclavian nerves originate out of the superior trunk. The three trunks, after a short course on the upper side or behind the middle third of the clavicle, split within posterior and anterior divisions. The anterior divisions go to the flexor group muscles and posterior divisions go to the extensor group muscles. The six branches that emerge combine with each other to form cords. The cords that begin to form in the cervicoaxillary canal are labeled based on their location in relation to the axillary artery. The anterior division of the inferior trunk alone creates the medial cord, located medial to the axillary artery. The anterior divisions of the middle trunk and superior trunk combine to create the lateral cord, positioned lateral to the axillary artery. The posterior divisions of the whole (inferior, middle, superior) trunks merge to create the posterior cord, traveling behind the axillary artery (4,6). The lateral cord produces the lateral root of the median nerve (C5-7), the lateral pectoral nerve (C5-7), and the musculocutaneous nerve (C5-7). The medial cord gives rise to the medial root of the median nerve (C8,T1), the medial

pectoral nerve (C8,T1), the medial cutaneous nerve of forearm (C8,T1), the medial cutaneous nerve of arm (C8,T1), and the ulnar nerve (C8,T1). The posterior cord gives rise to the superior subscapular nerve (C5,6), the axillary nerve (C5,6), the inferior subscapular nerve (C5,6), the thoracodorsal nerve (C6-8), and the radial nerve (C5-8,T1) (4,6).

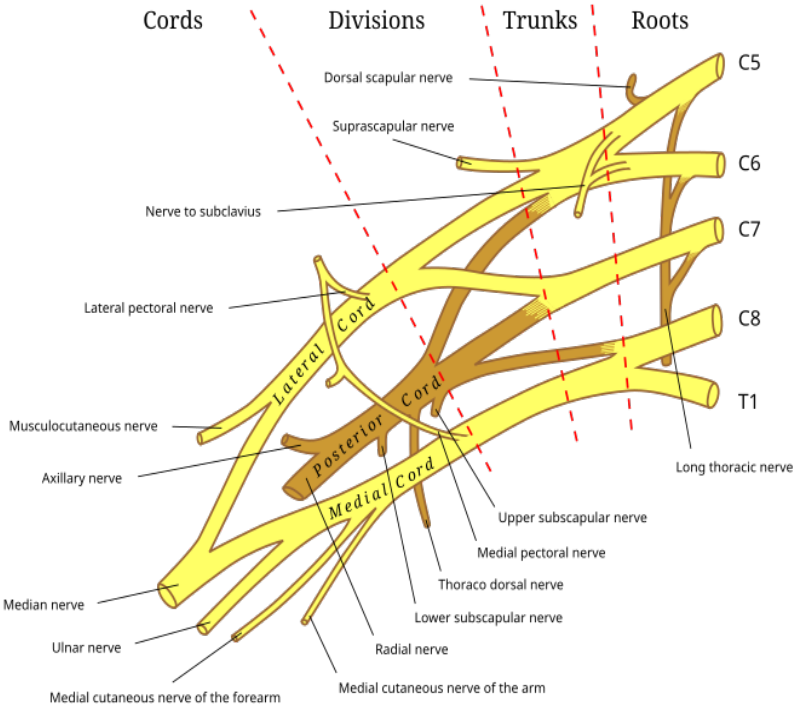

Figure 3. Branches and formation of the brachial plexus (9)

2.3. Anatomy of the Radial Nerve

The posterior cord continues into the radial nerve after giving off the axillar nerve. The radial nerve is the thickest nerve and one of the final branches in the brachial plexus (4,10). The radial nerve stimulates the muscles on the extensor surface of the forearm and arm, providing both motor and sensory functions. Initially, it is situated behind the third part of the axillary artery. Subsequently, the nerve moves distally, crossing anterior to the tendons of the subscapularis, the teres major, and the latissimus dorsi (4,6). Within the axilla, it divides into the posterior cutaneous nerve of arm, supplying the derm in the posterior arm region. The radial nerve changes direction with an inferolateral course at the inferior edge from the teres major, descends down the anterior wall from the humeral triangu-

lar space lateral to the caput longum of triceps brachii, and comes to the posterior surface from the body of humerus. It then travels alongside the profunda brachii artery through the humeromuscular canal, located amid the medial head and lateral head of triceps brachii and the groove for radial nerve (4,6). As the radial nerve progresses through this spiral channel, it gives off muscular branches that will innervate the posterior cutaneous nerve of forearm, the long head of triceps brachii, and the inferior lateral cutaneous nerve of arm. As it follows the groove for radial nerve along the posterior surface of humerus, it lies behind the upper fibers from the medial head of triceps brachii. At this location, it emits a branch that innervates the lateral head of triceps brachii and another branch that traverses the medial head of triceps brachii, reaches the anconeus (4,6). Along the transition from the lower and middle 1/3 of the arm, the radial nerve leaving the humeromuscular canal moves into the flexor compartment by perforating the lateral intermuscular septum of arm. Here, it traverses the area amid the brachioradialis, the brachialis, the extensor carpi radialis deep in the lateral bicipital groove, then reaches the cubital fossa. As it passes through the lateral epicondyle of humerus, it splits within two branches: the deep and the superficial branches (4). The deep branch travels amid the two heads of the supinator, then reaches the posterior compartment of forearm, at which point it is called the posterior interosseous nerve (Figure 4). The posterior interosseous nerve stimulates whole the muscles in the deep layer of the extensor compartment of forearm (6). The superficial branch continues distally in the flexor compartment of forearm, deep to the brachioradialis, and ends by receiving skin sensation from the lateral half of the back on the hand and the dorsal surfaces of first 3.5 fingers up to the middle phalanges (Figure 5) (6).

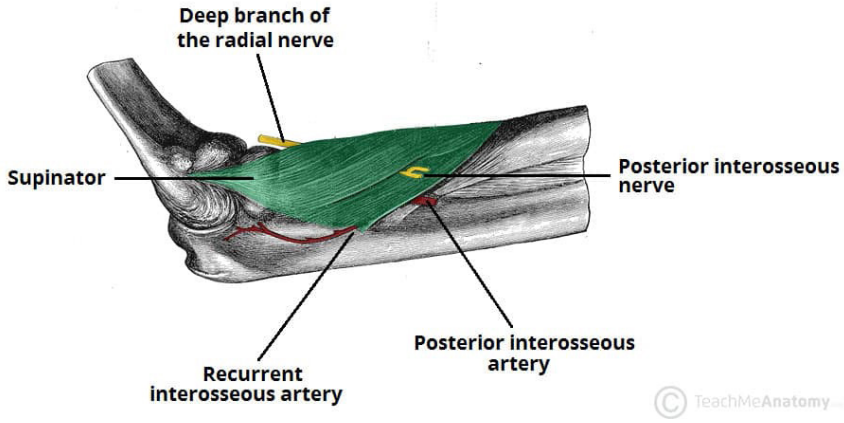

Figure 4. The posterior interosseous nerve (11)

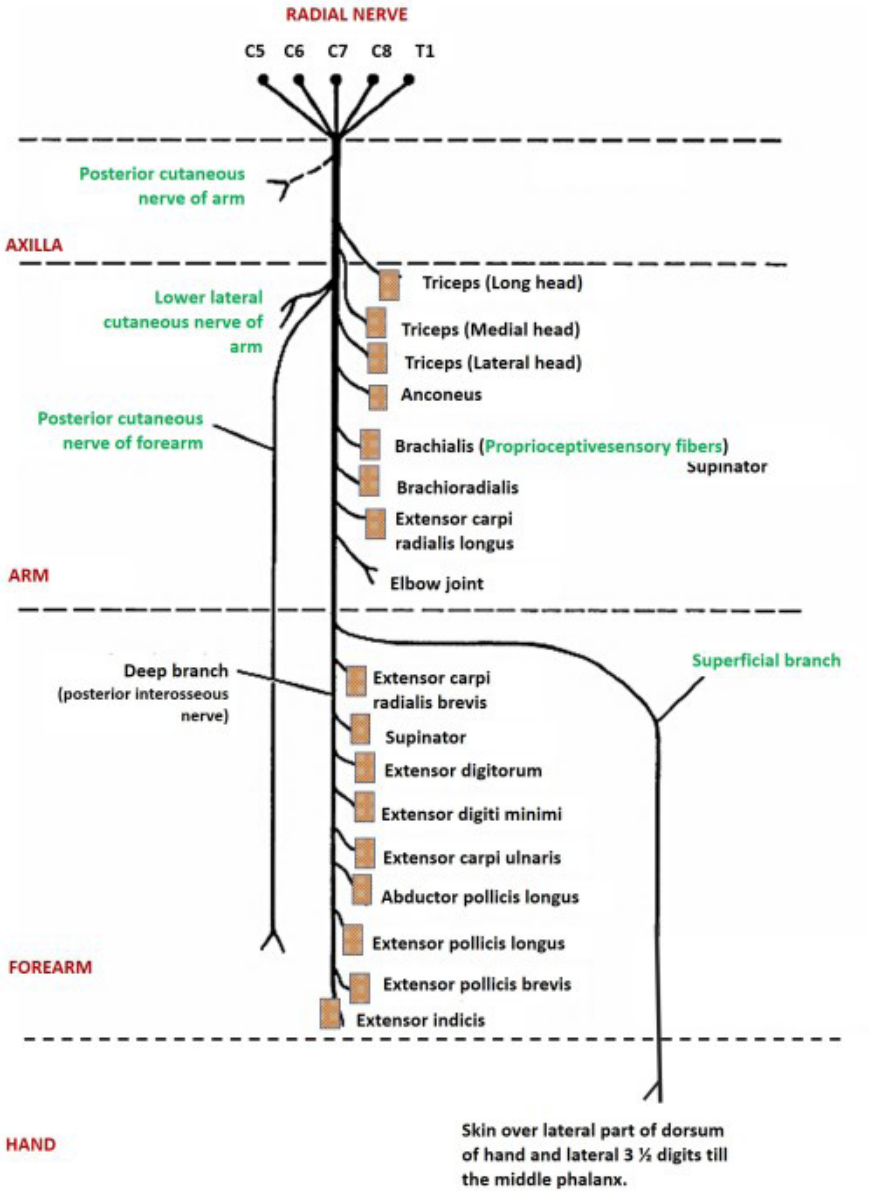

Figure 5. Anatomy of the radial nerve (branches) (12)

2.3.1. Branches of the Radial Nerve in the Arm

- Articular branches: Articular branches originating in the radial nerve innervate the posterior and anterior lateral parts of the elbow

joint (4,6). The elbow joint receives innervation from the articular branches of the musculocutaneous and the radial nerve (4,6).

