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Assignment Question

1. Discuss the physiology of sleep?
2. Discuss the role of basal ganglia in coordinating movement?

Answers

1.

Physiology of Sleep

 DEFINITION

Sleep is the natural periodic state of rest for mind and body with closed eyes characterized by partial or complete loss of consciousness. Loss of consciousness leads to decreased response to external stimuli and decreased body movements. Depth of sleep is not constant throughout the sleeping period. It varies in different stages of sleep.

SLEEP REQUIREMENT

Sleep requirement is not constant. However, average sleep requirement per day at different age groups is:

1. Newborn infants: 18 to 20 hours

2. Growing children: 12 to 14 hours

3. Adults: 7 to 9 hours

4. Old persons: 5 to 7 hours.

PHYSIOLOGICAL CHANGES DURING SLEEP

During sleep, most of the body functions are reduced to basal level. Following are important changes in the body during sleep:

1. Plasma volume: Plasma volume decreases by about 10% during sleep.

2. Cardiovascular system

Heart Rate:

During sleep, the heart rate reduces. It varies between 45 and 60 beats per minute.

Blood Pressure:

Systolic pressure falls to about 90 to 110 mm Hg. Lowest level is reached about 4th hour of sleep and remains at this level till a short time before waking up. Then, the pressure commences to rise. If sleep is disturbed by exciting dreams, the pressure is elevated above 130 mm Hg.

3. Respiratory system: Rate and force of respiration are decreased. Respiration becomes irregular and Cheyne-Stokes type of periodic breathing may develop.

4. Gastrointestinal tract: Salivary secretion decreases during sleep. Gastric secretion is not altered or may be increased slightly. Contraction of empty stomach is more vigorous.

5. Excretory system: Formation of urine decreases and specific gravity of urine increases.

6. Sweat secretion: Sweat secretion increases during sleep.

7. Lacrimal secretion: Lacrimal secretion decreases during sleep.

8. Muscle tone: Tone in all the muscles of body except ocular muscles decreases very much during sleep. It is called sleep paralysis.

9. Reflexes: Certain reflexes particularly knee jerk, are abolished. Babinski sign becomes positive during deep sleep. Threshold for most of the reflexes increases. Pupils are constricted. Light reflex is retained. Eyeballs move up and down.

10. Brain: Brain is not inactive during sleep.

There is a characteristic cycle of brain wave activity during sleep with irregular intervals of dreams. Electrical activity in the brain varies with stages of sleep (see below).

1. RAPID EYE MOVEMENT SLEEP – REM SLEEP Rapid eye movement sleep is the type of sleep associated with rapid conjugate movements of the eyeballs, which occurs frequently. Though the eyeballs move, the sleep is deep. So, it is also called paradoxical sleep. It occupies about 20% to 30% of sleeping period. Functionally, REM sleep is very important because, it plays an important role in consolidation of memory. Dreams occur during this period.

2. NON-RAPID EYE MOVEMENT SLEEP – NREM OR NON-REM SLEEP Non-rapid eye movement (NREM) sleep is the type of sleep without the movements of eyeballs. It is also called slow-wave sleep. Dreams do not occur in this type of sleep and it occupies about 70% to 80% of total sleeping period. Non-REM sleep is followed by REM sleep.

STAGES OF SLEEP AND EEG PATTERN

RAPID EYE MOVEMENT SLEEP

During REM sleep, electroencephalogram (EEG) shows irregular waves with high frequency and low amplitude. These waves are desynchronized waves.

NON-RAPID EYE+ MOVEMENT SLEEP

The NREM sleep is divided into four stages, based on the EEG pattern. During the stage of wakefulness, i.e. while lying down with closed eyes and relaxed mind, the alpha waves of EEG appear. When the person proceeds to drowsy state, the alpha waves diminish.

Stage I: Stage of Drowsiness

Alpha waves are diminished and abolished. EEG shows only low voltage fluctuations and infrequent delta waves.

Stage II: Stage of Light Sleep

Stage II is characterized by spindle bursts at a frequency of 14 per second, superimposed by low voltage delta waves.

Stage III: Stage of Medium Sleep

During this stage, the spindle bursts disappear. Frequency of delta waves decreases to 1 or 2 per second and amplitude increases to about 100 µV.

