Physiology of Pain

■ INTRODUCTION

Pain is defined as an unpleasant and emotional experience associated with or without actual tissue damage. Pain sensation is described in many ways like sharp, pricking, electrical, dull ache, shooting, cutting, stabbing, etc. Often it induces crying and fainting.

Pain is produced by real or potential injury to the body. Often it is expressed in terms of injury. For example, pain produced by fire is expressed as burning sensation; pain produced by severe sustained contraction of skeletal muscles is expressed as cramps.

Pain may be acute or chronic. **Acute pain** is a sharp pain of short duration with easily identified cause. Often it is localized in a small area before spreading to neighboring areas. Usually it is treated by medications. **Chronic pain** is the intermittent or constant pain with different intensities. It lasts for longer periods. It is somewhat difficult to treat chronic pain and it needs professional expert care.

■ BENEFITS OF PAIN SENSATION

Pain is an important sensory symptom. Though it is an unpleasant sensation, it has protective or survival benefits such as:

1. Pain gives warning signal about the existence of a problem or threat. It also creates awareness of injury.
2. Pain prevents further damage by causing reflex withdrawal of the body from the source of injury
3. Pain forces the person to rest or to minimize the activities thus enabling rapid healing of injured part
4. Pain urges the person to take required treatment to prevent major damage.

■ COMPONENTS OF PAIN SENSATION

Pain sensation has two components:

1. Fast pain
2. Slow pain.

Fast pain is the first sensation whenever a pain stimulus is applied. It is experienced as a bright, sharp and localized pain sensation. Fast pain is followed by the slow pain, which is experienced as a dull, diffused and unpleasant pain.

Receptors for both the components of pain are same, i.e. the free nerve endings. But, afferent nerve fibers are different. Fast pain sensation is carried by Aδ fibers and slow pain sensation is carried by C type of nerve fibers.

■ PATHWAYS OF PAIN SENSATION

Pain sensation from various parts of body is carried to brain by different pathways which are:

1. Pathway from skin and deeper structures
2. Pathway from face
3. Pathway from viscera
4. Pathway from pelvic region.

■ 1. FROM SKIN AND DEEPER STRUCTURES

Receptors

Receptors of pain sensation are the free nerve endings, which are distributed throughout the body.

First Order Neurons

First order neurons are the cells in posterior nerve root ganglia, which receive the impulses of pain sensation from pain receptors through their dendrites. These impulses are transmitted to spinal cord through the axons of these neurons.

Fast pain fibers

Fast pain sensation is carried by Aδ type afferent fibers which synapse with neurons of **marginal nucleus** in the posterior gray horn.

Slow pain fibers

Slow pain sensation is carried by C type afferent fibers, which synapse with neurons of **substantia gelatinosa** of Rolando in the posterior gray horn (Fig. 143.4).

Second Order Neurons

Neurons of marginal nucleus and substantia gelatinosa of Rolando form the second order neurons. Fibers from these neurons ascend in the form of the lateral spinothalamic tract.

Fast pain fibers

Fibers of fast pain arise from neurons of marginal nucleus. Immediately after taking origin, the fibers cross the midline via anterior gray commissure, reach the lateral white column of the opposite side and ascend. These fibers form the neospinothalamic fibers in lateral spinothalamic tract. These nerve fibers terminate in **ventral posterolateral nucleus** of thalamus. Some of the fibers terminate in ascending reticular activating system of brainstem.

Slow pain fibers

Fibers of slow pain, which arise from neurons of substantia gelatinosa, cross the midline and run along the fibers of fast pain as **paleospinothalamic fibers** in lateral spinothalamic tract. One fifth of these fibers terminate in ventral posterolateral nucleus of thalamus. Remaining fibers terminate in any of the following areas:

i. Nuclei of reticular formation in brainstem
ii. Tectum of midbrain
iii. Gray matter surrounding aqueduct of Sylvius.

Third Order Neurons

Third order neurons of pain pathway are the neurons in:

i. Thalamic nucleus
ii. Reticular formation
iii. Tectum
iv. Gray matter around aqueduct of Sylvius.

