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Application of Different Nerve Blocks under Ultrasound Guidance in Laparoscopic Cholecystectomy

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Abstract: Laparoscopic cholecystectomy is considered to be the gold standard for the treatment of cholecystolithiasis because of its advantages of less trauma and faster postoperative recovery, but intraoperative stress and postoperative pain still affect patients. Most patients are reluctant to get out of bed early after surgery due to pain, which is not conducive to patients' recovery. At present, ultrasound-guided regional nerve block techniques are gradually mature and applied to laparoscopic cholecystectomy, such as thoracic paravertebral nerve block (TPVB) and erector spinae plane block (ESPB) which have been widely used in clinic in recent years, can be combined with general anesthesia in laparoscopic cholecystectomy to reduce the pain caused by cholecystectomy. Although there are few reports on costotransverse block (CTB),which has been newly proposed in recent years, our team found that it may have greater advantages in cholecystectomy through anatomical observation. This article analyzes the research progress on TPVB, ESPB,and CTB in recent years, and explores the advantages and disadvantages of three different nerve block techniques under ultrasound guidance in laparoscopic cholecystectomy.

Keywords: laparoscopic cholecystectomy; thoracic paravertebral nerve block; erector spinae plane block;costotransverse block

Laparoscopic cholecystectomy is currently a widely used laparoscopic surgery[1], which avoids the disadvantages of traditional open cholecystectomy such as large incision, severe pain, and easy bleeding. It has the advantages of minimal trauma, mild stress response, easy postoperative recovery, and minimal scar formation. It has become the preferred surgical treatment for cholecystectomy. After laparoscopic cholecystectomy, patients often experience visceral pain caused by pneumoperitoneum and intra-abdominal trauma, right shoulder involvement pain, and local pain caused by abdominal wall incisions, resulting in pain peaks around 3 hours after surgery. Within 24 hours after surgery, approximately 65% of patients experience moderate pain, and 23% experience severe pain. If the postoperative analgesic effect is not ideal, it is not conducive to the patient's physical and mental recovery after surgery, while nerve block methods such as thoracic paravertebral block can achieve good analgesic effects.

Ultrasound has the advantages of real-time, dynamic, non-invasive, and non radioactive; Especially in recent years, with the continuous development of ultrasound diagnostic equipment and the improvement of ultrasound imaging technology, it has been widely used in clinical practice, providing reliable visualization services for anesthesiologists' "precise anesthesia". At present, ultrasound has been widely used in anesthesia and perioperative treatment, and ultrasound visualization guidance technology provides reliable anatomical basis for the revival of peripheral nerve block and the rise of fascial level block, gradually replacing traditional epidural block technology. More and more regional nerve block technologies are being applied in perioperative analgesia, which can improve effectiveness and safety while reducing the damage caused by puncture to the patient's body. Among them, ultrasound-guided thoracic paravertebral nerve block (TPVB) has long been applied in cholecystectomy and other surgical procedures, but due to its

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proximity to the pleura, spinal canal, and nerve axis, the operation is difficult and requires high technical requirements from anesthesiologists; However, erector spinae plane block (ESPB) and costotransverse block (CTB) are newly emerged nerve block techniques in recent years, with different advantages and disadvantages. This article will discuss the research progress of the three anesthesia block techniques mentioned above, and explore and analyze their advantages and disadvantages in the application of cholecystectomy.

1 TPVB

TPVB was first documented in 1905 and introduced by Eason and Wyatt in 1978 for clinical anesthesia treatment in areas such as the chest, abdomen, and pelvis. Previously, due to blind probing, TPVB had a high risk and difficulty factor, with an overall failure rate of up to 10%. However, with the emergence of ultrasound imaging technology, its safety, success rate, and analgesic effect have all significantly improved. In recent years, ultrasound-guided TPVB has been widely used in surgical treatment of different diseases, gradually replacing the "gold standard" epidural block.

From an anatomical perspective, the thoracic paravertebral space is a wedge-shaped area formed by the "closure" between the rib head and the rib neck. It is approximately triangular in cross-section, with the rib transverse process ligament forming the posterior wall of the space, the parietal pleura and diaphragm forming its anterior lateral wall, and the vertebral body, intervertebral foramen, and intervertebral disc collectively forming its medial wall. The paraspinal space is connected to the epidural space, intercostal space, and adjacent segmental paraspinal spaces, encompassing the intercostal nerves, posterior branches of the spinal nerves, intercostal blood vessels, sympathetic nerve communicating branches, and sympathetic nerve chains. The target of thoracic paravertebral nerve block is located at the starting point of the posterior branches of the spinal nerves, so the anterior and posterior branches of the paraspinal nerves can be blocked simultaneously; In addition, according to the injection of methylene blue on the corpse, there are potential "channels" between the paraspinal spaces of each segment and the adjacent paraspinal spaces above and below. Adequate doses of local anesthetic injection can not only block the corresponding level of paraspinal nerves, but also spread to adjacent intercostal spaces, paraspinal spaces, and epidural spaces to exert blocking effects.