State IV: Stage of Deep Sleep

Delta waves become more prominent with low frequency and high amplitude.

MECHANISM OF SLEEP

Sleep occurs due to the activity of some sleep-inducing centers in brain. Stimulation of these centers induces sleep. Damage of sleep centers results in sleeplessness or persistent wakefulness called insomnia.

SLEEP CENTERS

Complex pathways between the reticular formation of brainstem, diencephalon and cerebral cortex are involved in the onset and maintenance of sleep. However, two centers which induce sleep are located in brainstem:

1. Raphe nucleus

2. Locus ceruleus of pons.

Recently, many more areas that induce sleep are identified in the brain of animals. Inhibition of ascending reticular activating system also results in sleep.

1. Role of Raphe Nucleus Raphe nucleus is situated in lower pons and medulla. Activation of this nucleus results in non-REM sleep. It is due to release of serotonin by the nerve fibers arising from this nucleus. Serotonin induces non-REM sleep.

2. Role of Locus Ceruleus of Pons Activation of this center produces REM sleep. Noradrenaline released by the nerve fibers arising from locus ceruleus induces REM sleep.

Inhibition of Ascending Reticular Activating System

Ascending reticular activating system (ARAS) is responsible for wakefulness because of its afferent and efferent connections with cerebral cortex. Inhibition of ARAS induces sleep. Lesion of ARAS leads to permanent somnolence, i.e. coma.

APPLIED PHYSIOLOGY – SLEEP DISORDERS

1. Insomnia: Insomnia is the inability to sleep or abnormal wakefulness. It is the most common sleep disorder. It occurs due to systemic illness or mental conditions such as psychiatric problems, alcoholic addiction and drug addiction.

2. Hypersomnia: Hypersomnia is the excess sleep or excess need to sleep. It occurs because of lesion in the floor of the third ventricle, brain tumors, encephalitis, chronic bronchitis and disease of muscles. Hypersomnia also occurs in endocrine disorders such as myxedema and diabetes insipidus. 3. Narcolepsy and cataplexy: Narcolepsy is the sudden attack of uncontrollable sleep. Cataplexy is sudden outburst of emotion. Both the diseases are due to hypothalamic disorders. Refer Chapter 149 for details.

4. Sleep apnea syndrome: Sleep apnea is the temporary stoppage of breathing repeatedly during sleep. Sleep apnea syndrome is the disorder that involves fluctuations in the rate and force of respiration during REM sleep with short apneic episode. Apnea is due to decreased stimulation of respiratory centers, arrest of diaphragmatic movements, airway obstruction or the combination of all these factors. When breathing stops, the resultant hypercapnia and hypoxia stimulate respiration. Sleep apnea syndrome occurs in obesity, myxedema, enlargement of tonsil and lesion in brainstem. Common features of this syndrome are loud snoring, restless movements, nocturnal insomnia, daytime sleepiness, morning headache and fatigue. In severe conditions, hypertension, right heart failure and stroke occur.

5. Nightmare: Nightmare is a condition during sleep that is characterized by a sense of extreme uneasiness or discomfort or by frightful dreams. Discomfort is felt as of some heavy weight on the stomach or chest or as uncontrolled movement of the body. After a period of extreme anxiety, the subject wakes with a troubled state of mind. It occurs mostly during REM sleep. Nightmare occurs due to improper food intake, digestive disorders or nervous disorders. It also occurs during drug withdrawal or alcohol withdrawal.

6. Night terror: Night terror is a disorder similar to nightmare. It is common in children. It is also called pavor nocturnus or sleep terror. The child awakes screaming in a state of fright and semiconsciousness. The child cannot recollect the attack in the morning. Nightmare occurs shortly after falling asleep and during non-REM sleep. There is no psychological disturbance.

7. Somnambulism: Somnambulism is getting up from bed and walking in the state of sleep. It is also called walking during sleep or sleep walking (somnus = sleep; ambulare = to walk). It varies from just sitting up in the bed to walking around with eyes open and performing some major complex task. The episode lasts for few minutes to half an hour. It occurs during non-REM sleep. In children, it is associated with bedwetting or night terror without any psychological disturbance. However, in adults it is associated with psychoneurosis.

