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An Overview on Postoperative Pain after Laparoscopic Cholecystectomy

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Abstract:

Postoperative pain remains one of the most common complications following laparoscopic cholecystectomy despite the minimally invasive nature of the procedure. The origin of this pain is multifactorial and may include somatic pain from trocar insertion sites, visceral pain related to pneumoperitoneum, and referred shoulder pain due to diaphragmatic irritation. Several physiological, surgical, and patient-related factors influence the intensity and duration of postoperative pain. Understanding the mechanisms of pain transmission and the risk factors associated with postoperative discomfort is essential for improving perioperative pain control strategies. Recent advances in multimodal analgesia, regional anesthesia techniques, and enhanced recovery protocols have contributed to better pain management and improved patient outcomes. This review discusses the physiology of pain, mechanisms responsible for postoperative pain after laparoscopic procedures, associated risk factors, and current strategies for prevention and management.

Keywords: Postoperative pain; Laparoscopic cholecystectomy; Pneumoperitoneum; Multimodal analgesia; Regional anesthesia; Pain management.

Introduction:

Postoperative pain remains one of the most common clinical challenges following surgical procedures, even with the advancement of minimally invasive techniques. Laparoscopic surgery, particularly laparoscopic cholecystectomy, has significantly reduced surgical trauma compared with open procedures; however, patients still frequently experience postoperative pain of varying intensity. This pain may arise from several sources including incision sites, visceral irritation caused by pneumoperitoneum, and referred shoulder pain due to diaphragmatic irritation **(Bisgaard, 2006).**

The physiological process of pain perception involves activation of peripheral nociceptors followed by transmission of signals through A-delta and C nerve fibers to the dorsal horn of the spinal cord and subsequently to higher centers in the brain where pain is perceived. Pain perception is also influenced by psychological, environmental, and individual patient factors, making postoperative pain a multifactorial phenomenon **(Kehlet & Dahl, 2003).**

Although laparoscopic cholecystectomy is considered the gold standard treatment for symptomatic gallbladder disease, postoperative pain remains a significant concern that may delay recovery, prolong hospital stay, and increase analgesic requirements. The pain after laparoscopic procedures is typically composed of three main components: incisional pain from trocar sites, visceral pain from surgical manipulation and pneumoperitoneum, and shoulder tip pain caused by phrenic nerve irritation due to diaphragmatic stretching **(Bisgaard et al., 2001).**

Effective postoperative pain control is therefore essential for improving patient recovery and enhancing surgical outcomes. Current strategies emphasize multimodal analgesia, regional anesthesia techniques, and enhanced recovery protocols to minimize opioid consumption and optimize postoperative recovery **(Kehlet & Dahl, 2003).**

- **Physiology of pain**

The ability of the somatosensory system to detect noxious and potentially tissue-damaging stimuli is an important protective mechanism that involves multiple interacting peripheral and central mechanisms. The neural processes underlying the encoding and processing of noxious stimuli are defined as 'nociception'. In addition to these sensory effects, the perception and subjective experience of 'pain' is multi factorial and will be influenced by psychological and environmental factors in every individual. Acute pain perception begins with activation of specific sensory nerves, termed nociceptors. These are unencapsulated free nerve endings that are present in the skin, deep somatic tissue and viscera. Providing the stimulus is suitably intense, high threshold nociceptors will still activate in the absence of actual tissue damage. Nociceptors activation leads to an increase in H+ and K+ concentration. Nociceptors can be divided into two main classes; A-delta and C fibers **(Lee & Neumeister 2020).**

Multiple tracts and centers exist within the central nervous systems which are responsible for the transmission, modulation and perception of noxious stimuli. **Figure 1.** It is important to realize that these areas should not be considered as fixed or functioning in isolation. Rather, they are subject to change from both descending and ascending pathways and can alter or expand their connections to interact with adjacent nerves. Cell bodies of afferent nerves lie in the dorsal root ganglion (DRG) with fibers synapsing in the dorsal horn of the spinal cord. The output from the dorsal horn is however dependent on other neuronal input to the synapse. Afferent neurons may divide prior to entering the cord and send branches cephalic or caudal in the longitudinal tract of Lissauer before synapsing with dorsal horn neurons. The result of this being that a single C-fiber afferent may be responsible for innervating dorsal horn neurons at multiple spinal levels. The grey matter of the spinal cord can be divided into ten physiologically and histological distinct layers known as rexed lamina. Laminae 1 to 6 and 10 are the sites that sensory nerves synapse with dorsal horn cells and are important in pain transmission. Laminas 7-9 are involved with motor function **. (Lee & Neumeister 2020).**

