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Review

Postoperative Pain Management Procedures in Laparoscopic Gynecological Surgery: A Systematic Review

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Abstract: *Rationale* — Pain management (PM) is a critical parameter for achieving satisfactory surgical outcomes. Despite numerous studies on PM, no comprehensive study on postoperative PM in laparoscopic gynecological (LG) surgeries has been found. Consequently, the goal of this systematic review was to collect information on the procedures used for postoperative PM in invasive LG interventions.
Methods — MeSH keywords ("*postoperative*", "*postoperation*", "*postsurgery*", "*pain management*", "*pain control*", "*analgesia*", "*laparoscopy*", "*gynaecology*", and "*gynecology*") were identified for the systematic review in validated medical databases (WoS, PubMed, Scopus, ScienceDirect, and Embase). The collected articles were included in the primary and secondary screening according to the 2020 PRISMA guidelines. Articles of medium and high quality were finally selected based on the STROBE checklist, and the relevant articles were summarized and classified as a systematic review.
Results — A total of 421 articles were found in the initial search. Then, after excluding duplicates (n=182), 108 and 80 irrelevant articles were also excluded (primary and secondary screening, respectively); 22 low-quality studies were also ignored. Hence, 29 relevant high-quality articles were selected for data extraction and synthesis. All applicable PM procedures in LG surgeries were categorized into four major approaches: pharmacological, non-pharmacological, psychological, and gas management methods.
Conclusion — Since intraperitoneal organs are manipulated during LG surgeries, the use of intraperitoneal analgesia along with gas management and patient positioning are the main noninvasive pain management protocols.

Keywords: postoperative, pain management, analgesia, laparoscopy, gynecology, surgery, systematic review.

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Introduction

Laparoscopic gynecological (LG) surgeries are minimally invasive techniques characterized by small incisions and the use of laparoscopic equipment to perform a variety of intrapelvic procedures. Laparoscopy is used for both diagnostic and operative purposes [1]. The advantages of laparoscopic surgery include reduced postoperative pain, shorter hospital stay, reduced risk of infection, and shorter recovery time, allowing patients to return to their normal activities within 2–6 weeks after surgery [2]. Effective PM significantly impacts the overall outcomes of the surgery. Proper postoperative analgesia improves patient satisfaction by reducing the risk of complications such as pneumonia and blood clots [3]. In addition, patients are more likely to engage in physical activities necessary for recovery, such as walking and deep breathing. Postoperative PM is important in LG surgeries because of its potential significant impact on recovery and patient satisfaction [4]. By using multimodal approaches, opioid consumption and associated side effects are significantly minimized, resulting in better recovery [5].

Due to the various common postoperative PM procedures in LG surgeries, no comprehensive systematic review has been conducted on this topic. Furthermore, there is no consensus on the optimal postoperative PM procedures in LG surgeries. Therefore, the authors of this study aimed to collect all commonly used postoperative PM procedures in LG surgeries, paying special attention to the limitations and benefits of the study.

Methods

Search question and strategy

This systematic review was designed to obtain comprehensive information on the available procedures for postoperative PM in LG surgery. For the search strategy, relevant keywords were identified using Medical Subject Headings (MeSH) terms including "*postoperative*", "*postoperation*", "*postsurgery*", "*pain management*", "*pain control*", "*analgesia*", "*laparoscopy*", "*gynaecology*", and "*gynecology*". The search strategy was developed as follows: ("*postoperative*" OR "*postoperation*" OR "*postsurgery*") AND ("*pain management*" OR "*pain control*" OR "*analgesia*") AND ("*laparoscopy*") AND ("*gynaecology*" OR "*gynecology*"). The search process was applied to valid English language databases including PubMed, Scopus, WoS, ScienceDirect, and Embase. Finally, the Google Scholar search engine and references of all included articles were manually checked to achieve the maximum number of eligible studies. There

was no time limit, and all relevant articles were included by December 9, 2024.

Inclusion and exclusion criteria

All studies focusing on the process of postoperative PM after LG surgeries were included for data extraction. All included articles were written in English, while articles in other languages were excluded. Cross-sectional, cohort, and case-control studies were included in our systematic review, while reviews, case reports, case series, and animal studies were excluded from the study.