TPVB has many advantages. The wedge-shaped space next to the thoracic spine contains spinal nerves, sympathetic nerves, etc., which can block the anterior and posterior branches, communicating branches, and sympathetic chain of one side of the spinal nerves. The block plane is wide, and the use of anesthetic drugs is reduced, producing good analgesic effects while also reducing perioperative stress reactions. Currently, ultrasound-guided TPVB is mostly used in chest surgery, and it is also widely used in cholecystectomy. In the clinical application of thoracic paravertebral space block technique, the puncture needle needs to pierce the ligament above the transverse process of the rib, and local anesthetics can be injected into the bloodless and cerebrospinal fluid to produce the corresponding block effect. However, in practical operation, incomplete blockage may occur when the needle is inserted too shallowly, and there is a risk of vascular and nerve damage when the needle is inserted too deeply, even leading to pneumothorax. The success rate of paravertebral nerve block is highly correlated with the operator's experience. Although ultrasound visualization has significantly reduced the overall incidence of adverse reactions in paravertebral nerve block in recent years, hypotension is the most common adverse reaction, followed by vascular injury, pleural injury, and pneumothorax.

Due to the risks associated with the application of TPVB in cholecystectomy, there is an urgent need to find a more reliable alternative to improve patient comfort and safety after surgery.

2 ESPB

Ultrasound guided ESPB was first proposed by Forero et al. in 2016 and applied in the treatment of cancer pain patients. Currently, it is also used for severe chest and back neuropathic pain, and its analgesic effect is definite.

The erector spinae muscle is located deep on both sides of the spine, starting from the back of the sacrum and reaching behind the occipital bone, filling the deep groove between the spinous process and the rib angle. It covers a wide range from the sacrum to the occipital bone, and the blocking site is located below the erector spinae muscle. Local anesthetics are injected into the fascial plane (the fascia between the deep surface of the erector spinae muscle and the transverse process of the vertebral body) to produce anesthetic effects. This technique has been successfully applied in the treatment of severe acute postoperative pain and neuropathic pain.

The mechanism of action of ESPB under ultrasound guidance is currently not fully understood. Ivanusic et al. simulated clinical ESPB by applying toluene blue injection staining on cadavers, and conducted research on cadaver anatomy to explore the possible mechanism of ESPB's action. Research has found that there is extensive staining in the deep and shallow layers of the erector spinae muscle at the craniocaudal and medial lateral sides. However, no dye was found to spread to the ventral and dorsal branches of the

thoracic spinal nerve in front of the paraspinal space, and diffusion through the intercostal foramen was observed in the dorsal branch. According to anatomical confirmation, the thoracic spinal nerve divides into dorsal and ventral branches at the exit of the intervertebral foramen, with the dorsal branch branching out from the transverse process of the rib and running backwards and upwards to innervate the erector spinae muscle. It is further divided into lateral and intermediate branches, with the intermediate branch mainly innervating the rhombus and trapezius muscles, ultimately branching out into the posterior cutaneous branch. The ventral branch runs on the outer side to form intercostal nerves, which penetrate deep into the intercostal membrane and then pass between the intercostal muscles and the intercostal muscles. The intercostal nerve is divided into lateral cutaneous branches near the rib angle, mainly innervating the surface skin. It is further divided into anterior and posterior branches near the midaxillary line, mainly innervating the lateral chest wall. The anterior chest wall and upper abdominal skin are finally innervated by the branched anterior cutaneous branch, and the intercostal nerve ultimately branches into muscular branches, mainly innervating the intercostal muscles. ESPB can fully cover the course of the dorsal and ventral branches of the thoracic spinal nerve. After injection into the erector spinae muscle plane on fresh cadavers, CT scan results fully demonstrate this. Moreover, ESPB is a fascial block technique, in which the entire body is covered by fascia. The deep fascia is composed of multiple layers of structures, forming nerve and vascular sheaths that wrap around different organs. It also has branches of the spinal nerve and sympathetic nervous system, and contains mechanical stimuli and pain receptors. The deep fascial space, as a blocking target, is essentially a potential and continuous space. When local anesthetics are injected into these potential spaces, they can spread in the direction of lower resistance, which is the essence of fascial space blocking. As a newly defined fascial plane block, ESPB has been used to treat acute and chronic pain, and studies have shown that it is effective for all pain caused during cholecystectomy.