8. Nocturnal enuresis: Nocturnal enuresis is the involuntary voiding of urine at bed. It is also called or bedwetting. It is common in children.

9. Movement disorders during sleep: Movement disorders occur immediately after falling asleep. Sleep start or hypnic jerk is the common movement disorder during sleep. It is characterized by sudden jerks of arms or legs. Sleep start is a physiological form of clonus. Other movement disorders are teeth grinding (bruxism), banging the head and restless moment of arms or legs.

2. Basal Ganglia



INTRODUCTION

Basal ganglia are the scattered masses of gray matter submerged in subcortical substance of cerebral hemisphere. Basal ganglia form the part of extra pyramidal system, which is concerned with motor activities.

COMPONENTS OF BASAL GANGLIA

Basal ganglia include three primary components: Corpus striatum, substantia nigra, subthalamic nucleus of Luys.

CORPUS STRIATUM Corpus striatum is a mass of gray matter situated at the base of cerebral hemispheres in close relation to thalamus. Corpus striatum is incompletely divided into two parts by internal capsule: i. Caudate nucleus ii. Lenticular nucleus.

1. Caudate Nucleus

Caudate nucleus is an elongated arched gray mass, lying medial to internal capsule. Throughout its length, the caudate nucleus is related to lateral ventricle. Caudate nucleus has a head portion and a tail portion. a. Outer putamen b. Inner globus pallidus.

Putamen and caudate nucleus are the phylogenetically newer parts of corpus striatum and these two parts are together called neostriatum or striatum. Globus pallidus is phylogenetically older part of corpus striatum. And, it is called pallidum or paleostriatum. Globus pallidus has two parts, an outer part and an inner part.

Substantia nigra: Substantia nigra is situated below red nucleus. It is made up of large pigmented and small non­pigmented cells. The pigment contains high quantity of iron.

Subthalamic nucleus of luys: Subthalamic nucleus is situated lateral to red nucleus and dorsal to substantia nigra.

CONNECTIONS OF BASAL GANGLIA

Afferent and efferent connections of corpus striatum, substantia nigra and subthalamic nucleus of Luys. In addition to afferent and efferent connections, different components of corpus striatum of the same side are interconnected by intrinsic fibers.

1. Putamen to globus pallidus 2. Caudate nucleus to globus pallidus 3. Caudate nucleus to putamen.

Different components of corpus striatum in each side are connected to those of the opposite side by commissural fibers.

Functions of Basal Ganglia

Basal ganglia form the part of extrapyramidal system, which is concerned with integration and regulation motor activities. Various functions of basal ganglia are:

1. Control of muscle tone: Basal ganglia control the muscle tone. In fact, gamma motor neurons of spinal cord are responsible for development of tone in the muscles. Basal ganglia decrease the muscle tone by inhibiting gamma motor neurons through descending inhibitory reticular system in brainstem. During the lesion of basal ganglia, muscle tone increases leading to rigidity.

2. Control of motor activity

i. Regulation of Voluntary Movements: Movements during voluntary motor activity are initiated by cerebral cortex. However, these movements are controlled by basal ganglia, which are in close association with cerebral cortex. During lesions of basal ganglia, the control mechanism is lost and so the movements become inaccurate and awkward. Basal ganglia control the motor activities because of the nervous (neuronal) circuits between basal ganglia and other parts of the brain involved in motor activity. Neuronal circuits arise from three areas of the cerebral cortex:

 a. Premotor area b. Primary motor area c. Supplementary motor area.

All these nerve fibers from cerebral cortex reach the caudate nucleus. From here, the fibers go to putamen. Some of the fibers from cerebral cortex go directly to putamen also. Putamen sends fibers to globus pallidus. Fibers from here run towards the thalamus, subthalamic nucleus of Luys and substantia nigra. Subthalamic nucleus and substantia nigra are in turn, projected into thalamus. Now, the fibers from thalamus are projected back into primary motor area and other two motor areas, i.e. premotor area and supplementary motor area.

ii. Regulation of Conscious Movements: Fibers between cerebral cortex and caudate nucleus are concerned with regulation of conscious movements. This function of basal ganglia is also known as the cognitive control of activity. For example, when a stray dog barks at a man, immediately the person, understands the situation, turns away and starts running.

iii. Regulation of Subconscious Movements Cortical fibers reaching putamen are directly concerned with regulation of some subconscious movements, which take place during trained motor activities, i.e. skilled activities such as writing the learnt alphabet, paper cutting, nail hammering, etc.