Article screening

After selecting articles, all citations were imported into EndNote citation management software (x8, USA). Duplicate articles were detected and merged. Then, the titles and abstracts of the remaining articles were assessed according to the inclusion and exclusion criteria (primary screening). In the secondary screening, the full texts of the articles were assessed based on the inclusion/exclusion criteria. All selection steps were performed by two independent investigators (ZV and SNH), and the corresponding author (SAZJ) was responsible for resolving any potential conflicts or disagreements. All article screening processes were conducted according to the PRISMA 2020 flow chart guidelines (*Figure 1*) [6].

Article quality control

We used the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist to assess the quality of the studies according to 6 main scales and 32 different subgroups. The STROBE score ranges from 0 to 32 pts, and articles were classified as low-quality (0 to 15 pts) and moderate- or high-quality (16 to 32 pts). The latter category (STROBE score ≥ 16 pts) was fully included in this review [7].

Data extraction and categorization

After selecting the eligible articles, various data were extracted, including "*pain relief methods*", "*intervention procedures*", "*mechanism of action*", "*efficacy of analgesic procedure*", and "*clinical considerations*". The full texts were then assessed and procedures were classified into main headings and subheadings as follows in the *Results* section.

Results

After evaluating the selected articles, 421 primary articles were chosen. Using EndNote software, 182 duplicate articles were identified and merged; 108 and 80 irrelevant studies were also excluded during the primary and secondary screening, respectively. Then, 22 low-quality studies were excluded. Finally, 29 relevant high-quality articles were selected for data extraction and summarization (*Figure 1*). The collected data were categorized into four major approaches: pharmacological and surgical, non-pharmacological, psychological/spiritual approaches, and gas management techniques. In addition, the applicable methods were summarized and categorized in *Supplement 1* and 2.

Pharmacological approaches

Multimodal analgesia (MMA). MMA is a comprehensive PM strategy that uses a combination of different pharmacological agents to achieve effective analgesia and reduce the need for opioids [8]. Associated subgroups of MMA include opioids, nonsteroidal anti-inflammatory drugs (NSAIDs), acetaminophen, and adjuvant medications (such as gabapentinoids, ketamine, and alpha-2-adrenergic receptor agonists) [9]. One of the primary goals of MMA is to reduce opioid dependence, thereby reducing the risk of opioid-related adverse effects such as respiratory depression, tolerance, and addiction [10].

Local anesthetic infiltration (LAI). The LAI technique involves the administration of local anesthetics (such as bupivacaine or ropivacaine) directly into the surgical site. Studies have shown that LAI is effective in reducing postoperative pain during the first hours after surgery [11]. There are several approved and applicable subgroups of LAI including port site infiltration (PSI), subdiaphragmatic infiltration (SDI), continuous wound infiltration (CWI), incisional blocks, transverse abdominis plane (TAP) blocks, and intraperitoneal anesthesia technique.

PSI involves the injection of local anesthetics into the port sites of laparoscopic procedures targeting the nerve endings. Thus, analgesia is induced immediately during the first 12–24 hours after surgery [12].

In SDI, local anesthetic is infiltrated into the subdiaphragmatic space to relieve referred shoulder pain, which often occurs due to diaphragmatic irritation during LG surgeries [13].

CWI technique is a continuous delivery of local anesthetics through catheters placed in surgical wounds. This type of technique provides prolonged analgesia in various laparoscopic surgical procedures [14].

Incisional blocks involve injection of local anesthetics directly into the surgical incision site. Incisional blocks are effective in reducing pain only at the surgical site for a short period of time [15].

TAP blocks, as a method of regional anesthesia, are known as injection of local anesthetic into the abdominal wall to block the nerves of the anterior and lateral abdominal walls, along with the parietal layer of the peritoneum, and reduce pain in the postoperative period [16].

Intraperitoneal administration of local anesthetics is an innovative approach in postoperative PM, especially after LG surgeries. This technique involves delivery of local anesthetics directly into the peritoneal cavity, which can effectively combat visceral pain associated with surgical procedures [17].

