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**Medicine & Surgery**

**Neurophysiology**

**Questions**

1. **Discuss the physiology of sleep**
2. **Discuss the role of basal ganglia in coordinating movement.**
3. Sleep is defined as unconsciousness from which a person can be aroused by sensory or other stimuli. It is a natural periodic state of rest for mind and body with closed eyes. The loss of consciousness leads to a decreased response to external stimuli and decreased body movements. Sleep requirement varies per age group. But the average sleep requirement for newborn infants is 18-20 hours, for adults it is about 7-9 hours and for old people, about 5-7 hours.

 Some physiological changes occur during sleep some of which are:

* The plasma volume decreases by about 10%
* The heart rate reduces, varying between 45-60 beats per minute
* The systolic blood pressure falls to about 90-110mmHg. If sleep is disturbed by exciting dreams, the pressure is elevated above 130mmHg
* The rate and force of respiration are decreased, respiration becomes irregular and Cheyne-Stokes type of periodic breathing may develop.
* Salivary secretion decreases. Gastric secretion is not altered
* Formation of urine decreases
* Sweat secretion increases during sleep
* Lacrimal secretion decreases during sleep
* The muscle tone of the body except ocular muscles decreases. It is called paralysis
* The brain is not inactive during sleep. There is a characteristic cycle of brain activity during sleep.

There are 2 types of sleep

* Rapid eye movement sleep (REM)
* Non-rapid eye movement sleep (NREM)
* **RAPID EYE MOVEMENT SLEEP**

 REM sleep is the type of sleep associated with rapid conjugate movements of the eyeball which occurs frequently. Though the eyeballs move, the sleep is deep so it is also called paradoxical sleep. It plays a role in consolidating of memory. Dreams occur during this period. REM sleep occurs in episodes about 25% of the sleep time in young adults, each episode recurs after about 90 minutes. Some characteristics of REM sleep are

* It is an active form of sleep usually associated with dreaming and active bodily muscle movement
* The person is more difficult to arouse by sensory stimuli than during slow-wave sleep
* Muscle tone throughout the body is exceedingly depressed, indicating strong inhibition of the spinal muscle control areas
* Heart rate and respiration usually become irregular
* Despite inhibition of peripheral muscles, irregular muscle movements do occur in addition to rapid movement of the eye.
* **NON-RAPID EYE MOVEMENT SLEEP**

The NREM sleep is also called slow-wave sleep and it is divided into 4 stages based on the electroencephalogram

(EEG) pattern. During the stage of wakefulness i.e. while lying down with closed eyes and relaxed mind, the alpha waves of the EEG appear.

1. *Stage of Drowsiness*: The alpha waves are diminished and abolished. EEG only shows low voltage fluctuations and infrequent delta waves.
2. *Stage of light sleep*: This stage is characterized by spindle bursts at a frequency of 14 per second, superimposed by low voltage delta waves.
3. *Stage of medium sleep*: During this stage, the spindle bursts disappear. Frequency of the delta waves decreases to 1 or 2 per second and amplitude increases to about 100μV
4. *Stage of deep sleep*: Delta waves become more prominent with low frequency and high amplitude.

 Differences between REM and NREM sleep

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| --- | --- | --- |
| **Characteristics**  | **REM Sleep** | **NREM sleep** |
| Rapid eye movement | Present  | Absent |
| Dreams  | Present | Absent  |
| Muscle twitching | Present  | Absent  |
| Heart rate | Fluctuating  | Stable  |
| Blood pressure  | Fluctuating | Stable |
| Respiration  | Fluctuating | Stable |
| Body temperature  | Fluctuating | Stable |
| Neurotransmitter  | Noradrenaline | Serotonin |

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 **Mechanism of sleep**

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

The 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 the brainstem.

* Raphe nucleus: It is situated in the lower pons and medulla. Activation of this nucleus results in NREM sleep. It is due to release of serotonin by the nerve fibers arising from this nucleus. Serotonin induces non-REM sleep.
* Locus ceruleus of pons: Activation of this center produces REM sleep. Nor-adrenaline released by the nerve fibers arising from locus ceruleus induces REM sleep.

 Inhibition of ascending reticular activating system (ARAS) also results in sleep. ARAS is responsible for wakefulness because of its afferent and efferent connections with cerebral cortex. Inhibition of it induces sleep and lesion od it leads to permanent somnolence i.e. coma.

 **Cycle Between Sleep and Wakefulness**

 When the sleep centers are not activated, the mesencephalic and upper pontile reticular activating nuclei are released from inhibition, which allows the reticular activating nuclei to become spontaneously active. This spontaneous activity in turn excites both the cerebral cortex and the peripheral nervous system, both of which send numerous positive feedback signals back to the same reticular activating nuclei to activate them still further. Therefore, once wakefulness begins, it has natural tendency to sustain itself because of all this positive feedback activity. Then after the brain remains activated for many hours, even the neurons in the activating system presumably become fatigue. Consequently, the positive feedback cycle between the mesencephalic reticular nuclei and the cerebral cortex fades and the sleep-promoting effects of the sleep centers take over, leading to rapid transition from wakefulness back to sleep.