- Cutaneous branches: The cutaneous branches originating in the radial nerve within the extensor compartment of arm are the inferior lateral cutaneous nerve of arm, posterior cutaneous nerve of arm, and the posterior cutaneous nerve of forearm (4,6). The posterior cutaneous nerve of arm originates from the radial nerve in the axillary fossa as a thin branch and extends medially along the arm to the skin of the posterior arm near the olecranon. The inferior lateral cutaneous nerve of arm and the posterior cutaneous nerve of forearm separate from the radial nerve, then pierce the lateral head of triceps brachii, subsequently course subcutaneously on the deep fascia (4,6). The inferior lateral cutaneous nerve of arm becomes superficial distal to the deltoid tuberosity (4,6). It travels to anterior region of the elbow together with the cephalic vein and is dispensed onto the lateral region derm on the bottom half of the arm. The posterior cutaneous nerve of forearm first extends to the lateral arm and then to the wrist joint at the back of the forearm, where it is distributed in the skin of this region (4,6).
- Muscular branches: It supplies the extensor carpi radialis longus, the brachioradialis, the brachialis, the anconeus, the triceps brachii in three separate groups: medial, lateral, and posterior (4,6). The medial muscular branch leaves the medial aspect of the arm in the axillary fossa, then innervates the medial head and the long head of triceps brachii (4,6). The lateral muscular branch, leaves the radial nerve just anterior to the lateral intermuscular septum of arm, innervates the lateral part of brachialis, the extensor carpi radialis longus, and the brachioradialis (4,6). The thicker posterior muscular branch separates as the radial nerve courses within the groove for radial nerve and innervates the anconeus, the lateral head and the medial head of triceps brachii. The branch which innervates the anconeus is a long branch that runs distally, innervating the medial head of triceps brachii. This branch travels behind the elbow joint and reaches the anconeus, where it courses parallel to the medial collateral artery, that is a branch from the profunda brachii artery (4,6).

2.3.2. Branches of the Radial Nerve in the Forearm

Activation of the extensor compartment of forearm is provided through the radial nerve. While it crosses the lateral wall of cubital fossa, the radial nerve provides impulses for the extensor carpi radialis longus

and the brachioradialis, prior to splitting towards the deep and superficial branches (13).

- The deep branch, travels amid the two heads of the supinator, circling the lateral side of the radius to reach the extensor compartment of the forearm. The deep branch gives nerve supply to the supinator and the extensor carpi radialis brevis, subsequently travels amid the two heads of the supinator, following courses downward with the posterior interosseous artery amid the deep and superficial extensor muscles. During its course, it gives off three small branches that innervate the extensor digiti minimi, the extensor digitorum, and the extensor carpi ulnaris; medially to extensor indicis and extensor pollicis longus; laterally, it gives off two long branches going to extensor pollicis brevis and abductor pollicis longus. After giving off these motor branches, the thinning deep branch progresses between the dorsal surface from the interosseous membrane and the extensor pollicis longus, taking the name as the posterior interosseous nerve. The posterior interosseous nerve ends with sensory branches that give to the intercarpal and metacarpophalangeal joints on the dorsal aspect of the wrist (4,6).
- The superficial branch, lies along the radial aspect of the forearm just below the brachioradialis. Beneath the brachioradialis, it courses downward with the radial artery on the anterolateral side of the proximal two-thirds of the forearm (4,6). It usually moves away from the radial artery approximately 7 cm higher than the wrist level and progresses along the inferior surface of the brachioradialis tendon (14). It then passes amid the extensor carpi radialis longus tendon and the brachioradialis tendon, penetrates the deep fascia, following reaches the superficial nerve to the dorsal part of the wrist (4,6). In this region, it divides into five, sometimes four, branches and usually connects to the lateral cutaneous nerve of forearm, the posterior cutaneous nerve of forearm (4,6).

3. ANATOMY OF THE SUPERFICIAL BRANCH OF THE RADIAL NERVE

The superficial branch is a final branch of the radial nerve, that ends by dividing into two in front of the lateral epicondyle. It is a nerve that receives sensation from the skin, but also gives articular branches for the elbow joint. It is positioned deep to the brachioradialis, traveling the radial side of the forearm (4). It approaches the radial artery in the proximal 1/3 of the forearm, sits just lateral to the radial artery in the middle 1/3,

and moves away from the radial artery in the distal 1/3, passes laterally from the deep side of the brachioradialis tendon and reaches the level of the wrist, passes the superficial aspect of the abductor pollicis longus tendon and the extensor pollicis brevis tendon, following moves towards the dorsal region of the hand (Figure 6). The superficial branch of the radial nerve splits into lateral and medial branches (15). The lateral branch is thinner and spreads over the radial skin of the thumb and joins the palmar branch of the lateral cutaneous nerve of forearm (16). The medial branch connects to the ulnar nerve on the back of the hand via a branch called the communicating branch with ulnar nerve. The branches that branch off from the superficial branch of the radial nerve on the dorsal part of the hand then head distally to form the dorsal digital nerves. Typically, four or five dorsal digital nerves are situated under the skin (17). The initial branch innervates the derm on the radial aspect of the thumb as well as the thenar eminence located immediately adjacent to this area. The initial branch also connects with branches from the lateral cutaneous nerve of forearm. The second branch receives sensory input from the medial aspect of the thumb; the third branch from the lateral aspect of the index finger; and the fourth branch from the opposite aspects of the middle and index fingers. The fifth branch connects with the dorsal branch of the ulnar nerve via the communicating branch with the ulnar nerve. The branches of the dorsal digital nerves going to the first finger extend to the nail root, while the branches going to the second finger proceed to the middle of the proximal phalanx (15). In the lateral half of the third and fourth fingers, the nerves are distributed in the skin area up to the proximal interphalangeal joints of the hand. The sole branch of the radial nerve which reaches the hand is the superficial branch, and this nerve is a completely sensory that innervates the derm of the first three and a half fingers covering the dorsal surface of hand, and the radial nerve has no motor innervation in the hand (6).

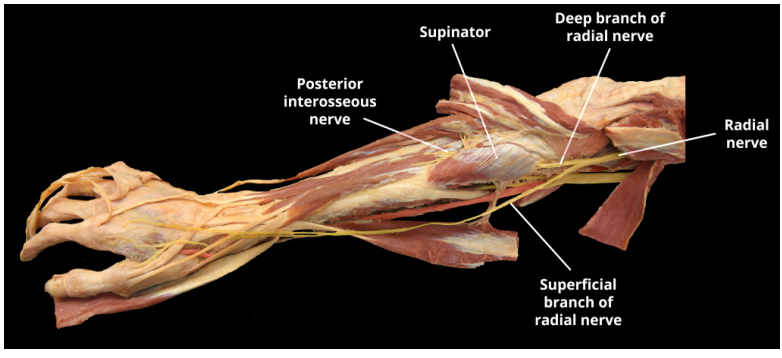

Figure 6. The superficial branch of the radial nerve (18)