Intravenous lidocaine infusions. Intravenous lidocaine infusions are increasingly recognized as an effective treatment for postoperative pain [18]. This technique involves the administration of lidocaine through an intravenous catheter during and after surgical procedures to enhance analgesia and improve recovery outcomes [19].

Low-dose opioid spinal anesthesia. Low-dose opioid spinal anesthesia is a technique used for postoperative PM that combines a local anesthetic, usually bupivacaine, with a small dose of an opioid such as fentanyl or morphine administered intrathecally. This approach aims to provide effective analgesia while minimizing the side effects typically associated with higher doses of local anesthetics and opioids [20].

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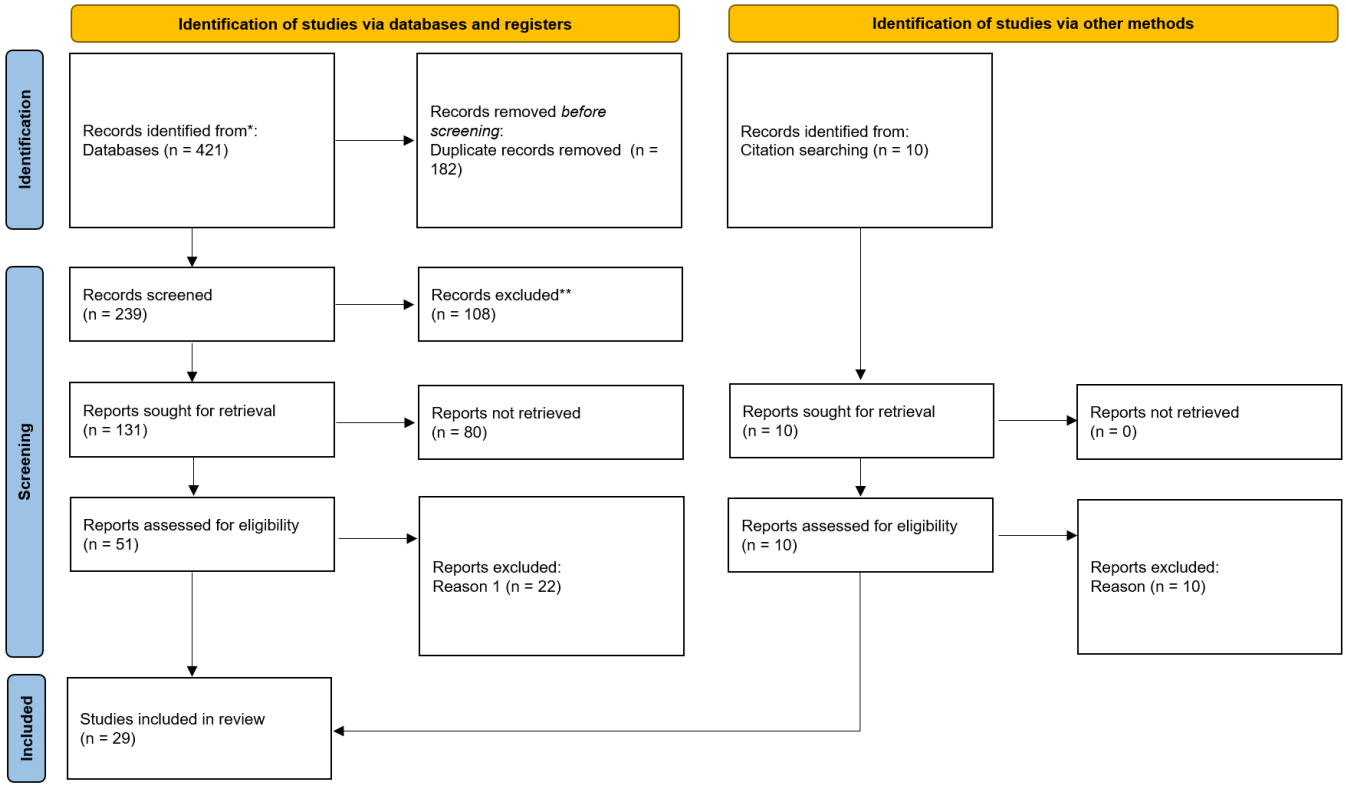

Figure 1. PRISMA 2020 flow chart for new systematic reviews depicting searches of databases, registers, and other sources.