3. Control of reflex muscular activity:

Some reflex muscular activities, particularly visual and labyrinthine reflexes are important in maintaining the posture. Basal ganglia are responsible for the coordination and integration of impulses for these reflex activities. During lesion of basal ganglia, the postural movements, especially the visual and labyrinthine reflexes become abnormal. These abnormal movements are associated with rigidity. Rigidity is because of the loss of inhibitory influence from the cerebral cortex on spinal cord via basal ganglia.

4. Control of automatic associated movements: Automatic associated movements are the movements in the body, which take place along with some motor activities. Examples are the swing of the arms while walking, appropriate facial expressions while talking or doing any work. Basal ganglia are responsible for the automatic associated movements. Lesion in basal ganglia causes absence of these automatic associated movements, resulting in poverty of movements. Face without appropriate expressions while doing any work is called mask-like face. Body without associated movements is called statue-like body.

5. Role in arousal mechanism: Globus pallidus and red nucleus are involved in arousal mechanism because of their connections with reticular formation. Extensive lesion in globus pallidus causes drowsiness, leading to sleep.

6. Role of neurotransmitters in the functions of basal ganglia: Functions of basal ganglia on motor activities are executed by some neurotransmitters released by nerve endings within basal ganglia. Following neurotransmitters are released in basal ganglia:

i. Dopamine released by dopaminergic fibers from substantia nigra to corpus striatum (putamen and caudate nucleus: dopaminergic nigrostriatal fibers): deficiency of dopamine leads to Parkinsonism

ii. Gamma­aminobutyric acid (GABA) secreted by intrinsic fibers of corpus striatum and substantia nigra

iii. Acetylcholine released by fibers from cerebral cortex to caudate nucleus and putamen.

iv. Substance P released by fibers from globus pallidus reaching substantia nigra

v. Enkephalins released by fibers from globus pallidus reaching substantia nigra

vi. Noradrenaline secreted by fibers between basal ganglia and reticular formation

vii. Glutamic acid secreted by fibers from subthalamic nucleus to globus pallidus and substantia nigra. Among these neurotransmitters, dopamine and GABA are inhibitory neurotransmitters. So, the fibers releasing dopamine and GABA are inhibitory fibers. All other neurotransmitters have excitatory function.

APPLIED PHYSIOLOGY – DISORDERS OF BASAL GANGLIA

1. PARKINSON DISEASE

Parkinson disease is a slowly progressive degenerative disease of nervous system associated with destruction of brain cells, which produce dopamine. It is named after the discoverer James Parkinson. It is also called parkinsonism or paralysis agitans. Great boxer Mohammed Ali is affected by parkinsonism because of repeated blows he might have received on head resulting in damage of brain cells producing dopamine.

Causes of Parkinson Disease

Parkinson disease occurs due to lack of dopamine caused by damage of basal ganglia. It is mostly due to the destruction of substantia nigra and the nigrostriatal pathway, which has dopaminergic fibers. Damage of basal ganglia usually occurs because of the following causes:

i. Viral infection of brain like encephalitis

ii. Cerebral arteriosclerosis

iii. Injury to basal ganglia

iv. Destruction or removal of dopamine in basal ganglia. It occurs mostly due to long­term treatment with antihypertensive drugs like reserpine. Parkinsonism due to the drugs is known as drug-induced parkinsonism.

v. Unknown causes: Parkinsonism can occur because of the destruction of basal ganglia due to some unknown causes. This type of parkinsonism is called idiopathic parkinsonism.