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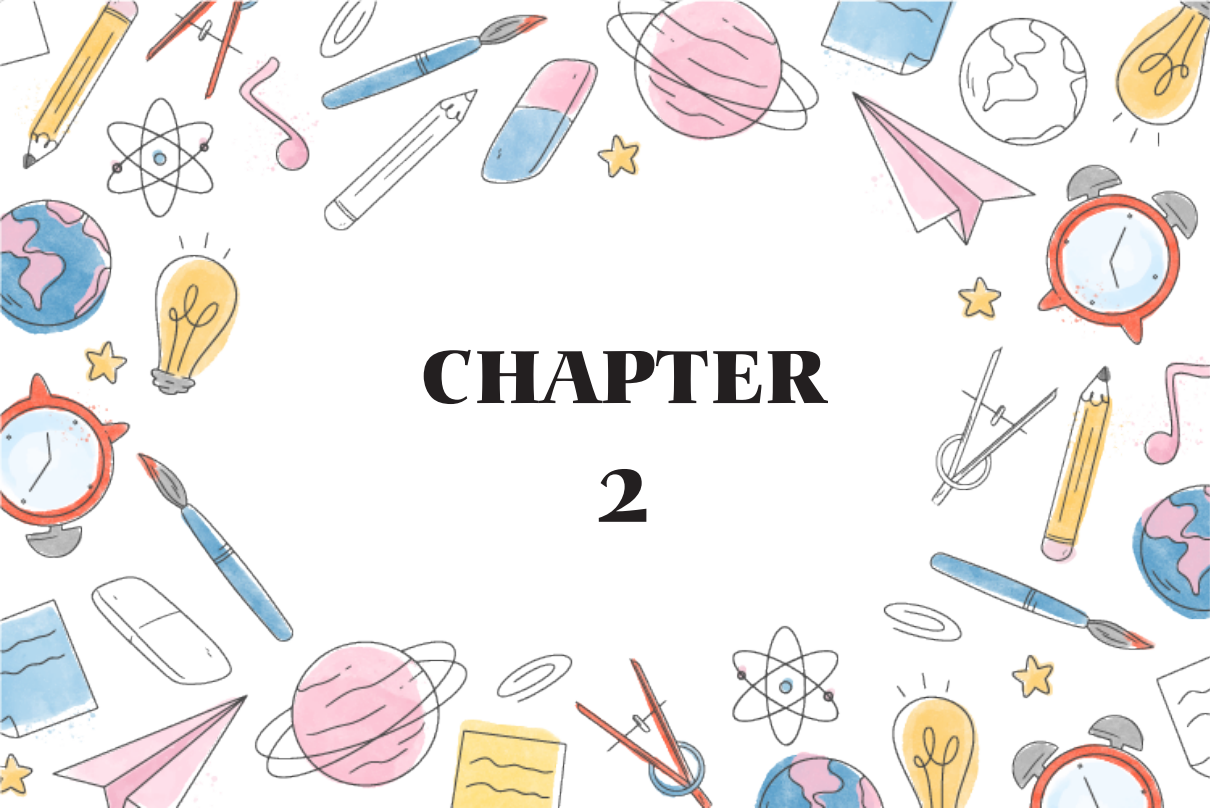

CHAPTER 2

MICROCIRCULATION MAP OF THE HUMAN BRAIN

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Introduction

Microcirculation is an extremely complex and regulatory vascular system that ensures the sustainability of surrounding tissue by meeting their oxygen and nutrient needs (Munoz et al., 2020). In an organ with high metabolic requirements such as the brain, the healthy functioning of this system is crucial to sustaining of neural functions. Microcirculation regulates tissue perfusion through arterioles, capillaries, and venules and maintains neurovascular integrity (Wang et al., 2021). Impairment of this network is thought to contribute to the development of numerous neurological diseases. Recent investigations have peeled back the layers of microcirculatory function, shedding new light on how oxygen moves through these tiniest vessels (Munoz et al., 2020). In what follows, we'll map out the cerebral vasculature with special attention to the arterial microvessels.

Definition and Importance of Microcirculation

The brain's microvascular bed springs from small arterioles, fans out into capillary meshes, and then drains into post-capillary venules. Vessels under ~20 μm in diameter form the critical interface where oxygen delivery, nutrient uptake and removal of metabolic by-products occur between blood and neural cells. Although this represents the final conduit of systemic circulation, its proper function is indispensable—when microcirculatory flow falters, cell viability is rapidly jeopardized.

Microcirculation's duties extend well beyond gas exchange. It serves as a transit hub for circulating hormones; it governs the movement of solutes across the vascular–interstitial boundary; and it orchestrates localized immune surveillance and coagulation responses. Upon arrival in the capillary network, erythrocytes off-load oxygen by passive diffusion in direct proportion to tissue demand. Crucially, this microvascular web is not static: arteriolar and capillary diameters constrict or dilate in real time, dynamically tuning blood supply to the brain's ever-changing metabolic requirements (Guven et al., 2020).

Neurovascular Unit: Cellular Components

The neurovascular unit (NVU) is described as a complex and regulatory network in the central nervous system (CNS) where neurons, glial cells and vascular structures interact in a functional integrity. The healthy functioning of this structure the sustainability of many basic processes such as controlling blood-brain barrier (BBB) permeability, providing metabolic support and protecting nervous tissue (Wang et al., 2021). An expanded understanding of the NVU, considering it not only at the cellular level but

also in conjunction with the entire vasculature of the brain, provides a new framework for understanding how cerebrovascular functions are dynamically regulated. The interactions between intracerebral vascular segments and peripheral signals demonstrate how the neurovascular system is shaped not only locally but also at the systemic level. This approach allows for a more comprehensive analysis of vascular contributions to neurological diseases by focusing on the modular structure of the neurovascular complex (Soto-Rojas et al., 2021). The NVU is a dynamic structure composed of the interactive association of astrocytes, microglia, endothelial cells, neurons, and peripheral immune cells (Kempuraj et al., 2024). The NVU is the basic structural and functional unit in the CNS and contains endothelial cells, pericytes, vascular smooth muscle cells, basal lamina, astrocytes, microglia, and neurons (Schaeffer & Iadecola, 2021).

1. Endothelial cells

Occupying the inner lining of the smallest cerebral vessels, endothelial cells orchestrate local blood flow.

They sense mechanical shear stress, interact with adjacent cells and detect a variety of chemical messengers;

these inputs are transduced via surface receptors, intracellular signaling pathways and tight-junction proteins.

When this finely tuned system breaks down, endothelial dysfunction can trigger microvascular disorders—most notably cerebral small-vessel disease (Ashby & Mack, 2021).

2. Pericytes

Pericytes envelop about 70–80 % of the brain's capillary surface—far more densely than in any other tissue (Uemura et al., 2020).

Positioned between endothelial tubes and the basal lamina, they:

- reinforce vessel wall stability
- preserve blood–brain barrier integrity
- adjust capillary diameter to regulate perfusion
- modulate inflammatory signaling in the CNS (Liu et al., 2020).

These specialized mural cells originate, in part, from mesenchymal precursors that differentiate into pericyte-like phenotypes—a process essential for capillary network formation and tissue homeostasis.

Given their pivotal role in shaping vessel architecture and function, pericytes are emerging as promising targets for therapies aimed at restoring vascular health (Cen et al., 2024; Vanlandewijck et al., 2018; Jain, 2005).

3. Astrocytes

Astrocytes help to match neuronal activity with blood flow, which is important for microcirculation. These cells are sensitive to neural signals and biochemical changes in the brain, and thus ensure that blood flow is directed according to energy needs. Thus, they coordinate the efficient delivery of essential circulating nutrients to nerve cells. These functions indicate that astrocytes serve as a regulatory intermediate component in the neuro-vascular union (Gordon et al., 2016).

4. Interaction with microglia and neurons

Microglia continuously survey the CNS environment, extending and retracting processes to sample the perivascular space and parenchyma. They engage in bidirectional communication with neurons—responding to neurotransmitter spillover and releasing cytokines or growth factors that modulate neuronal survival and function. Simultaneously, microglia crosstalk with endothelial cells and pericytes via purinergic and chemokine signals, influencing blood–brain barrier integrity and vascular tone. During pathology, microglial cells shift their morphology—from ramified to amoeboid forms—and alter gene expression profiles, reflecting an activated state that can either exacerbate or ameliorate inflammation. Because their interactions with vascular structures wax and wane over time, the precise sequence of microglia-driven vascular adaptations remains incompletely mapped and warrants further investigation (Gullotta et al., 2023).

5. Blood-brain barrier relationship

The BBB, an important part of the neurovascular structure, is crucial to the maintenance of homeostasis by providing selective passage control for the central nervous system. Since disruption of this structure can lead to serious consequences such as brain edema and neurological tissue damage, holistic evaluation of cellular interactions within the NVU is of great importance for developing treatment strategies for the protection and repair of the BBB (Gong et al., 2025).