Dexamethasone administration. Dexamethasone injection refers to the use of dexamethasone, a potent corticosteroid, in the perioperative period to relieve postoperative pain and reduce inflammation. This drug is often administered as a single intravenous injection before, during, or after surgery [21]. Its role in postoperative PM is increasingly recognized due to its anti-inflammatory properties and potential analgesic effect. Studies show that dexamethasone can significantly reduce postoperative pain levels, especially in the first 24 hours after surgery [22]. It has been shown to reduce pain perception and opioid requirements in a variety of surgical procedures, including laparoscopic and abdominal surgeries [23].

Patient-controlled analgesia (PCA). PCA is a PM technique that allows patients to self-administer pain relief, usually following surgery. This method allows for controlled delivery of pain medication using a computerized pump connected to an intravenous line [24]. The PCA pump is pre-programmed by health care professionals to deliver a specific dose of pain medication, usually an opioid such as morphine, hydromorphone, or fentanyl. Patients can self-administer additional doses by pressing a button when pain occurs, allowing for immediate relief without nursing intervention [25].

Non-pharmacological approaches

Non-pharmacological approaches to postoperative PM after LG surgeries include various methods aimed at relieving pain without the use of drugs [26]. These methods are categorized as described below.

Passive physical therapy. These procedures refer to therapeutic interventions that are performed without the need for active participation of the patient. (1) In heat/cold therapy, reducing inflammation, improving blood flow, numbing the affected area and muscle relaxation can ultimately lead to postoperative PM [27]. (2) Acupuncture involves inserting a thin needle into specific dermal points to relieve pain [28]. (3) Transcutaneous electrical nerve stimulation (TENS) is a device that uses electrical impulses to relieve pain [29]. (4) Massage therapy involves manual manipulation of soft tissues to relieve tension and improve blood circulation, which helps in suppressing pain [30].

Physical activity. Physical activity plays a vital role in pain relief and recovery by promoting healing, improving mobility, and improving overall physical function. Postoperative physical therapy can significantly reduce pain associated with stiffness and muscle weakness. Gentle walking combined with deep breathing techniques improves circulation and reduces stiffness, which is necessary for pain relief [31].

Psychological/spiritual approaches

Psychological and spiritual approaches play a significant and effective role in postoperative PM by addressing the emotional and mental aspects of pain perception and recovery. These approaches can improve patient outcomes by reducing anxiety, improving pain coping mechanisms, and developing a sense of control over pain [26].

Cognitive behavioral therapy (CBT). CBT is a widely used technique that helps patients reframe their thoughts about pain and surgery and promotes more adaptive coping strategies. Research has shown that CBT can reduce pain intensity and disability in postoperative patients by addressing negative beliefs and encouraging positive recovery-related behaviors [32].

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Psychoeducation. Providing patients with accurate information about expectations during the recovery period can be effective in reducing preoperative anxiety and postoperative pain. Teaching patients PM strategies can potentially help them feel more confident and less fearful of the surgical process [33].

Meditation and relaxation techniques. Techniques such as guided imagery, deep breathing exercises, and progressive muscle relaxation can reduce anxiety and stress. By promoting relaxation, these techniques can increase pain tolerance and improve overall recovery [34].

Distraction techniques. Using music therapy, talking, or other forms of distraction can help take attention away from pain, thereby reducing its perception [35].

Gas management techniques

Management of gas insufflated into the peritoneal cavity is a critical factor in the occurrence of postoperative pain. In this process, carbon dioxide (CO_2) is insufflated into the abdominal cavity, creating a working space for the surgeon [36]. However, residual CO_2 can lead to significant discomfort and pain postoperatively, often manifested as shoulder pain or abdominal distension due to irritation of the diaphragm and surrounding tissues. Several strategies have been used to alleviate gas-related pain, such as lower insufflation pressures (8 vs. 14 mmHg), aspiration of residual gas present in the peritoneal cavity, and patient positioning (encouraging patients to change positions frequently during the postoperative period) [37].