The ultrasound images of the thoracic transverse process and muscle space guided by ESPB are easy to identify and can directly locate the target nerve. Its anatomical positioning is clear, which can ensure the accuracy of local anesthetic diffusion around the target nerve during block. The operation is relatively simple, and continuous block can be generated by placing a catheter, with a low failure rate; At the same time, due to the absence of important blood vessels, nerves, and other organs at the injection target site, the risk of hematoma, nerve and spinal cord injury, and pneumothorax in ESPB guided by ultrasound is relatively low, with low requirements for coagulation function, low incidence of complications, and relatively safe operation. However, ESPB mainly relies on the diffusion of local anesthetics to produce related effects, with high requirements for the dosage of local anesthetics, requiring a longer time to take effect, and there is a certain degree of variability in the range, duration, and intensity of analgesia.

3 CTB

CTB is a newly discovered ultrasound-guided technique in recent years, also known as transverse process pleural midpoint block. In the past, the key to the success of ultrasound-guided TPVB operation was whether local anesthetics could be injected through the ligament above the transverse process of the rib. However, Costache proposed a different viewpoint. They injected dye methylene blue superficially into the ligament above the transverse process of the rib on an uncorroded corpse and found that the dye leaked from the posterior edge of the transverse process and the midpoint of the pleura of the corpse and at least spread to the paraspinal space. This indicates that the ligament above the transverse process of the rib is not a barrier to drug diffusion, that is, the paraspinal space is not a truly closed anatomical room [36], and some people have proposed that the ligament above the transverse process of the rib is a new fascial plane block. Target. Cho et al. used a microscope to discover that the thoracic paravertebral space is a very narrow space, and the posterior intercostal vessels are very close to the pleura. The ligament on the transverse process of the rib has not completely formed the closure of the posterior wall of the thoracic paravertebral space. Shallow injection of the ligament on the transverse process of the rib can spread to the thoracic paravertebral space, but all of this still needs further clinical verification.

As a new technology, CTB has achieved good postoperative analgesic effects in multiple reports. Compared with other nerve block methods, CTB has the advantages of clear positioning and simple operation. Its anatomical points are clear: adjacent transverse processes and ribs are its upper and lower boundaries, the pleural wall layer is its inner surface, and the inner surface of the erector spinae muscle forms its posterior part. The injection target is located at the midpoint of the line connecting the adjacent transverse processes and the midpoint of the line connecting the parietal pleura and erector spinae muscle. After local anesthetic injection, it spreads through the transverse processes and pleura to the paraspinal space, and finally spreads horizontally and vertically to the gaps in the middle and outer sides of the rib transverse process ligament, producing a

blocking effect on the intercostal nerves, posterior branches of the spinal nerves, and sympathetic ganglia, which is the same as the effect of thoracic paravertebral block. At the same time, local anesthetic drugs can diffuse deep into the erector spinae muscle through the intercostal muscles and intercostal spaces, blocking the intercostal nerves and producing effects similar to intercostal nerve block and erector spinae muscle block. CTB operation is simple: compared with TPVB, it does not require breaking through the transverse process ligament to inject drugs into the paraspinal space; The needle insertion point of CTB is the midpoint of the transverse process and pleura. As a shallow block, it can quickly and easily feel the surface position, even if the ligament on the transverse process is not visible, it can achieve effective blockade, and the time of CTB is significantly shortened compared to TPVB. In addition, place the needle away from the pleura to minimize the incidence of pneumothorax. Even patients with affected posture or obesity can easily undergo CTB, which can reduce the risk of anesthesia.

In summary, CTB is a safe and novel paravertebral block technique that can alleviate pain and stress reactions in patients undergoing laparoscopic cholecystectomy during and after surgery, reduce the use of opioid drugs during the perioperative period, minimize interference with the patient's nervous and endocrine systems, and promote rapid recovery.

4 Conclusion

The concept of rapid rehabilitation has been proposed in recent years to reduce the harmful pain to patients and improve their comfort. Laparoscopic cholecystectomy is the preferred surgical treatment for cholecystitis and gallstones. Physical pain and visceral pain are the main causes of intraoperative and postoperative pain in patients. Postoperative pain is still common, and traditional pain management methods are plagued by the increase of analgesic drugs and the occurrence of side effects. With the higher demand for comfortable medical care from patients, the treatment of pain is still a long way to go, and it is extremely important to pay attention to perioperative pain management.