Signs and Symptoms of Parkinson Disease

Parkinson disease develops very slowly and the early signs and symptoms may be unnoticed for months or even for years. Often the symptoms start with a mild noticeable tremor in just one hand. When the tremor becomes remarkable the disease causes slowing or freezing of movements followed by rigidity. Following are the common signs and symptoms of Parkinson disease:

i. Tremor: In Parkinson disease, the tremor occurs during rest. But it disappears while doing any work. So, it is called static tremor or resting tremor. It is also called drum-beating tremor, as the movements are similar to beating a drum. Thumb moves rhythmically over the index and middle fingers. These movements are called pill-rolling movements.

ii. Slowness of movements: Over the time, movements start slowing down (bradykinesia) and it takes a long time even to perform a simple task. Gradually the patient becomes unable to initiate the voluntary activity (akinesia) or the voluntary movements are reduced (hypokinesia). It is because of hypertonicity of the muscles.

iii. Poverty of movements Poverty of movements is the loss of all automatic associated movements. Because of absence of the automatic associate movements, the body becomes statue-like. The face becomes mask-like, due to absence of appropriate expressions like blinking and smiling.

iv. Rigidity Stiffness of muscles occurs in limbs resulting in rigidity of limbs. The muscular stiffness occurs because of increased muscle tone which is due to the removal of inhibitory influence on gamma motor neurons. It affects both flexor and extensor muscles equally. So, the limbs become more rigid like pillars. The condition is called lead-pipe rigidity. In later stages the rigidity extends to neck and trunk.

v. Gait Gait refers to manner of walking. The patient looses the normal gait. Gait in Parkinson disease is called festinant gait. The patient walks quickly in short steps by bending forward as if he is going to catch up the center of gravity.

vi. Speech problems Many patients develop speech problems. They may speak very softly or sometimes rapidly. The words are repeated many times. Finally, the speech becomes slurred and they hesitate to speak.

vii. Emotional changes The persons affected by Parkinson disease are often upset emotionally.

viii. Dementia In later stages, some patients develop dementia.

Treatment for Parkinson Disease

As Parkinson disease is due to lack of dopamine caused by damage of dopaminergic fibers, it is treated by dopamine injection. Dopamine does not cross the blood­brain barrier. So, another substance called levodopa (L­dopa) which crosses the blood­brain barrier is injected. L­dopa moves into the brain and there it is converted into dopamine. Since, L­dopa can be converted into dopamine in liver, some side effects occur due to excess dopamine content in liver and blood. So, along with L­dopa, another substance called carbidopa is administered. Carbidopa prevents the conversion of L­dopa into dopamine and carbidopa cannot pass through blood­brain barrier. Thus, L­dopa moves into the brain tissues and is converted into dopamine. Some of the symptoms of Parkinson disease such as tremor are abolished by surgical destruction of basal ganglia or thalamic nuclei.

1. WILSON DISEASE

Wilson disease is an inherited disorder characterized by excess of copper in the body tissues. It is also known as progressive hepatolenticular degeneration. This disease develops due to damage of the lenticular nucleus particularly, putamen. In Wilson disease, copper is deposited in the liver, brain, kidneys and eyes. Copper deposits cause damage of tissues. And the affected organs stop functioning. In addition to symptoms of Parkinson disease, liver failure and damage to the central nervous system are the most predominant effects of this disorder. Wilson disease is fatal if not treated early.

1. CHOREA

Chorea is an abnormal involuntary movement. Chorea means rapid jerky movements. It mostly involves the limbs. Chorea is due to the lesion in caudate nucleus and putamen.

1. ATHETOSIS

Athetosis is another type of abnormal involuntary movement, which refers to slow rhythmic and twisting movements. It is because of the lesion in caudate nucleus and putamen.

1. CHOREOATHETOSIS

Choreoathetosis is the condition characterized by aimless involuntary muscular movements. It is due to combined effects of chorea and athetosis.

1. HUNTINGTON CHOREA

Huntington disease is an inherited progressive neural disorder due to the degeneration of neurons secreting GABA in corpus striatum and substantia nigra. This disease starts mostly in middle age. It is characterized by chorea, hypotonia and dementia. In severe cases bilateral wasting of muscles occurs. It is otherwise called Huntington disease, chronic progressive chorea, degenerative chorea or hereditary chorea.

1. HEMIBALLISMUS

Hemiballismus is a disorder characterized by violent involuntary abnormal movements on one side of the body involving mostly the arm. While walking, the arm swings widely. These movements are called the flinging movements. These movements are due to the release phenomenon because of the absence of inhibitory influence on movements. Hemiballismus occurs due to degeneration of subthalamic nucleus of Luys.

1. KERNICTERUS

Kernicterus is a form of brain damage in infants caused by severe jaundice. Basal ganglia are the mainly affected parts of brain.