Discussion

Despite the published studies on postoperative PM, there is no systematic study on PM in LG surgeries. That is why we conducted this systematic review that summarized the published data on relevant PM procedures in LG surgeries. Effective postoperative PM is crucial in LG surgeries to speed up recovery, reduce complications, and improve patient satisfaction.

MMA has become the mainstay of postoperative analgesia in LG surgeries. Geng et al. demonstrated that the implementation of an MMA-based enhanced recovery protocol significantly improved the quality of recovery and reduced opioid consumption in patients undergoing laparoscopic procedures. This approach combines various analgesic methods, including NSAIDs, acetaminophen, and regional anesthesia techniques, to provide comprehensive analgesia and minimize the adverse effects of opioid use [10]. Among regional techniques, TPA block has demonstrated significant efficacy. Anusha et al. conducted a randomized clinical trial comparing TAP blocks with local infiltration at the port site. They found that TAP blocks provided superior postoperative analgesia [12]. Similarly, Saccardi et al reported that peri-incisional and intraperitoneal ropivacaine significantly reduced pain scores after laparoscopic surgery [15]. These results highlight the importance of regional anesthesia in improving postoperative PM [38]. Kang et al. investigated the efficacy of continuous wound infiltration systems for postoperative PM in gynecologic patients undergoing single-port laparoscopy. Their study showed that continuous infusion could significantly reduce pain scores compared with traditional methods, suggesting that continuous delivery of local anesthetic may provide prolonged analgesia and improve patient comfort [14]. When comparing studies of TAP blocks and other regional techniques, it is evident that although TAP blocks are effective, their success may vary depending on technique and patient-related factors. For example, Ahmed and Bhattacharjee highlighted the benefits of combining port site infiltration with intraperitoneal bupivacaine irrigation, which also resulted in significant pain reduction after laparoscopic cholecystectomy [13]. In contrast, Zdravkovic and Kamenik focused on the opioid-sparing properties of combined spinal and general anesthesia compared with general anesthesia, demonstrating that multimodal strategies can effectively reduce opioid requirements while maintaining adequate analgesia [9].

Despite the advantages of these techniques, they may lead to complications. Regional anesthesia techniques such as TAP block may result in temporary nerve injury or hematoma formation at the injection site [39]. In addition, although multimodal analgesia reduces opioid consumption, patients may still experience side effects of NSAIDs or other adjuvant medications such as gastrointestinal discomfort or renal dysfunction [10]. It is critical for physicians to weigh these risks and benefits when developing individualized pain management plans.

Further research should focus on optimizing PM protocols through personalized medical approaches that take into account individual patient characteristics such as age, comorbidities, and pain sensitivity. Exploring the role of new analgesics and non-pharmacological interventions (e.g., acupuncture or transcutaneous electrical nerve stimulation) may further improve postoperative PM strategies. Furthermore, the integration of pain monitoring technologies via wearable devices can provide real-time data to dynamically adjust PM regimens. Despite advances in postoperative PM techniques, several limitations remain. Many studies have small sample sizes or do not provide long-term follow-up data on pain outcomes beyond the immediate postoperative period. In addition, variability across surgical techniques and patient populations can complicate comparisons across studies. The subjective nature of pain assessment also poses challenges: reliance on self-reported measures may introduce bias. Furthermore, although multimodal approaches are effective, their use may be inconsistent across institutions due to differences in physician training and resource availability. Standardization of evidence-based protocols will be critical to optimizing postoperative care in LG procedures.

Conclusion

Effective postoperative PM in LG surgeries requires an integrated approach including multimodal analgesic strategies and regional anesthesia techniques such as TAP blocks. The results showed that, along with pharmacological interventions, three key procedures can contribute to more effective PM in LG surgeries: the use of intraperitoneal analgesia, gas management, and postoperative patient positioning. Eliminating complications and side effects through careful monitoring and individualized treatment will improve recovery outcomes for patients undergoing these surgeries.

Author contributions

SAJ and ZV conceptualized and designed the study, supervised data collection, interpreted the results, and edited the manuscript. SAJ, AEJ, and SNH collected the data, prepared the tables, and wrote the methodology and results. All authors read and approved the final version of the manuscript.