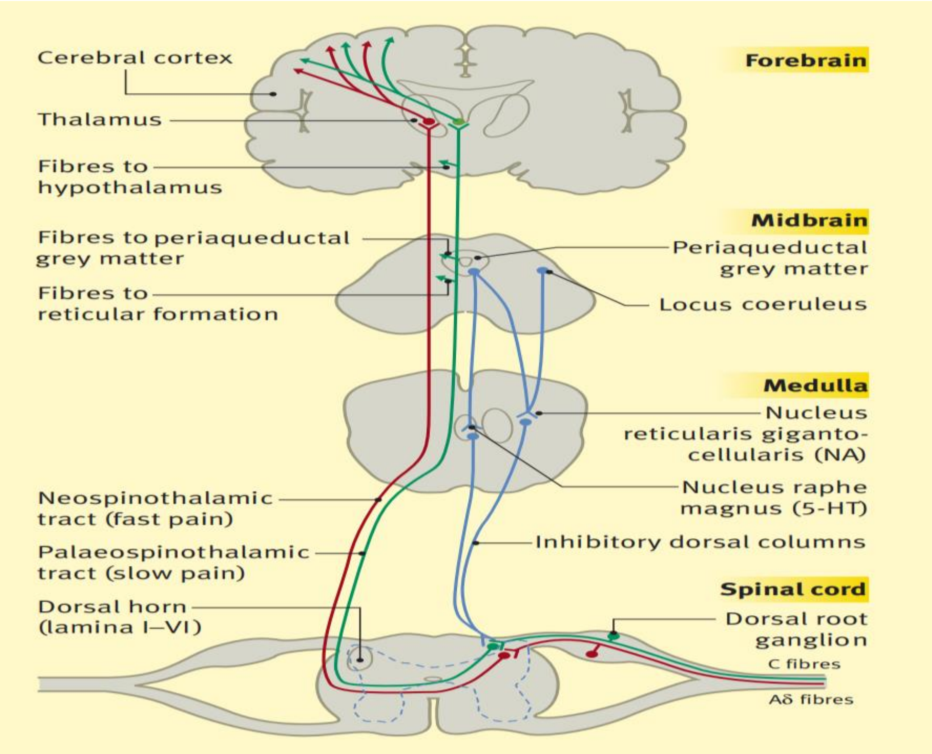

Figure (1): Spinal and supraspinal pathways of pain **(Lee & Neumeister 2020).**

Ascending nociceptive fast (red) and slow (green) pathways. Descending inhibitory tracts (blue). NA: Noradrenaline; 5-HT: 5-hydroxytryptamine.

Detection of noxious and potentially tissue-damaging stimuli is an important protective mechanism that activates nociceptors and transduction into action potentials for conduction to the central nervous system. Nociceptors are stimulated by chemical, thermal or mechanical damage and trigger the nociceptive impulses. Nociceptive primary afferents are widely distributed throughout the body (skin, muscle, joints, viscera, meninges) and comprise both lightly myelinated A-delta fibers (diameter 2-5 mm) and slow-conducting unmyelinated C-fibers (diameter <2 mm). These fibers enter the dorsal horn of the spinal cord and synapse at different sites (Aδ at laminae II and V, C at laminae II) **(Kehlet & Dahl, 2003).**

The substantia gelatinosa (lamina II) integrates these inputs and second-order neurons form the ascending spinothalamic and spinoreticular pathways on the contralateral side. The larger AB fibres conducting "touch" and descending pathways stimulate inhibitory interneurons within the substantia gelatinosa and inhibit C fibre nociceptive inputs. This is the basis of the gate theory of pain. Pain may be modified by altering the neural pathway from its origin at the nociceptor to its interpretation within the central nervous system by various agents. Psychological factors that influence the experience of pain include the processes of attention, other cognitive processes (e.g., memory, learning, thought processing, beliefs and mood), behavioural responses, and interactions with the person's environment **(Kehlet & Dahl, 2003).**