Axons from these neurons reach the sensory area of cerebral cortex (Fig. 145.2). Some fibers from reticular formation reach hypothalamus.

Center for Pain Sensation

Center for pain sensation is in postcentral gyrus of parietal cortex. Fibers reaching hypothalamus are concerned with arousal mechanism due to pain stimulus.

■ 2. FROM FACE

Pain sensation from face is carried by trigeminal nerve (Chapter 144).

■ 3. FROM VISCERA

Pain sensation from thoracic and abdominal viscera is transmitted by sympathetic (thoracolumbar) nerves. Pain from esophagus, trachea and pharynx is carried by vagus and glossopharyngeal nerves.

4. FROM PELVIC REGION

Pain sensation from deeper structures of pelvic region is conveyed by sacral parasympathetic nerves.

VISCERAL PAIN

Pain from viscera is unpleasant. It is poorly localized.

CAUSES OF VISCERAL PAIN

1. *Ischemia*

Substances released during ischemic reactions such as bradykinin and proteolytic enzymes stimulate the pain receptors of viscera.

2. *Chemical Stimuli*

Chemical substances like acidic gastric juice, leak from ruptured ulcers into peritoneal cavity and produce pain.

3. *Spasm and Overdistention of Hollow Organs*

Spastic contraction of smooth muscles in gastrointestinal tract and other hollow organs of viscera cause pain by stimulating the free nerve endings. Overdistention of hollow organs also causes pain.

REFERRED PAIN

DEFINITION

Referred pain is the pain that is perceived at a site adjacent to or away from the site of origin. Deep pain and some visceral pain are referred to other areas. But, superficial pain is not referred.

EXAMPLES OF REFERRED PAIN

1. Cardiac pain is felt at inner part of left arm and left shoulder (Fig. 145.1)
2. Pain in ovary is referred to umbilicus
3. Pain from testis is felt in abdomen
4. Pain in diaphragm is referred to shoulder
5. Pain in gallbladder is referred to epigastric region
6. Renal pain is referred to loin.

MECHANISM OF REFERRED PAIN

Dermatomal Rule

According to dermatomal rule, pain is referred to a structure, which is developed from the same **dermatome** from which the pain producing structure is developed.