Availability of data and materials

The datasets used and analyzed for this study are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare no conflicts of interest.

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Supplement 1. Pharmacological, non-pharmacological, psychological, and gas management as post-operative PM approaches.

Techniques	*Medical Interventional Procedure*	*Mechanism of action*	*Efficacy*	*Clinical Considerations*
MMA	Oral administration	Opioids: Provide analgesia by acting on central mu-opioid receptors. NSAIDs (flurbiprofen, celecoxib): Inhibit cyclooxygenase enzymes to reduce inflammation and pain. Acetaminophen: Acts centrally to lower pain perception without anti-inflammatory effects. Gabapentinoids (gabapentin): Modulate calcium channels to alleviate neuropathic pain.	– Reduces opioid consumption – Improves pain control within the first 24-48 hours post-surgery – Lower numeric pain scores in patients – ERAS times, such as earlier ambulation and bowel function return	– Individualized therapy is essential; effectiveness can vary based on patient factors such as age, comorbidities, and specific surgical procedures. – Monitoring for potential side effects from various medications is necessary, including gastrointestinal risks from NSAIDs or sedation from opioids. – Healthcare providers must be trained in implementing MMA strategies effectively to ensure safe practices. – Protocols should be adjusted based on patient responses to optimize outcomes.
PSI	Local anesthetics (bupivacaine) are injected into the trocar incision sites at the end of the surgery.	Local Anesthetic Effect: Bupivacaine works by blocking sodium channels in nerve fibers, leading to temporary loss of sensation. Targeted Pain Relief: The infiltration directly at the port site aims to reduce nociceptive pain resulting from incisional trauma while potentially minimizing central sensitization and other sources of postoperative pain (residual pneumoperitoneum).	– Pain Reduction: Significant reductions in postoperative pain scores and opioid consumption when local anesthetics are used at port sites. – Variable Outcomes: Other research suggests limited effectiveness due to factors like residual intra-abdominal trauma and central sensitization that may not be addressed by local infiltration alone.	– Individual Variability: The effectiveness of PSI can vary based on individual patient factors such as pain threshold, type of surgery performed, and presence of other pain sources. – Technique Standardization: Proper technique for injection depth and volume is crucial for achieving desired outcomes. – Monitoring for Complications: While generally safe, clinicians should monitor for potential adverse effects such as hematoma or infection at the injection site.
SDI	SDI involves administration of local anesthetics (lidocaine or ropivacaine) into subdiaphragmatic space to manage pain related to surgical trauma and CO2 insufflation.	Local Anesthetic Effect: The local anesthetic blocks nerve conduction in the area, reducing pain transmission from the diaphragm and surrounding structures. Reduction of Visceral Pain: By targeting the nerves supplying the diaphragm and upper abdominal organs, this technique aims to alleviate shoulder tip pain and visceral discomfort associated with laparoscopic procedures.	– Some trials indicate that SDI can reduce shoulder pain and overall postoperative pain scores. – A randomized clinical trial found no significant difference in postoperative pain scores between patients receiving subdiaphragmatic lidocaine and those receiving standard spinal anesthesia.	– Patient Selection: Not all patients may benefit equally; individual factors such as previous abdominal surgeries or comorbidities should be considered. – Technique Variability: The effectiveness may depend on the volume and concentration of the local anesthetic used, as well as the timing of administration (e.g., preoperative vs. intraoperative). – Monitoring for Side Effects: Potential risks include LAST at the injection site.
CWI	CWI involves the continuous infusion of local anesthetics (ropivacaine) directly into the surgical wound through a multi-holed catheter.	This technique provides localized analgesia by blocking nerve conduction at the site of surgery, reducing pain perception and inflammation.	– CWI reduces postoperative pain scores compared to traditional analgesic methods. – A meta-analysis found that CWI provides similar analgesia to epidural analgesia and patient-controlled intravenous analgesia within the first 48 hours after surgery, with lower opioid consumption and fewer side effects.	– Proper placement of the catheter is crucial for efficacy; it should be positioned close to the nerve pathways to ensure adequate analgesia. – The technique is generally safe but requires monitoring for potential complications such as infection or catheter dislodgment. – Individual patient factors (e.g., comorbidities) should be considered when implementing CWI as part of a MMA strategy.
Incisional Blocks	Local anesthetics (bupivacaine or ropivacaine) are injected into the incision site or surrounding tissues.	The anesthetic works by blocking sodium channels in nerve fibers, preventing the transmission of pain signals from the surgical site to the central nervous system.	– Incisional blocks lead to significant reductions in postoperative pain scores post-surgery (e.g., 6, 12, 24, and 48 hours) with less opioid medication for PM.	– Technique Proficiency: Proper technique is essential to avoid complications such as hematoma or infection at the injection site. – Patient Selection: Not all patients may be suitable candidates for incisional blocks; factors such as allergies to local anesthetics or specific medical conditions should be considered. – Monitoring for Side Effects: While generally safe, monitoring for potential adverse effects is necessary during and after administration.