Macroscopic Brain Vessels

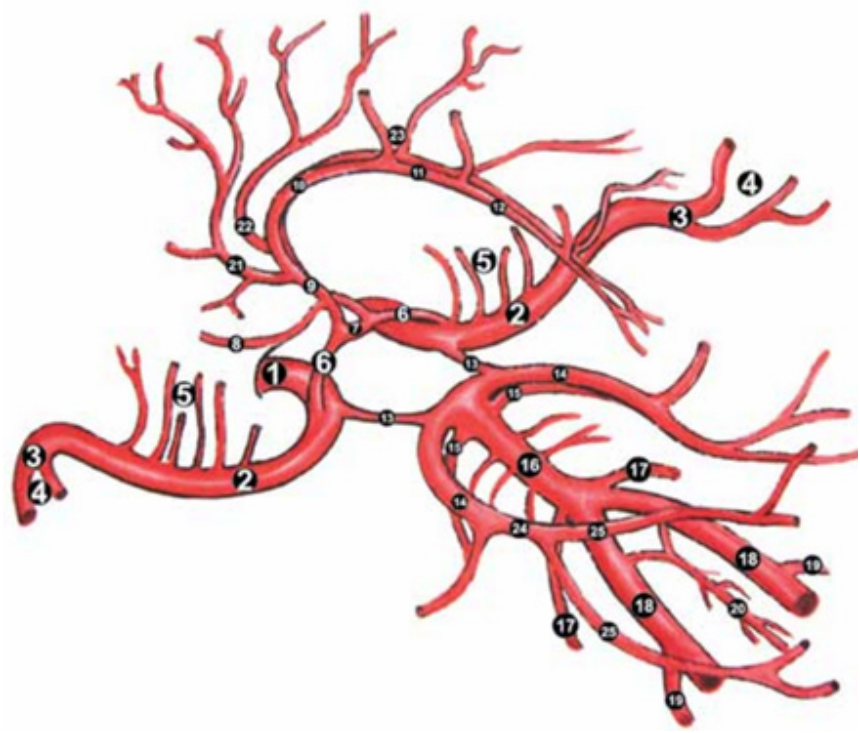

Figure 1; 1. A. Carotis Interna 2. A. Cerebri Media (MCA), M1 = First horizontal segment of MCA 3. MCA bifurcation, the point where the A. Cerebri Media divides into two main cortical branches 4. M2 = The segment in which the MCA courses around the insula 5. Aa. Lenticulostriatae 6. A. Cerebri Anterior (ACA), A1 = Initial segment extending from A. Carotis Internal to A. Communicans Anterior 7. A. Communicans Anterior 8. A. Frontopolaris 9. A2 = The segment starting after A. Communicans Anterior 10. A3 = The segment starting after A. Communicans Anterior 11. A4 = Distal ACA segment on the Cingulate Gyrus 12. A5 = The most extreme segment of the ACA 13. A. Communicans Posterior 14. A. Cerebri Posterior (PCA), P1 = First segment of PCA arising from the basilar artery 15. A. Cerebelli Superior 16. A. Basilaris 17. A. Cerebelli Anterior Inferior (AICA) 18. A. Vertebralis 19. A. Cerebelli Posterior Inferior (PICA) 20. A. Spinalis Anterior 21. A. Callosomarginalis 22. A. Frontalis Interna 23. A. Paracentralis 24. P2 = The segment of the PCA surrounding the temporal lobe 25. P3 = The segment of the PCA surrounding the temporal lobe (Ökten & Güzel, 2012).

The brain is supplied with blood by four major arteries: two internal carotid arteries and two vertebral arteries. These vessels unite in the subarachnoid space to form the arterial ring called the circle of Willis. This

structure is an important anastomosis system that ensures continuity of cerebral blood flow.

The internal carotid artery branches off from the common carotid artery in the neck and enters the skull base, where it divides into three parts: pars cervicalis, pars petrosa and pars cavernosa. The terminal branches of this artery are A. Cerebri Anterior, A. Cerebri Media and A. Choroidea Anterior.

A. Cerebri Anterior supplies the medial aspect of the hemispheres, especially the prefrontal cortex and areas related to the lower extremities. It also supplies blood to structures such as the nucleus caudatus and the internal capsule with its deep branches.

A. Cerebri Media supplies the lateral aspect of the brain and especially the motor, sensory and language centers. It also gives off deep branches to the basal ganglia.

A. Choroidea Anterior feeds tractus opticus, crus cerebri, capsula interna and plexus choroideus. Posterior Communicans A connects Internal Carotid A to Posterior Cerebri A and completes the posterior part of the polygon.

The vertebral artery originates from the subclavian artery, passes through the spinal canals, reaches the cranial cavity, and unites to form the basilar artery. Its main branches are: A. Spinalis Anterior, A. Spinalis Posterior and A. Inferior Posterior Cerebelli. A. Basilaris passes through the brainstem and gives off branches such as Aa. Pontis, A. Labyrinthi, A. Inferior Anterior Cerebelli and A. Superior Cerebelli. Terminal branches of Aa. Cerebri Posteriores supply structures such as the occipital lobe, visual cortex, and thalamus. These arteries complete the Willis circle by anastomosing with the A. Carotis Internal via the A. Communicans Posterior (Arıncı & Elhan, 2020; Arifoğlu, 2024; Lang, 2001; Critchley, 1930; Feekes & Cassell, 2006).

The mentioned arteries and their branches are presented in detail in Table 1, compiled from relevant sources (Arıncı & Elhan, 2020; Arifoğlu, 2024).

Table 1. Main Branches of the Brain Arteries and the Regions They Supply

Main Artery	Branches	Regions It Feeds / Notes
A. carotis interna	- A. ophtalmica	Eyeball, structures of the orbit
	- A. choroidea anterior	Lateral ventricle, basal ganglia, optic tract, parts of thalamus
	- A. cerebri anterior (ACA)	Medial frontal and parietal lobes, anterior part of corpus callosum
	- A. cerebri media (MCA)	Lateral surface cortex, basal ganglia
	- A. communicantes anterior ve posterior	Willis polygon connections
A. vertebralis	- A. spinalis anterior	Anterior part of spinal cord
	- A. spinalis posterior	Posterior part of the spinal cord
	- A. cerebelli inferior posterior (PICA)	Inferior part of the cerebellum, the posterior lower part of the brainstem
	- A. basilaris	Main artery to the brainstem and cerebellum
A. basilaris	- A. cerebelli superior (SCA)	Upper part of the cerebellum, upper part of the brainstem
	- A. cerebri posterior (PCA)	Occipital lobe, medial surface of temporal lobe, thalamus,hippocampus
	- A. labyrinthi (auricularis interna)	Inner ear and hearing balance organs
	- A. communicantes posterior	Willis polygon connection

Mapping Brain Microcirculation

In recent years, high-resolution Micro-Computed Tomography techniques have come to the fore in detailed anatomical mapping of the microcirculation. This method is applied on post-mortem (ex vivo) tissue samples with silicone-based contrast agents that are injected into the vascular system and become fixed. Studies on experimental animals have made it possible to create a three-dimensional anatomical map of the microcirculatory network in the mouse brain. This method enabled volumetric visualization of the entire vascular architecture, from large arterial branches to the finest capillary structures. The obtained data were processed through computer-aided analysis software, allowing regional topographic analyses of vessel density, diameter measurements and branching patterns to be per-

formed. Thus, different anatomical organizations of the microcirculation in cerebral regions could be comparatively evaluated (Quintana et al., 2019).

These techniques provide a fundamental infrastructure to explain not only the morphological aspects of microvascular organization but also the circulatory dynamics. The theoretical models put forward by Pries and Secomb (2005) are still valid, especially in the evaluation of physiological variables such as vascular wall shear stress and pressure distribution. These studies have been an important starting point in understanding hemodynamic balance at the microvascular level.

Microanatomical studies of human brain microcirculation are quite limited due to ethical and technical constraints. Brett et al. (2002) drew attention to this situation and emphasized the paucity of quantitative data on human brain microvasculature. This deficiency was later partially addressed by morphometric analyses of the human cerebral cortex microcirculation by Lauwers et al. (2008), which was one of the first studies to describe regional profiles of microcapillary density and distribution.

Recently developed high-field magnetic resonance imaging (MRI) methods allow more detailed mapping of pathologies, especially small vessel disease. Diffusion MRI, cerebrovascular reactivity measurements, and functional techniques to assess vascular function are beginning to be included for investigational purposes in randomized clinical trials. However, the integration of these methods into routine clinical practice is still limited due to technical and hardware limitations (van den Brink et al., 2022).

The VINE-seq method, developed to map the vascular system of the human brain at the molecular level, is one of the first comprehensive attempts in this field. This technique, which enables the transcriptomic profiling of vascular and perivascular cells, is based on the sequencing of cell nuclei of vascular structures isolated from human brain tissue.

Data obtained with this method showed how microvascular organization differs not only at the morphological but also at the genetic level. Generating human brain-specific vascular maps is a critical step both to understand the regulation of healthy circulation and to unravel vascular-based changes in neurodegenerative diseases (Yang et al., 2022). In the study by Sargent and colleagues based on volumetric electron microscopy data, the morphological features of the capillaries located in the mouse cerebral cortex, especially in the primary visual area, were examined in detail. In the study, images obtained by in vivo two-photon microscopy were compared with volumetric EM data; thus, a significant heterogeneity in capillary diameters was detected. Morphologically significant differences were observed especially between the transitional segments and typical ca-

pillary regions. Sergent et al.'s study is one of the few volumetric analyses conducted on the microvascular architecture of the cortex, revealing that the anatomical diversity in capillary diameters is related to the basic cellular structure, such as the number of endothelial cells forming the vascular wall (Sargent et al., 2023).

Detailed anatomical mapping of the microcirculation not only produces structural information but also allows a better understanding of the pathophysiological processes of the circulatory system. Advances in this field have the potential to bridge the gap between clinical and experimental neuroanatomy.

Microcirculation Changes in Pathological Conditions

Alzheimer's disease and some other neurodegenerative disorders are characterized by structural and functional changes in the cerebral microcirculation. In these diseases, irregularities in the diameter of capillaries are observed and decreases in microvascular density are reported. Such a change not only causes an increase in intravascular resistance and a corresponding decrease in regional blood flow, but may also disrupt the spectrum of capillary diameters required for optimal perfusion.

Increased heterogeneity in capillary diameters may prevent adequate oxygen and nutrient delivery, especially during the functional hyperemia response. This contributes to the disruption of neuron-glia-vascular integrity. Although the role of changes in endothelial structure in these pathological processes has not been fully elucidated, ıt is of great importance to examine these changes in detail to determine mechanical targets for improving microvascular perfusion (Sargent et al., 2023).