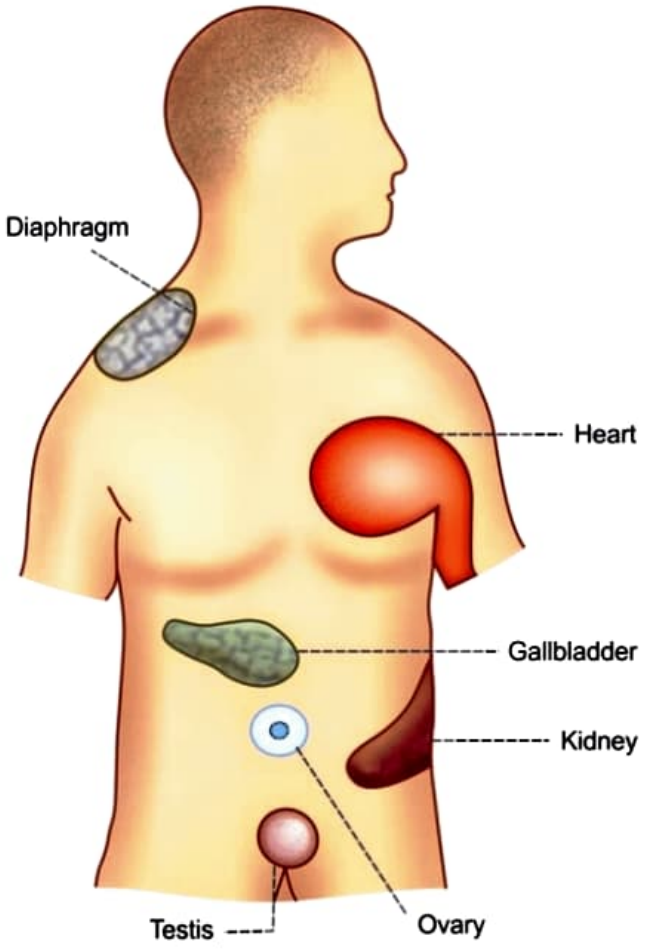

FIGURE 145.1: Sites of referred pain

A dermatome includes all the structures or parts of the body, which are innervated by afferent nerve fibers of one dorsal root. For example, the heart and inner aspect of left arm originate from the same dermatome. So, the pain in heart is referred to left arm.

NEUROTRANSMITTERS INVOLVED IN PAIN SENSATION

Glutamate and substance P are the neurotransmitters secreted by pain nerve endings. Aδ afferent fibers, which transmit impulses of fast pain secrete glutamate. The C type fibers, which transmit impulses of slow pain secrete substance P.

ANALGESIA SYSTEM

Analgesia system means the pain control system. Body has its own analgesia system in brain, which provides a short-term relief from pain. It is also called

endogenous analgesic system. Analgesia system has got its own pathway through which it blocks the synaptic transmission of pain sensation in spinal cord and thus attenuates the experience of pain. In fact analgesic drugs such as opioids act through this system and provide a controlled pain relief.

■ ANALGESIC PATHWAY

Analgesic pathway that interferes with pain transmission is often considered as descending pain pathway, the ascending pain pathway being the afferent fibers that transmit pain sensation to the brain (Fig. 145.2).

Role of Analgesic Pathway in Inhibiting Pain Transmission

1. Fibers of analgesic pathway arise from frontal lobe of cerebral cortex and hypothalamus
2. These fibers terminate in the gray matter surrounding the third ventricle and aqueduct of Sylvius (periaqueductal gray matter)
3. Fibers from here descend down to brainstem and terminate on:
   i. **Nucleus raphe magnus,** situated in reticular formation of lower pons and upper medulla
   ii. **Nucleus reticularis,** paragigantocellularis situated in medulla
4. Fibers from these reticular nuclei descend through lateral white column of spinal cord and reach the synapses of the neurons in afferent pain pathway situated in anterior gray horn
   Synapses of the afferent pain pathway are between:
   i. Aδ type afferent fibers and neurons of marginal nucleus
   ii. C type afferent fibers and neurons of substantia gelatinosa of Rolando.
5. At synaptic level, analgesic fibers release neurotransmitters and inhibit the pain transmission before being relayed to brain.

Neurotransmitters of Analgesic Pathway

Neurotransmitters released by the fibers of analgesic pathway are serotonin and opiate receptor substances namely enkephalin, dynorphin and endorphin.

■ GATE CONTROL THEORY

Psychologist **Ronald Melzack** and the anatomist **Patrick Wall** proposed the gate control theory for pain in 1965 to explain the pain suppression.

According to them, the pain stimuli transmitted by afferent pain fibers are blocked by gate mechanism