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Techniques	*Medical Interventional Procedure*	*Mechanism of action*	*Efficacy*	*Clinical Considerations*
TAP blocks	TAP block involves the injection of local anesthetics (bupivacaine) into the transversus abdominis plane, targeting the nerves supplying anterior abdominal wall (T6-L1).	This technique blocks sensory nerve fibers, providing analgesia to the skin and muscles of the abdominal wall, thus reducing pain perception following surgery.	– Significant reductions in postoperative NRS and opioid consumption.	– Individualization of the TAP block technique is essential; factors such as patient anatomy, surgical approach (posterior vs. lateral), and type of local anesthetic used can influence outcomes. – Monitoring for potential complications (e.g., hematoma formation or infection at the injection site) is necessary.
IP analgesia	In IP, local anesthetics are directly injected into the IP cavity following LG surgeries.	Local Anesthetic Effect: Bupivacaine and other local anesthetics block sodium channels in nerve fibers, inhibiting pain signal transmission. Visceral Pain Relief: Targeting the IP space directly addresses visceral pain associated with laparoscopic procedures. Synergistic Effects: Combining local anesthetics with adjuvants like dexmedetomidine enhances analgesic efficacy and prolongs pain relief.	– Meta-analyses indicate significant reductions in VAS scores for pain at 6 and 24 hours postoperatively. – Decreased time to first rescue analgesic request and lower total opioid consumption post-surgery. – Efficacy is consistent across various LG procedures.	– Dosing Variability: There is no standardized dose for IP local anesthetics; optimal dosing requires further research. – Potential Toxicity Risks: Careful monitoring is needed to avoid LAST due to higher absorption rates from the peritoneal cavity. – Patient Selection: Not all patients may be suitable for IP analgesia; individual assessment is necessary.
Intravenous Lidocaine Infusions	Intravenous lidocaine is often integrated into ERAS protocols to optimize recovery.	Sodium Channel Blockade: Lidocaine acts as a local anesthetic by blocking sodium channels in nerve cells, inhibiting the transmission of pain signals. Anti-Inflammatory Effects: Reduces inflammatory mediators that contribute to postoperative pain. Gastrointestinal Motility: Promotes recovery of gastrointestinal function post-surgery, aiding in a faster return to normal activities.	– Reduced postoperative pain scores. – Decreased opioid consumption by up to 35% to 83% when administered perioperatively.	– Safety Profile: While generally safe, intravenous lidocaine must be administered carefully to avoid potential side effects such as central nervous system toxicity or cardiovascular issues. – Dosing Protocols: Optimal dosing strategies typically involve continuous infusion rates of 1-2 mg/kg/h for effective analgesia without toxicity. – Training for Staff: Proper training for healthcare providers is essential for administering and monitoring intravenous lidocaine safely.
Spinal anesthesia with low-dose opioids	Administrated by spinal anesthesia routine protocol.	Local Anesthetic Action: Bupivacaine or levobupivacaine blocks sodium channels in nerve fibers, providing sensory block at the surgical site. Opioid Action: Low-dose opioids (e.g., morphine) act on mu-opioid receptors in the central nervous system to modulate pain perception. Synergistic Effect: The combination enhances overall analgesia while minimizing side effects associated with higher doses of either agent alone.	– Significantly reduces postoperative pain scores. – Lower opioid consumption and fewer side effects, such as nausea and sedation. – Patients report improved early postoperative pain control and faster recovery times.	– Proper dosing is crucial; using too high a dose can lead to excessive motor block or respiratory complications. – Patient selection is important; those with contraindications to spinal anesthesia should be carefully evaluated. – Training for anesthesiologists in administering spinal anesthesia is essential to minimize risks associated with improper technique.
Dexamethasone administration	Orally and IP administration.	Dexamethasone reduces inflammation by inhibiting phospholipase A2, leading to decreased production of prostaglandins and leukotrienes. It modulates the stress response and has analgesic properties that may enhance postoperative pain control. Dexamethasone also interferes with the COX pathway, contributing to its anti-inflammatory effects.	– Significant reductions in VAS pain scores particularly at 6 and 24 hours post-surgery. – Dexamethasone decreases opioid consumption within the first 24 hours post-surgery. – IP administration has effectively reduced shoulder pain and PONV following gynecological laparoscopy.	– Individualized dosing is important; effective doses often exceed 0.1 mg/kg for optimal analgesic effects. – Monitoring for potential side effects such as hyperglycemia, especially in diabetic patients. – The timing of administration (preoperative vs. intraoperative) can influence efficacy; preoperative dosing is generally recommended for better outcomes.
PCA	PCA is used to manage pain effectively post-surgery, allowing patients to self-	Opioid Administration: PCA typically uses opioids (e.g., morphine, hydromorphone) that act on mu-opioid receptors in the central	– PCA provides effective analgesia comparable to intermittent intramuscular injections of opioids, with no	– Individual patient factors (e.g., history of opioid use, and anxiety levels) may influence PCA effectiveness. – Education on PCA use is essential to ensure