In summary, with the development of ultrasound technology, although paraspinal nerve technology has been widely used in clinical practice, its puncture is close to blood vessels, pleura, and nerves, making it difficult to operate and easily leading to pneumothorax and vascular and nerve damage, which requires high operational requirements for anesthesiologists. In recent years, emerging technologies such as ESPB and CTB have avoided these risks, but ESPB must rely on high-dose local anesthetic diffusion, block the onset time for a long time, and the range, duration, and intensity of analgesia have certain variability. As a new technology, many clinical reports have shown that CTB has achieved good analgesic effects in the perioperative period of various diseases. According to its operation method, it is likely to have better effects in cholecystectomy. Therefore, the author will observe and experiment in clinical practice to explore the effects of ultrasound-guided TPVB, ESPB, and CTB on stress response and rapid recovery of patients undergoing laparoscopic cholecystectomy.

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Reference:

[1] Edebo A ,Andersson J ,Gustavsson J , et al.Benefits and risks of using laparoscopic ultrasonography versus intraoperative cholangiography during laparoscopic cholecystectomy for gallstone disease: a systematic review and meta-analysis.[J].Surgical endoscopy,2024,(prepubulish):1-12.

[2] Pil J Y ,Young H K ,Jieun J , et al.Analgesic effect of ultrasound-guided transversus abdominis plane block with or without rectus sheath block in laparoscopic cholecystectomy: a randomized, controlled trial[J].BMC Anesthesiology,2024,24(1):203-203.

[3] Jain K ,Goyal D .Comparative Analysis of Monopolar Electrocautery and Ultrasonic Activated Scalpel in Laparoscopic Cholecystectomy: A Comprehensive Evaluation Using Clinical, Laboratory, and Imaging Techniques.[J].Cureus,2024,16(6):e61925.

[4] Park S ,Park H J ,Park S , et al.Ultrasound-guided subcostal approach of transversus abdominis plane block compared with wound infiltration for postoperative analgesia following laparoscopic cholecystectomy: A systematic review and meta-analysis.[J].Medicine,2024,103(18):e38044-e38044.

[5] Badawy A ,Samer B ,Sabra T .Analysis of the sonographic predictors of difficult laparoscopic cholecystectomy in symptomatic cholelithiasis.[J].Asian journal of endoscopic surgery,2024,17(2):e13300-e13300.

[6] Aly S M ,Jamal Z ,Khawaja Z , et al.Outcomes of Percutaneous Image-Guided and Laparoscopic Cholecystostomies in High-Risk Patients With Acute Calculus Cholecystitis: A Five-Year District General Hospital Experience.[J].Cureus,2024,16(2):e54313-e54313.

[7] Khan A ,Khan G ,Khan S , et al.Double Cystic Ducts Encountered During Laparoscopic Cholecystectomy in a Male Patient With Cholelithiasis: A Case Report.[J].Cureus,2024,16(2):e54814-e54814.

[8] Marco P ,Caterina B ,Carlo A , et al.Extrahepatic abscess and dropped gallstones: a case report and a narrative review of an unusual delayed complication of laparoscopic cholecystectomy[J].Acta Chirurgica Belgica,2024,124(1):57-61.

[9] Martín F T M ,Álvarez L S ,Vilches V F L .Comment on: "Ultrasound-guided external oblique and rectus abdominis plane "EXORA" block for postoperative pain after laparoscopic cholecystectomy: a propensity-matched study".[J].Minerva anestesiologica,2024.

[10] Khan B H ,Ali A ,Zahid J M , et al.Validating an Ultrasonographical Assessment Tool for Predicting Difficult Laparoscopic Cholecystectomy in a Tertiary Care Hospital.[J].Cureus,2024,16(1):e52048-e52048.

[11] Uzunay T N ,Mingir T ,Erginoz E , et al.Comparison of laparoscopic-guided versus ultrasound-guided TAP block in laparoscopic cholecystectomy.[J].Cirugia y cirujanos,2024,92(2):174-180.

[12] Magdy M M ,Ezzat E A ,Mohamed A F , et al.Comparison of analgesic efficacy of ultrasound-guided erector spinae block with port site infiltration following laparoscopic cholecystectomy[J].Egyptian Journal of Anaesthesia,2023,39(1):528-537.

[13] Qingyun X ,Manyu Y ,Kangyi J , et al.Laparoscopic cholecystectomy assisted by combined intravenous and intracholecystic fluorescent cholangiography: a case report.[J].The Journal of international medical research,2023,51(12):30006..