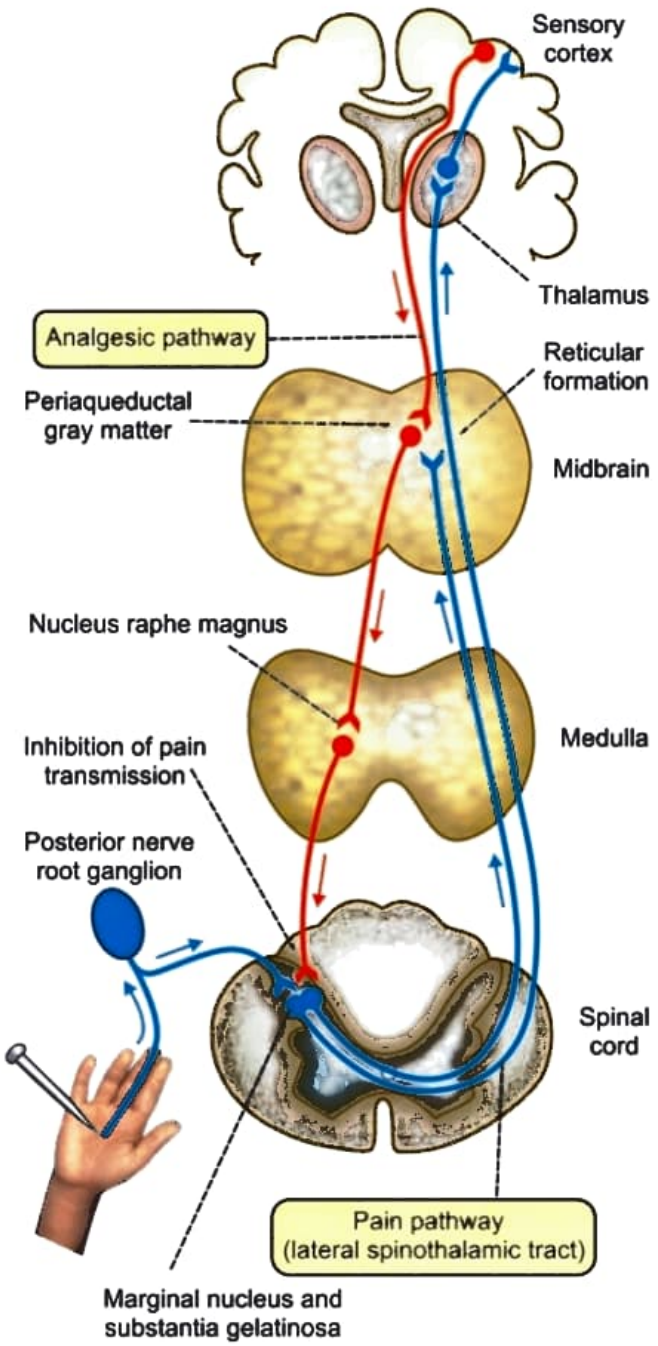

FIGURE 145.2: Pain pathway and analgesic pathway

located at the posterior gray horn of spinal cord. If the gate is opened, pain is felt. If the gate is closed, pain is suppressed.

Mechanism of Gate Control at Spinal Level

1. When pain stimulus is applied on any part of body, besides pain receptors, the receptors of other sensations such as touch are also stimulated

2. When all these impulses reach the spinal cord through posterior nerve root, the fibers of touch sensation (posterior column fibers) send collaterals to the neurons of pain pathway, i.e. cells of marginal nucleus and substantia gelatinosa
3. Impulses of touch sensation passing through these collaterals inhibit the release of glutamate and substance P from the pain fibers
4. This closes the gate and the pain transmission is blocked (Fig. 145.3).

Role of Brain in Gate Control Mechanism

According to Melzack and Wall, brain also plays some important role in the gate control system of the spinal cord as follows:

1. If the gates in spinal cord are not closed, pain signals reach thalamus through lateral spinothalamic tract
2. These signals are processed in thalamus and sent to sensory cortex