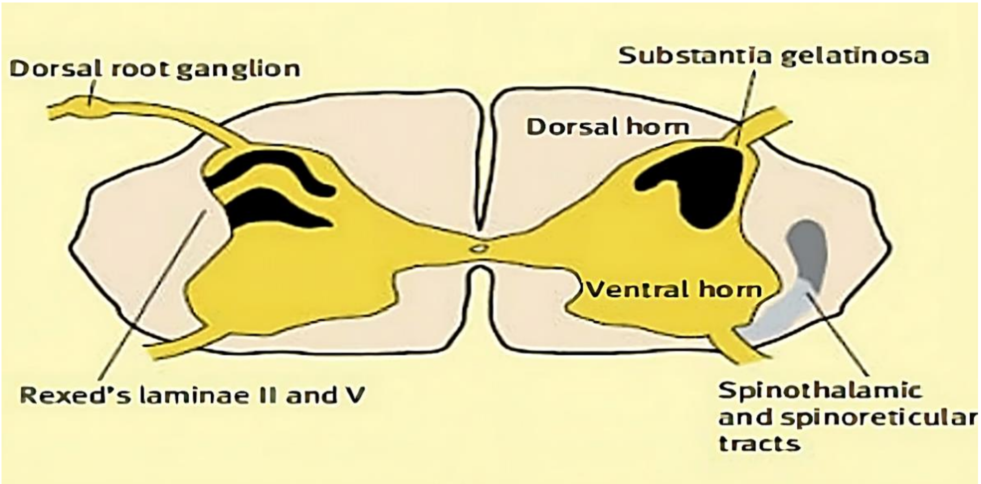

Fig (2): Physiology of pain **(Lee & Neumeister 2020).**

- **Mechanisms of pain following laparoscopic procedures**

In contrast to the largely somatic nature of postoperative pain following open cholycystectomy, the pain experienced after laparoscopic surgery includes elements of both somatic and visceral origin, The postoperative pain following laparoscopic surgeries is often a sharp pain that is typically localized in the abdomen, The causes of this pain involve the puncturing of the abdominal wall and the introduction of trocars and sutures. (**Golzari et al., 2016**).

The exact mechanisms of visceral pain following laparoscopy are not fully understood. Proposed mechanisms include stretching of the diaphragm, which can cause shoulder tip pain due to phrenic nerve irritation. However, the short duration of the pain and the fact that the diaphragm is elevated by the pneumoperitoneum make it unlikely that the main phrenic nerve is mechanically injured. It is suggested that subdiaphragmatic fibers may be stretched by the increased concavity of the diaphragm induced by the pneumoperitoneum. Loss of visceral surface tension after pneumoperitoneum creation may also contribute to increased weight on the diaphragmatic attachments of the liver, leading to shoulder tip pain. Some studies argue that more severe pain is observed in the left shoulder tip due to protection of the right diaphragm by the liver. Neuropathic pain can be elicited by various stimuli, including chemical irritation, ischemia, and compression. Attempts to alleviate shoulder tip pain through gas aspiration or local anesthesia to the diaphragm have shown only moderate success. **(Pournajafian et al., 2021; Umano et al., 2021).**

Pneumoperitoneum can cause pain through potential trauma to the peritoneum. Peritoneal biopsies taken after laparoscopy have shown peritoneal inflammation, capillary and neuronal rupture, and granulocyte infiltration. Decreased levels of free radical scavengers in peritoneal biopsies have been strongly correlated with exposure to carbon dioxide and the duration of the procedure. **(Chang et al., 2021).**

Another potential mechanism of pain is the formation of intraperitoneal carbonic acid from carbon dioxide. Localized peritoneal acidosis has been demonstrated in a previous study with carbon dioxide pneumoperitoneum, and the degree of acidosis is related to the duration of pneumoperitoneum and intra-abdominal pressure. Intraperitoneal acidosis has also been observed in humans after carbon dioxide pneumoperitoneum, and it has been noted in a small number of patients undergoing argon pneumoperitoneum, suggesting that acidosis may arise from local ischemia. Saline solution may help in diluting the acid rather than restoring visceral surface tension, as proposed by some researchers **(Sao et al., 2019).**

Apart from local effects, systemic hypercarbia (elevated carbon dioxide levels in the bloodstream) during pneumoperitoneum may cause excitation of the sympathetic nervous system, leading to an amplification of the local tissue inflammatory response. Splanchnic mucosal ischemia, even in healthy patients, has been observed after pneumoperitoneum and is another potential mechanism of postoperative pain. In the gynecological literature, it has been noted that the type of intra-abdominal procedure can influence the degree of postoperative pain. For example, patients tend to experience more pain after laparoscopic sterilization compared to diagnostic laparoscopy, despite the duration of the tubal ligation procedure being shorter. The method of sterilization used also affects pain levels. It remains uncertain whether similar differences in pain exist between different general surgical operations. Therefore, the origin of pain after laparoscopic cholecystectomy is multifactorial, involving pain from the incision sites, the presence of pneumoperitoneum, and the cholecystectomy itself **(Umano et al., 2021).**

- **Risk factors for post operative pain after Laparoscopic Cholecystectomy**

Postoperative pain following laparoscopic cholecystectomy can be influenced by various risk factors

1. ***Surgical factors*** play a role, with longer durations of the surgical procedure often associated with increased postoperative pain.