Significant changes are observed in the cerebral vascular structure with age. It is observed that vascular density decreases with age, and the vascular network becomes sparser, especially in regions associated with cognitive functions such as the frontal, temporal and posterior cingulate cortex. This decrease in vascular density indicates that cerebral microcirculation is impaired, which may lead to a decrease in cognitive performance. Changes in the vascular structure, especially in regions such as the dorsolateral prefrontal cortex and medial temporal lobe, have a strong relationship with cognitive functions. Age-related vascular changes are the main causes of neurological diseases and cognitive decline (Sarabi et al., 2024).

Conclusion

The microcirculatory system of the human brain is not only a hemodynamic transport network, but also an anatomical infrastructure system that shows a high level of organization and differentiates according to regional functions. The distribution of capillary networks ensures continuity of cognitive functions, especially concentrated in the prefrontal cortex, temporal lobe and hippocampus. Anatomically, this structure supplies the brain parenchyma at the microvascular level via branches of the anterior and posterior cerebral circulation. Aging, degenerative diseases and vascular disorders can disrupt the organization of this microcirculatory network, causing cognitive and neurological losses.

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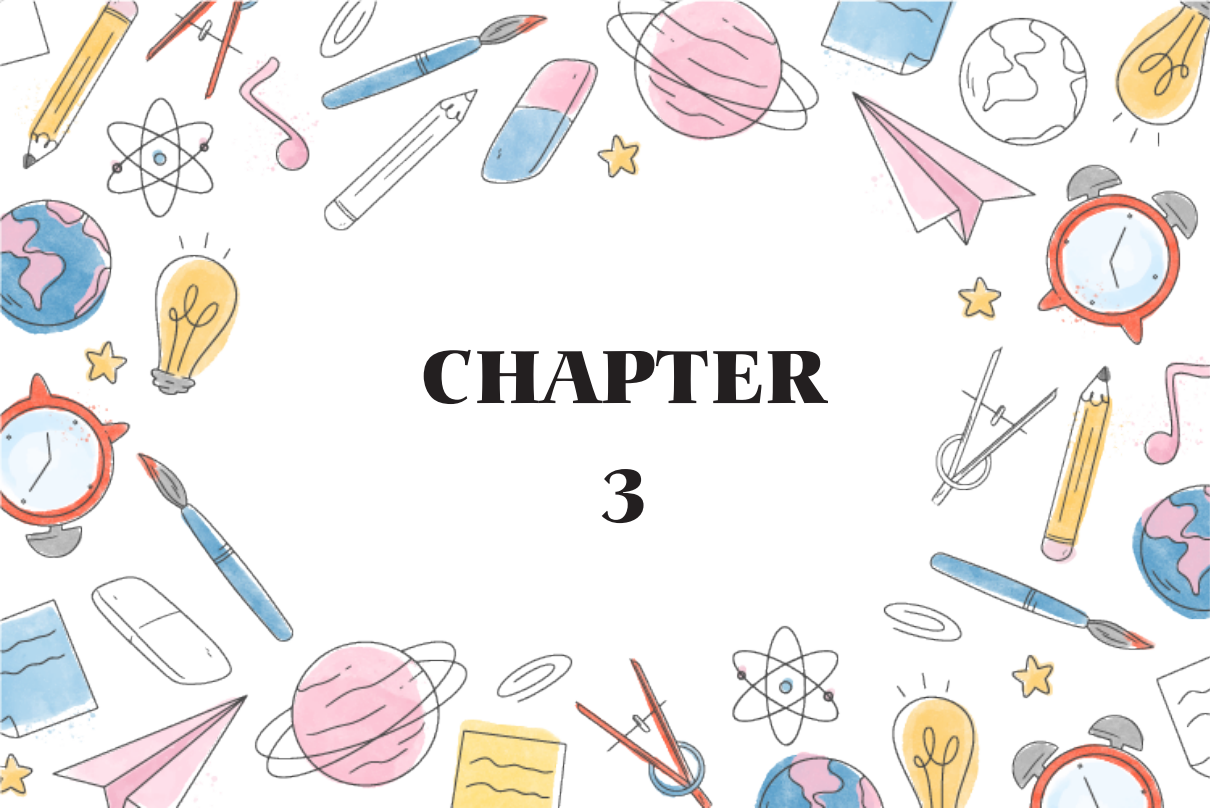

CHAPTER 3

ANATOMICAL APPROACHES IN FACE YOGA

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Yoga and Yoga's effects

Yoga originated in India thousands of years ago. It is an exercise discipline developed with the principle of uniting body, mind and soul. It is derived from the Sanskrit words "yug" (to unite) or "yoke" (to centralize). The basis of the practice is based on helping the individual reach his/her own nature(Birdee vd., 2008).

Yoga has many anatomical and physiological effects. Some of these are increasing vagal tone by providing autonomic nervous system regulation, stimulating the limbic system with relaxation, stimulating antagonist neuromuscular systems, balancing heart rate, regulating blood pressure, supporting digestive system function by regulating bowel movements and increasing metabolism, increasing the release of hormones related to well-being such as cortisol, serotonin, and endorphin by providing stress management, increasing respiratory capacity, and strengthening the immune system by supporting lymphatic flow (Brown & Gerbarg, 2009; Taneja, 2014; Torgutalp, 2018).

Face Yoga Basics

Face yoga is similar to traditional yoga. Face yoga is based on a number of facial exercises, breathing techniques and classical massage practice. The exercise includes stretching, relaxation that improves body awareness, core stabilization and posture exercises(Ozmen & Unuvar, 2024a). Movements usually consist of poses that imitate facial expressions. Dry skin is preferred when entering poses in exercise. As in all sports, exercises should be combined with breathing. Exercises performed with breath control in the correct pose not only affect the face but also heal the body and soul(Gupta & Shadmaan, 2025). The effect of exercises on the face is great for the muscles and lymphatic system. It is reported that it is an effective method for rejuvenation by contributing to tightening the face, increasing skin elasticity, stimulating facial muscles, softening facial lines, lifting the skin, increasing blood circulation, renewing skin cells, increasing collagen production and reducing tension on the face thanks to its stimulating effect(Güzel vd., 2025). It is also believed to reduce pain in trigger points(Ozmen & Unuvar, 2024a).

Classical massage therapy used in face yoga is applied according to the fiber directions and resistance levels of the face and neck muscles. In order to get the highest efficiency, it should be applied to all muscles on the face for an average of 15-20 minutes. Cold pressed oils should be used for the application(Gao vd., 2022). This massage applied in yoga also has effects such as stimulating soft tissue, providing tissue nutrition, mental relaxation and tissue healing. In addition, massage reduces inflammatory

cytokines, activates mitochondrial biogenesis mechanisms and reduces pain. It activates mitochondrial biogenesis in trigger points, increases mitochondrial quantity. It activates energy metabolism in the muscle and breaks the pain-spasm cycle(Ozmen & Unuvar, 2024a).

Anatomical Information for Face Yoga

Face yoga is related to the anatomy of the head-neck and face area. For this reason, it is valuable to know the anatomy of the area that we can affect in yoga practice.

Head and Neck Anatomy:

There are two fasciae surrounding the head and neck: Fascia capitis (buccopharyngeal fascia, masseteric fascia, parotid fascia, temporal fascia) and cervical fascia (superficial, pretracheal, prevertebral lamina)(Özbağ, D., 2019).

The vessels that feed the head and neck are; a. subclavian arter, external carotid arter, internal carotid arter, internal jugular ven and external jugular ven. The lymphatic drainage of the region is provided by superficial (occipital, mastoid, parotid, submandibular, submental) and deep cervical lymph nodes (nodi cervicales profundi). From here, the system drains into the thoracic duct and ductus lymphaticus dexter via the truncus jugularis(Ozan, H., 2005).

Skin and Muscles of the Head: The entire area under the scalp and skin is called SCALP. SCALP consists of five layers: Skin, superficial fascia (Connective tissue), galea apeneurotica (Aponeurosis epicranialis), loose areolar tissue (Loose areolar tissue), Pericranium[11].

Epicranius muscle: This muscle consists of the occipitofrontal muscle and temporoparietal muscle groups. The venter frontalis part of the occipitofrontal muscle creates transverse wrinkles in the forehead area, while the venter occipitalis part pulls the scalp back and stretches the forehead. The temporoparietal muscle is a different muscle that develops from the fascia(Mutluay, 2020).

Fascial Region (Facial Area): The skin of the facial area is in contact with the facial bones with loose connective tissue. There are mimic muscles under the skin. These muscles are innervated by facial nerve. These muscles basically start from the cartilage and ligaments between the bones that form the facial skeleton and attach to the skin. There is no fascia for any facial muscle except for buccinator muscle. There is no deep fascia in

this area. It is a region rich in fat tissue, sweat glands and nerves. Fat tissue decreases with age(Deniz, G., Algül, S., 2023).

Facial muscles (Muscles of Expression): There are many small muscles on the face, including those around the mouth, cheeks, lips, nose, eyes and ears(Arifoğlu, Y., 2019; Deniz, G., Algül, S., 2023; Mutluay, 2020) (Figure 1).