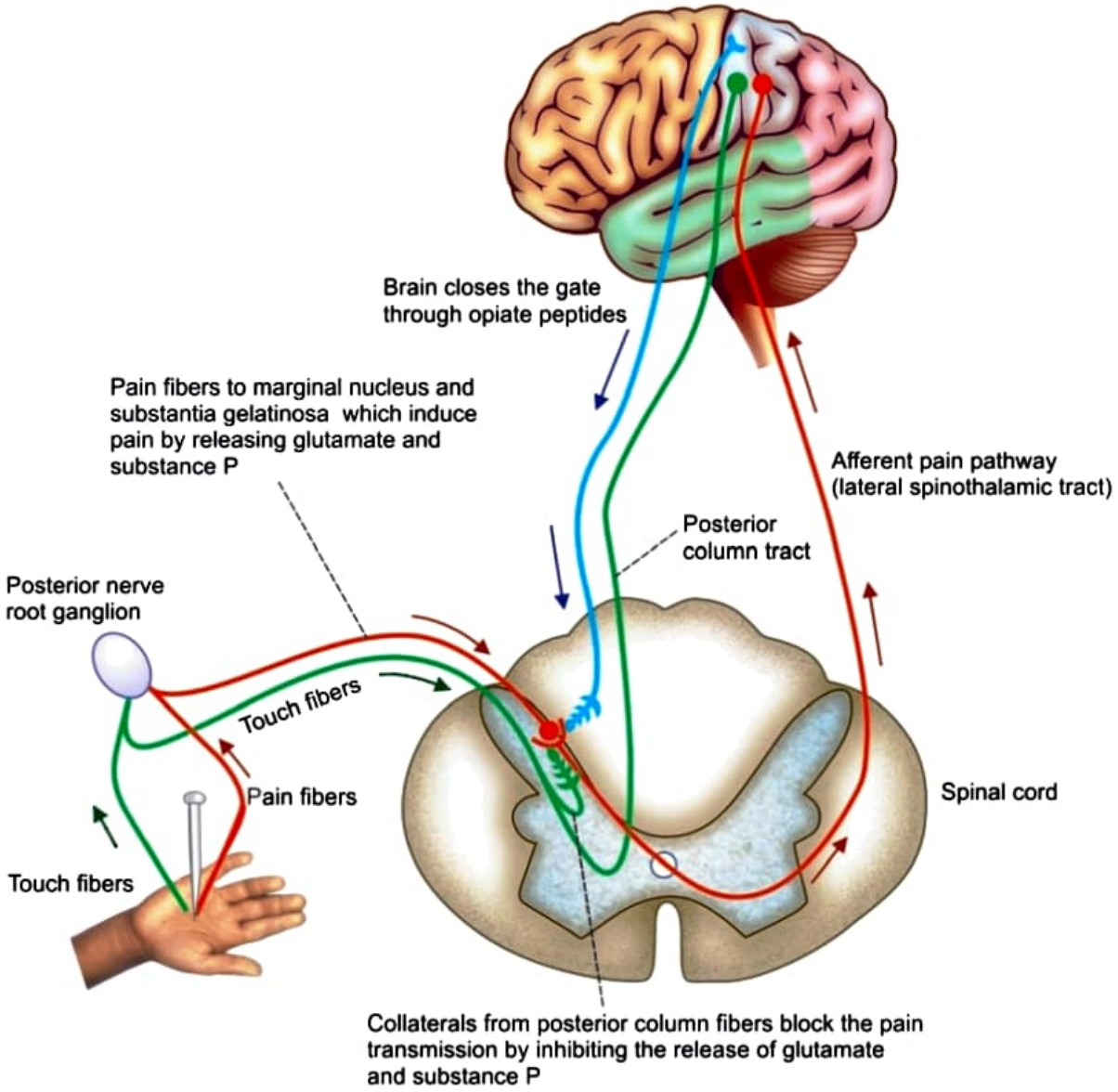

FIGURE 145.3: Gate control system

3. Perception of pain occurs in cortical level in context of the person's emotional status and previous experiences
4. The person responds to the pain based on the integration of all these information in the brain. Thus, the brain determines the severity and extent of pain.
5. To minimize the severity and extent of pain, brain sends message back to spinal cord to close the gate by releasing pain relievers such as opiate peptides
6. Now the pain stimulus is blocked and the person feels less pain.

Significance of Gate Control

Thus, gating of pain at spinal level is similar to presynaptic inhibition. It forms the basis for relief of pain through rubbing, massage techniques, application of ice packs, acupuncture and electrical analgesia. All these techniques relieve pain by stimulating the release of endogenous pain relievers (opioid peptides), which close the gate and block the pain signals.

■ APPLIED PHYSIOLOGY

1. *Analgesia*

Analgesia means loss of pain sensation.

2. *Hyperalgesia*

Hyperalgesia is defined as the increased sensitivity to pain sensation.

3. *Paralgesia*

Abnormal pain sensation is called paralgesia.