The volume and pressure of gas used for pneumoperitoneum, as well as the type of gas employed, can also impact pain levels. Higher gas volumes, elevated pressure, and certain gas types, such as carbon dioxide, have been linked to greater postoperative pain **(Han et al., 2020)**.

The rate of insufflation of carbon dioxide has been found to influence the incidence of shoulder tip pain, with lower rates of insufflation resulting in lower rates of pain **(Nikoubakht et al., 2022).**

The volume of residual gas left in the abdomen after surgery has been found to correlate with postoperative pain.

Bile spillage during laparoscopic cholecystectomy has been associated with faster resolution of the pneumoperitoneum, possibly due to subsequent lavage and displacement of carbon dioxide. However, bile spillage itself does not lead to increased pain or slower postoperative recovery. It is also important to standardize certain variables, such as the use of suxamethonium for anesthesia induction, due to its potential side effect of muscle pain **(Khan et al., 2012).**

2. ***Patient-related factors*** are another consideration. Preoperative inflammation, particularly in cases of acute cholecystitis, may sensitize the central nervous system, resulting in heightened postoperative pain. Female patients, in some studies, have shown a tendency to experience higher levels of pain after laparoscopic cholecystectomy compared to males. Age also plays a role, with advanced age identified as a risk factor for increased postoperative pain. Older patients may exhibit reduced pain tolerance and diminished physiological reserve, contributing to higher pain levels **(Panda et al., 2020)**.

Body mass index (BMI) is an additional risk factor. Higher BMI has been associated with increased postoperative pain, potentially due to factors such as increased tissue trauma during surgery, challenges in establishing pneumoperitoneum, and extended surgical duration.

Moreover, Psychological factors should not be overlooked. Anxiety, depression, and catastrophizing tendencies can influence pain perception, potentially leading to higher levels of postoperative pain **(Sato et al., 2020).**

- **Prevention and management of postoperative pain in laparoscopic cholecystectomy:**

Recovery after Laparoscopic Cholecystectomy (LC) is usually rapid and most patients may be discharged from hospital the same day or the next day. However, although LC results in substantially less severe discomfort compared with the open surgery, postoperative pain (POP) can still be considerable. Pain can result in increased postoperative morbidity and delayed hospital discharge, issues that have health economic implications as LC can often be performed on a day surgery setting **(Ergin et al., 2021; Yilmaz et al., 2013).**

A crucial aspect of Enhanced Recovery After Surgery (ERAS) protocols is preoperative optimization, which prepares patients physically and nutritionally before surgery. Ensuring proper nutrition, hydration, and minimizing fasting can help mitigate the stress response and reduce postoperative pain. Techniques like carbohydrate loading contribute to improved patient comfort and lower pain levels after laparoscopic cholecystectomy **(Kalogera et al., 2019).**

Implementing preoperative pain management strategies can significantly impact postoperative pain levels following laparoscopic cholecystectomy. For instance, preemptive analgesia involves giving pain relief medications before surgery to prevent or lessen pain development. Research indicates that administering NSAIDs or acetaminophen before surgery can effectively reduce postoperative pain and minimize the requirement for intraoperative and postoperative opioids **(Barazanchi et al., 2018).**

Effective intraoperative pain control is key to minimizing postoperative pain following laparoscopic cholecystectomy. Techniques such as administering local anesthesia at the surgical site or employing regional anesthesia methods, such as the transversus abdominis plane (TAP) block, Erector spinae plane block, Rectus sheath abdominal plane block, Quadratus lumborum block, Paravertebral block and External Oblique Intercostal Plane (EOIP) Block can significantly alleviate postoperative discomfort. By interrupting pain pathways during the surgery, these methods contribute to reduced pain postoperatively and lower the dependence on systemic pain medications **(Grape et al., 2021).**

Continuous infusion analgesia, including methods like continuous epidural or intrathecal analgesia, provides ongoing pain relief after laparoscopic cholecystectomy. These techniques deliver a steady stream of analgesics, ensuring consistent pain management and lowering pain levels during the recovery period. Continuous infusion is especially advantageous for patients experiencing moderate to severe pain **(Bourgeois et al., 2024).**

Patient-controlled analgesia (PCA) offers a tailored method for managing postoperative pain following laparoscopic cholecystectomy. By allowing patients to self-administer pain relief within defined limits, PCA enhances personal control over pain management. Research indicates that PCA can decrease the overall opioid consumption and provide more effective pain relief, leading to higher patient satisfaction **(Kim & Lee, 2024).**

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