Muscles around the mouth:

- ***Orbicularis oris muscle:*** It has two parts, pars labialis and pars marginalis. It puckers and closes the lips.
- ***Depressor labii inferioris muscle:*** It pulls the lower lip down.
- ***Depressor anguli oris muscle:*** It pulls the corner of the lip down.
- ***Mental muscle:*** Pulls the skin of the chin upwards.
- ***Levator labii superioris muscle:*** Pulls the upper lip upwards.
- ***Levator anguli oris muscle:*** Pulls the corner of the lip upwards.
- ***Zygomaticus major muscle:*** Pulls the corner of the mouth upwards and to the side.
- ***Zygomaticus minor muscle:*** Pulls the corner of the mouth upwards and to the side.
- ***Levator labii superioris alaque naşi muscle:*** Widens the nostril, moves the upper lip upwards.
- ***Risorius muscle:*** Opens the corner of the lip to the side.
- ***Buccinator muscle:*** It is the blowing muscle. It brings the cheeks closer to the teeth. It allows air and food to pass from the vestibulum oris to the cavitas oris propria.

Muscles around the nose:

- ***Nasal muscle:*** It has two parts: pars transversa and pars alaris. The transverse part narrows the nostril, while the alar part widens the nostrils.
- ***Procerus muscle:*** It is the muscle that forms the transverse line on the eyebrows.

Eye area muscles:

- ***Orbicularis oculi muscle:*** It has three parts: pars orbitalis, pars palpebralis and pars lacrimale. While the orbital and palpebral parts close the eyelids, the lacrimal part drains the saccus lacrimalis.
- ***Depressor supercilii muscle:*** It creates transverse wrinkles between the eyebrows and moves the eyebrows downward.
- ***Corrugator supercilii muscle:*** It is the muscle that frowns the eyebrows.

Muscles around the ear:

- ***Auricularis superior muscle:*** Moves the auricle upwards.
- ***Auricularis anterior muscle:*** Moves the auricle forwards.
- ***Auricularis posterior muscle:*** Moves the auricle backwards.

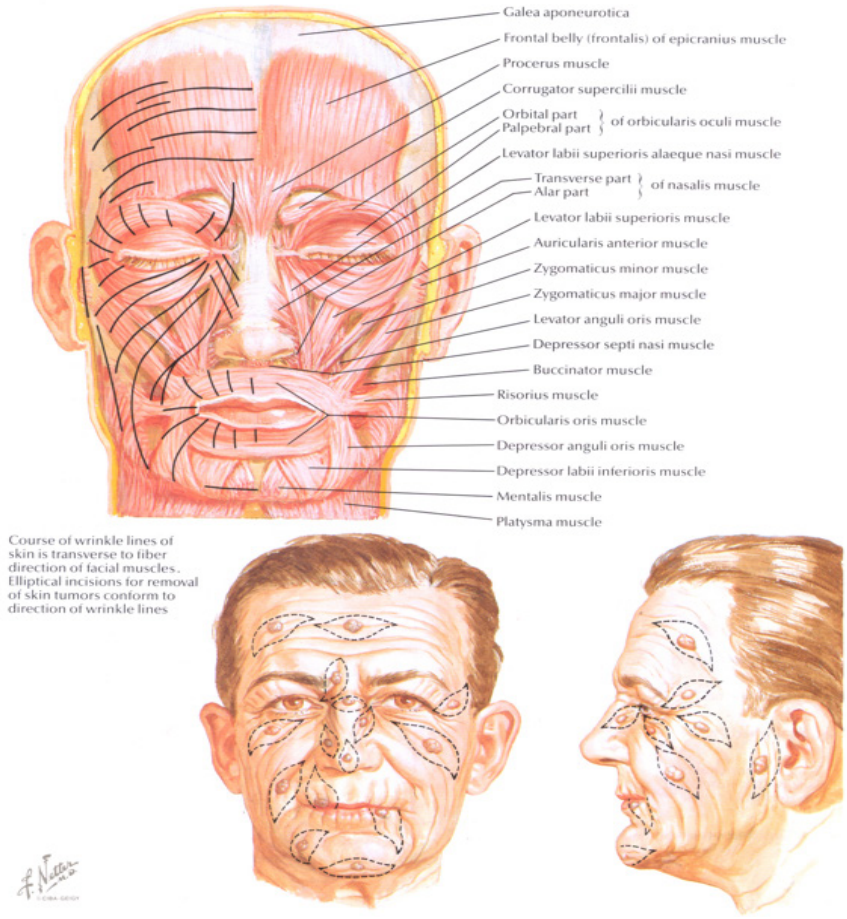

Figure 1. *Facial Muscles*[14]

Muscles of Mastication: Motor innervation of the muscles of mastication is provided by the mandibular nerve[14].

- ***Masseter muscle:*** This muscle, which is quadrangular, has a thick fascia called masseteric fascia. It consists of three layers: superficial, middle and deep. It is the muscle we palpate when we clench our teeth. It closes the mouth when it contracts bilaterally. It pulls the mandible to its side when it contracts unilaterally.
- ***Temporal muscle:*** It is the strongest of the chewing muscles. It is wrapped in a sheath called temporal fascia. It closes the mouth when it contracts bilaterally. It pulls the mandible to its side when it contracts unilaterally. Its posterior fibers retract the mandible.
- ***Pterygoideus medialis muscle:*** It closes the mouth.

- ***Pterygoideus lateralis muscle:*** It is the only muscle that opens the mouth.

Front and Side Areas of the Neck: This area includes, from outside to inside, the skin, superficial fascia, platysma, cervical fascia and some deep muscles(Deniz, G., Algül, S., 2023; Sancak, B., Cumhur, M., 2012) (Figure 2).

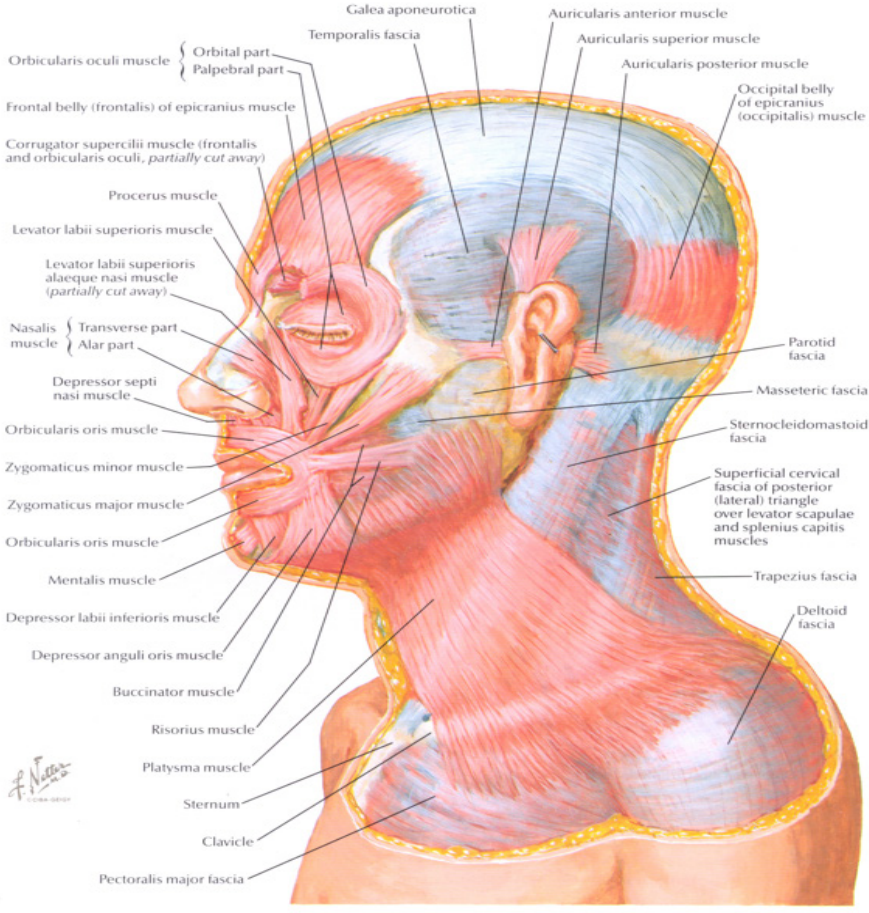

Figure 2. *Front and Side Areas of the Neck(Nettee, F., 2018)*

The muscles of the neck region consist of three parts: superficial (platysma, sternocleidomastoid muscle), middle (suprahyoid and infrahyoid muscles) and deep (prevertebral and paravertebral muscles) (Figure 2- Figure 3).

- ***Platysma:*** This muscle, innervated by facial nerve, is surrounded by the superficial fascia. It provides tension to the skin of the an-

terior-lateral neck region. It pulls the lower lip down and helps in the formation of facial movements.

- ***Sternocleidomastoid muscle:*** In its unilateral contraction, it causes lateral flexion of the neck to the same side and rotation to the opposite side. In its bilateral contraction, it pulls the chin tip forward with head extension. It is innervated by the accessory nerve.
- ***Suprahyoid muscles (digastric muscle, stylohyoid muscle, mylohyoid muscle, geniohyoid muscle):*** These muscles pull the hyoid bone upwards.
- ***Infrahyoid muscles (sternohyoid muscle, sternotyrohyoid muscle, thyrohyoid muscle, omohyoid muscle):*** These muscles pull the hyoid bone downwards.
- ***Prevertebral muscles (longus colli muscle, longus capitis muscle, rectus capitis anterior muscle, rectus capitis lateralis muscle):*** The longus colli muscle causes head flexion when it contracts bilaterally. It causes lateral flexion on the same side when it contracts unilaterally. The longus capitis muscle and rectus capitis anterior muscle cause head flexion. The rectus capitis lateralis muscle causes lateral flexion of the head and neck. These muscles are innervated by the anterior branches of the cervical spinal nerves.