 **Physiological Functions of Sleep**

 Sleep causes two major types of physiological effects: first, effects on the nervous system, and second, effects on the functional systems of the body. Lack of sleep does not affect the functions of the central nervous system. However, prolonged wakefulness is often associated with progressive malfunction of the thought processes and sometimes even cause abnormal behavioral activities. A person can become irritated or even psychotic after forced wakefulness. Sleep has been postulated to serve many functions of the central nervous system, some of which are:

1. Neural maturation
2. Facilitation of learning or memory
3. Cognition
4. Clearance of metabolic waste products generated by neural activity in the awake brain
5. Conservation of metabolic energy.

**Applied Physiology.**

* Insomnia: This is the inability to sleep or abnormal wakefulness. It occurs due to systematic illness or mental conditions such as psychiatric problems, alcoholic addiction and drug addiction
* Hypersomnia: Hypersomnia is excess sleep or excess need to sleep. It occurs due to lesion in the floor of the third ventricle, brain tumors, encephalitis, chronic bronchitis and disease of muscles. It can also occur in endocrine disorders like myxedema and diabetes insipidus
* Narcolepsy & Cataplexy: This is the sudden attack of uncontrollable sleep. Cataplexy is sudden outburst of emotion. Both are due to hypothalamic disorders
* Sleep Apnea Syndrome: This is the temporary shortage of breathing repeatedly during sleep. It involves fluctuations in the rate of respiration during REM sleep with short apneic episode. Sleep Apnea Syndrome occurs in obesity, myxedema, enlargement of tonsil and lesion in brainstem. Features of this syndrome include loud snoring, restless movements, nocturnal insomnia, morning headache
1. The Basal Ganglia are the scattered mass of gray matter submerged in subcortical substance of cerebral hemisphere. They form part of the extrapyramidal system which is concerned with motor activities. The Basal ganglia is composed of 3 things: corpus striatum, Substantia nigra, subthalamic nucleus of Luys.

 The basal ganglia control the muscle tone, the gamma motor neurons of spinal cord are responsible for development of muscle tone. The basal ganglia decrease the muscle tone by inhibiting the gamma motor neurons. One of the principal roles of the basal ganglia in motor control is to function in association with the corticospinal system to control complex patterns of motor activity. An example is writing of letters of the alphabet, another is cutting paper with scissors, hammering a nail, passing a football, controlled movements of the eye, vocalization and any other skilled movement.

The neural pathway of the Putamen circuit shows the principal pathway through the basal ganglia for executing learned patterns of movement. They begin mainly in the premotor and supplementary areas of the motor cortex and in the somatosensory areas of the sensory cortex. Next, they pass to the putamen then to the internal portion of the globus pallidus, and next to the ventroanterior and ventrolateral relay nuclei of the thalamus and they finally return to the cerebral primary motor cortex and to portions of the premotor and supplementary cerebral areas closely associated with the primary motor cortex. The putamen circuit has its inputs mainly from the parts of the brain adjacent to the primary motor cortex, then its outputs go mainly back to the primary motor cortex or closely associated premotor and supplementary cortex.

If a portion of the circuit is blocked or damaged, certain patterns of movement become severely abnormal. For instance, lesions in the globus pallidus frequently leads to spontaneous and often continuous writhing movements of a hand, an arm, the neck, or the face. These movements are called athetosis. A lesion in the subthalamus often leads to sudden flailing movements of an entire limb, a condition called hemiballismus. Multiple small lesions in the putamen leads to flicking movements in the hands, face and other parts of the body called chorea. Lesions of the substantia nigra lead to the common and extremely disease of rigidity, akinesia and tremors known as Parkinson’s disease.

The basal ganglia is also involved in regulation of conscious movements and this is called cognitive control of activity and it involves the fibers between cerebral cortex and caudate nucleus are concerned with regulation of conscious. For example, when a stray dog barks at a man, immediately the person, understands the situation, turns away and starts running.

Some reflex muscular activities particularly visual and labyrinthine reflexes are important for the 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, and this abnormality is associated with rigidity.

Basal ganglia are responsible for the automatic associated movements examples of this movements are the swing of the arms, while walking, appropriate facial expressions while talking or doing any work. Lesions in basal ganglia causes absence of these automatic associated movements resulting in poverty of movements. A face without appropriate expressions while doing any work is called mask-like face while a body without associated movements is called statue-like body.

 **PUTAMEN CIRCUIT**



Relation of the basal ganglia circuitry to the corticospinal-cerebellar system for movement control