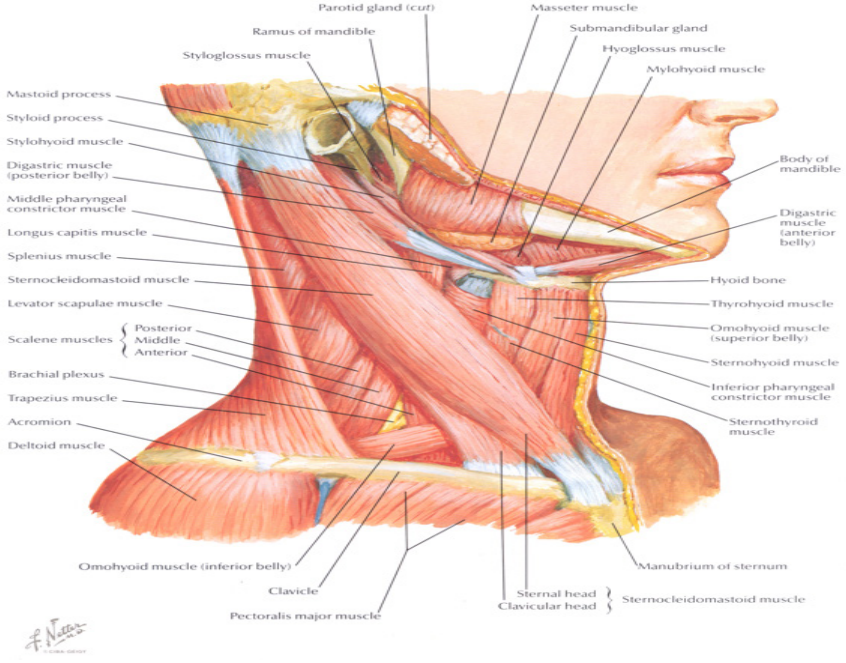

Figure 3. *Front and Side Areas of the Neck(Nettee, F., 2018)*

- ***Paravertebral muscles (scalenius anterior, medius, posterior muscles):*** This muscle group works together. They elevate the costa to which they are attached and expand the ribcage. They are active during deep inspiration. They perform lateral flexion of the neck during unilateral contraction, while they perform neck flexion during bilateral contraction. These muscles are innervated by the anterior branches of the cervical spinal nerves (Figure 4).

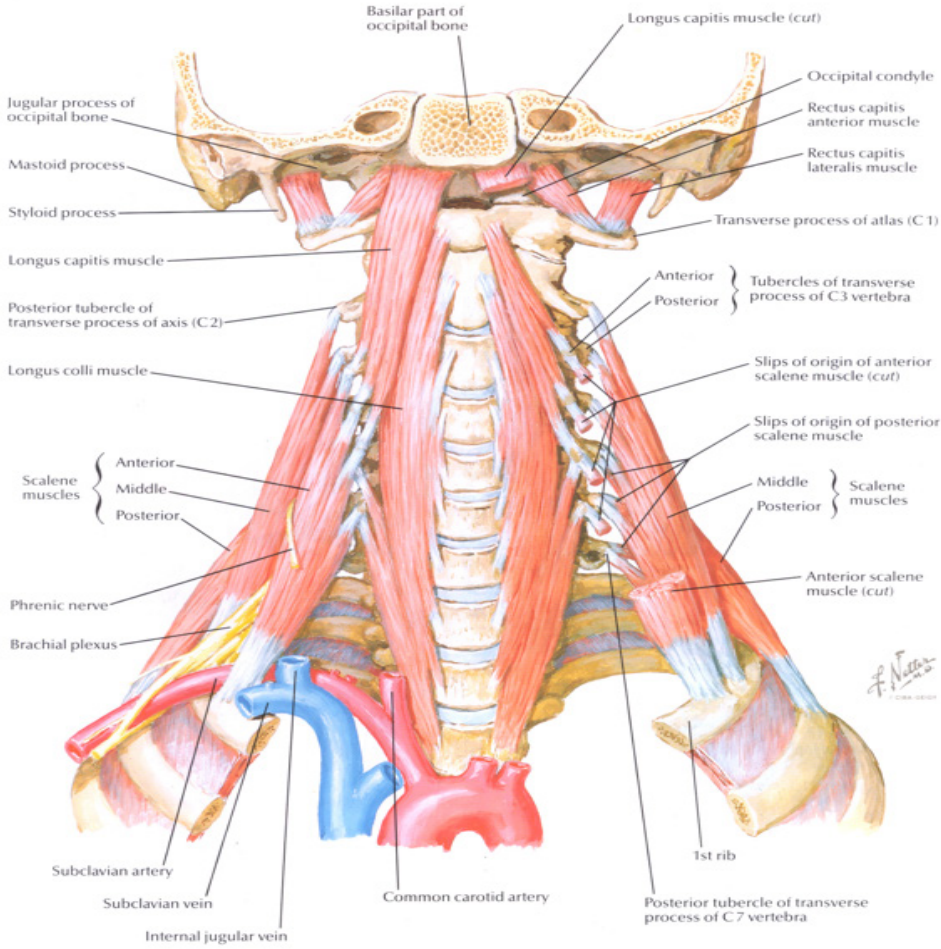

Figure 4. *Front and Side Areas of the Neck(Nettee, F., 2018)*

Muscles of the Posterior Neck Region: These are the muscles located between the first two cervical vertebrae and the occipital bone. These muscles are obliquus capitis superior muscle, obliquus capitis inferior muscle, rectus capitis posterior major muscle, rectus capitis posterior minor muscle. When the muscles contract unilaterally, they cause lateral

flexion and rotation of the head. When they contract bilaterally, they cause head extension. They are innervated by the suboccipital nerve(Deniz, G., Algül, S., 2023).

Things to Consider in Face Yoga(Çabuk, L., 2014; Hagen, An, 2008)

- Face yoga is a practice that can be easily done by men and women after the age of 22, when acne and pimples have ended and puberty has passed. The effect of a massage performed before this period can cause unwanted acne and pimples to form or increase on the skin.
- People who practice face yoga regularly 2-3 times a week for an average of 30 minutes experience a significant improvement in the face in the first two weeks. Skin vitality reaches its maximum level by the 6th month. For this reason, the application can be shortened after 6-9 months.
- Before starting face yoga, you need to make sure your hands and face are clean.
- The practice of sitting or standing in a comfortable and correct position is valuable for correct breathing.
- If you have contact lenses, they must be removed when applying around the eyes.
- Practicing in front of a mirror will prevent you from staying in the wrong pose as it improves body awareness and will increase the effectiveness of the practice.
- There should be no oil on the hands when entering the exercise poses, and cold-pressed oil should be used in massage applications.
- In areas where the vessels are superficial, such as the neck and temporal region, the transitions should be soft.
- During the application, poses can be compensated according to the existing disease condition. For example, we can provide poses by protecting the head of an individual with neck stenosis from hyperextension or a person with a neck hernia from hyperflexion.

Massage Application in Face Yoga: Classic massage application with cold pressed oil, approximately 15 minutes before yoga exercises, nourishes the face area. It is appropriate to perform facial massage from the insertion area of m. platsyma to the hair starting area. While soft transitions are recommended in the cervical and orbicular areas in facial massage, medium hard touches are recommended in other areas(Günay, G., 2022).

Exercise Application in Face Yoga: It is important to maintain head-neck neutrality and to prevent anterior tilt of the neck by keeping the neck in a chin tuck position while performing the exercises. We can also address the desired muscle groups during the exercise by keeping the spine in an upright and centered position and rolling the shoulders back and down. During the exercise, tapping can be done on the area where the exercise is performed to stimulate the muscle and increase circulation(Çabuk, L., 2014; Günay, G., 2022; Hagen, An, 2008).

Neck Area: These are exercises performed to work the area between the lower end of the mandible and the clavicle (Figure 5).

- **Exercise 1:** Place both hands on top of each other in the middle of the chest and pull the fascia down. Slowly extend the head. Feel the stretch in the platysma muscle, which is the front part of the neck. We can close the eyes to concentrate. Mouth closed, tongue on the palate, take deep and long breaths through the nose.
- **Exercise 2:** Place both hands on top of each other in the middle of the chest and pull the fascia down. Slowly bring the head into lateral flexion, right and left one by one. Feel the side neck muscles relax. We can close the eyes to concentrate. Mouth closed, tongue on the palate, take deep and long breaths through the nose.
- **Exercise 3:** Place both hands on top of each other in the middle of the chest and pull the fascia down. Slowly bring the head into extension with right lateral flexion. Feel the anterior side areas of the left neck. We can close the eyes to concentrate. Mouth closed, leave your tongue to the vestibulum oris. Take deep and long breaths through the nose.
- **Exercise 4:** Place both hands on top of each other in the middle of the chest and pull the fascia down. While the head is extending, protraction the chin. After working on the breath in neutral for 10 seconds, extend it in right and left lateral flexion. Work again for 10 breaths, keeping the chin protraction.
- **Exercise 5:** It is a four-way isometric exercise of the neck, including head-neck flexion/extension/right-left lateral flexion. For the flexion isometric exercise, place your hand on your forehead in a neutral position, and resist with your hand while pushing your head forward. For the extension isometric exercise, place your hand behind your head in a neutral position, and resist with your hand while pushing your head back. For the lateral flexion isometric exercise, place your hand next to your head in a neutral

position, and resist with your hand while pushing your head to the side. Repeat the same movement for the other side.

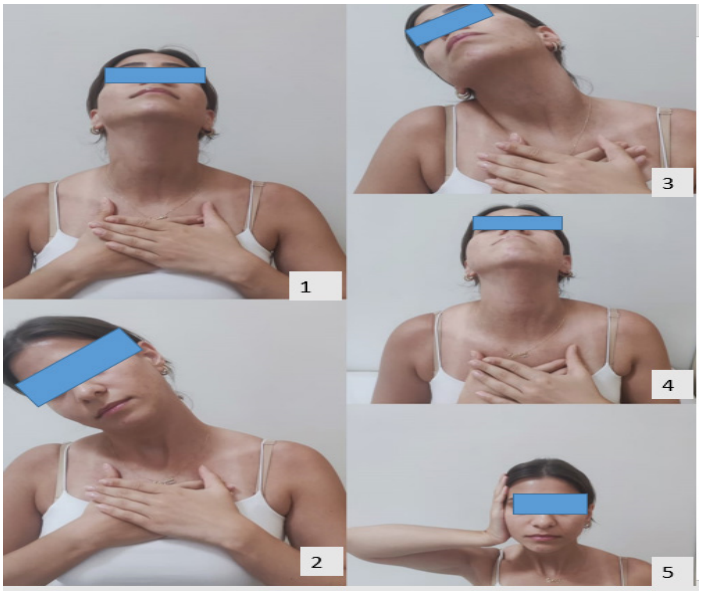

Figure 5. *Neck Area Exercises*

Lower-middle Face Area Exercises: These are exercises performed to work the muscles of the zygomatic and oral regions.

- **Exercise 1:** While sitting upright, place your hands on your cheeks and slightly pull them to the side to straighten the nasolabial sulcus. In this position, say the sounds "a, u, o, i" in an exaggerated manner with slow transitions (Figure 6).

Figure 6. *Lower-middle Face Area Exercises*

- **Exercise 2:** While sitting upright, fill your mouth with air, keeping the index and middle fingers slightly pressed on your lips. While pulling your hand back, slowly release the air (Figure 7).

Figure 7. *Lower-middle Face Area Exercises*

- **Exercise 3:** While sitting upright, take the hands to the sides of the nasolabial sulcus and gently pull towards the ear. We take the tongue towards the philtrum, between the right philtrum and the right nasolabial sulcus, to the nasolabial sulcus region, and to the lower mental muscle region, respectively, by placing the tongue in the vestibulum oris. We wait for the tongue at each stop we take. We go clockwise and repeat the exercise counterclockwise. We repeat the same exercise on the left side (Figure 8).

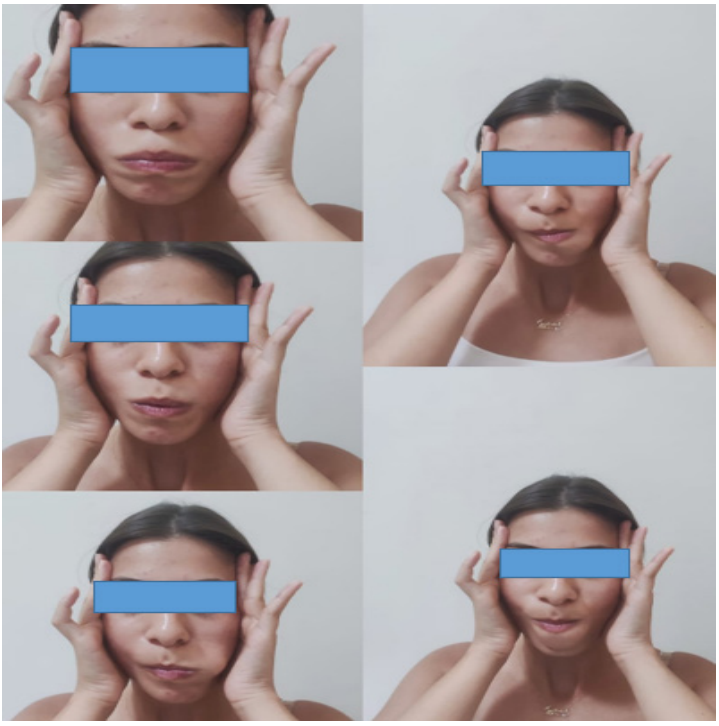

Figure 8. *Lower-middle Face Area Exercises*

Cheek Area Exercises: These exercises are especially used for masseter muscle and temporomandibular joint problems.

- **Exercise 1:** While sitting upright, place one hand under the chin in a fist. Grasp the elbow of the fisted hand with the other hand. Open the jaw in three stages and wait a little at each stage (Figure 9).

Figure 9. *Cheek Area Exercise*

- **Exercise 2:** While sitting upright, slightly open the jaw. Place three fingers on the jawline and the thumb under the chin. Relax the area with small pressures along the jawline. Maintain constant breath control (Figure 10).
- **Exercise 3:** While sitting comfortably and upright, slightly open the jaw. Place three fingers on the temples and apply pressure. Do the exercise until the end of the masseter muscle (Figure 10).

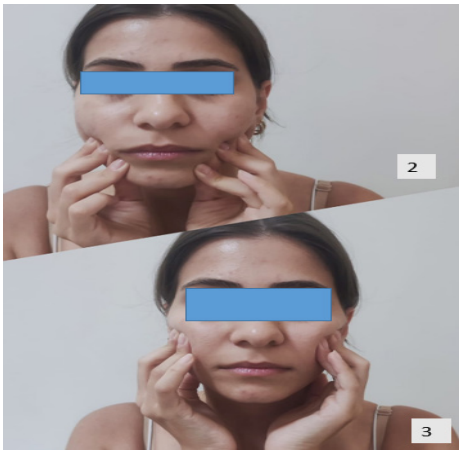

Figure 10. *Cheek Area Exercise*

Eye Contour Exercises:

- **Exercise 1:** While sitting upright, we gently pull the hand placed on the temples up and to the side. We open and close the squinted eyes 10 times (Figure 11).

Figure 11. *Eye Contour Exercises*

- **Exercise 2:** While sitting upright, we pull the eyebrows up with our hands and wait here for a while.
- **Exercise 3:** We will look ahead while sitting upright and relaxed. Make the index fingers in the shape of a hook and place them on the corrugator supercili muscle. Sweep the muscle from bottom to top, sliding it towards the brow arch (Figure 12).

Figure 12. *Eye Contour Exercises*

- **Exercise 3:** While sitting upright, we breathe deeply with the mouth closed and the tongue on the palate. While maintaining this position, we pull the gaze to the maximum right and maximum left without turning the neck. Then we send the gaze up and down. Finally, in the same position, we move the eyes to the right side

up side - left down side, then left up side - right down side (Figure 13).

Figure 13. *Eye Contour Exercises*

- **Exercise 5:** We will look ahead while sitting upright and relaxed. Place the index fingers on the eyebrows and the thumbs under the eyes. Place the hands as if looking through binoculars and open the fingers outwards. In this position, first open and close the eyes as much as possible, secondly, squint and relax the eyes (Figure 14).

Figure 14. *Eye Contour Exercises*

Clinical Use of Face Yoga

Face yoga, which is a noninvasive and supportive application, can be applied by dermatologists, physiotherapists and nurses for facial asymmetry such as fascial paralysis, temporomandibular joint pain, bruxism, and post-operative facial aesthetics, as well as skin rejuvenation and anti-aging effects(Güzel vd., 2025; Ozmen & Unuvar, 2024b).

In the protocols applied in the literature to see the effect of face yoga, applications of 45 minutes-1 hour twice a week for an average of 6-8 weeks are noteworthy. Skin cleansing before the session, ensuring skin moisture and using a mirror for the feedback mechanism are important(Ozmen & Unuvar, 2024b).

The most commonly applied muscles are; orbicularis oculi muscle, orbicularis oris muscle, mental muscle, frontal muscle, procerus muscle, zygomaticus major muscle, masseter muscle, platysma(Manincor vd., 2024). It is very important for the person who will practice face yoga to have a good knowledge of anatomy, as she/he determines the program according to the anatomy of the area she wants to affect. For example, to reduce vertical wrinkles above the upper lip, the orbicularis oris muscle should be exercised. To redu-

ce folds in the nasolabial sulcus, the orbicularis oris and zygomaticus minor muscles should be exercised. To achieve a more defined jawline, the masseter, sternocleidomastoid and mylohyoid muscles should be exercised, while to reduce wrinkles on the forehead, the frontalis muscle should be exercised. In addition, in bruxism and temporomandibular joint problems, relaxation of the masseter muscle and the muscles around the neck should be ensured. Thus, recovery can be achieved by establishing biomechanical balance(Ozmen & Unuvar, 2024b; Yu vd., 2025).

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