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	administer analgesics as needed through a computerized pump.	nervous system to provide analgesia. Patient Control: Patients can self-administer predetermined doses of medication, allowing for personalized PM based on their needs. Lock-Out Mechanism: Prevents overdose by limiting the frequency of doses administered.	significant differences in pain scores or patient satisfaction. – Research shows that most patients cease requiring parenteral analgesia within 24 hours after LG surgery.	patients understand how to operate the device safely. – Monitoring for side effects such as sedation and respiratory depression is critical, especially in opioid-naïve patients.

Data extraction and categorization based on the eligible study selection (PRISMA 2020). MMA, Multimodal Analgesia; PSI, Port Site Infiltration; SDI, Subdiaphragmatic Infiltration; CWI, Continuous Wound Infiltration; TAP, Transversus Abdominis Plane; IP, Intraperitoneal; PCA, Patient-controlled Analgesia; TENS, Transcutaneous Electrical Nerve Stimulation; LG, Laparoscopic gynecological; ERAS, Enhanced Recovery After Surgery; PM, Pain management; NSAIDs, Nonsteroidal anti-inflammatory drugs; COX, Cyclooxygenase; NRS, Numerical Rating Scale; VAS, Visual Analog Scale; LAST, Local anesthetic systemic toxicity.

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Supplement 2. Pharmacological, non-pharmacological, psychological, and gas management as post-operative PM approaches

Techniques	*Medical Interventional Procedure*	*Mechanism of action*	*Efficacy*	*Clinical Considerations*
Heat/cold therapy	Tropical administration	Cold Therapy (Cryotherapy): Reduces inflammation and numbs the affected area by constricting blood vessels (vasoconstriction), which decreases swelling and pain perception. Heat Therapy: Increases blood flow and relaxes muscles through vasodilation, which can alleviate stiffness and improve comfort. Both modalities can activate descending inhibitory pathways in the central nervous system, enhancing analgesic effects through different mechanisms.	– Mixed results in efficacy for cold therapy in LG surgeries; some studies report no significant improvement in pain control or increased opioid consumption compared to control groups. – In contrast, other studies indicate that cold therapy can effectively reduce postoperative pain following various surgical procedures, including gynecological surgeries.	– Individual responses to heat/cold therapy can vary; some patients may not experience significant benefits from these modalities. – Proper application techniques are essential to avoid skin damage or adverse reactions (e.g., frostbite from excessive cold exposure). – Timing of application (immediate post-operative vs. later stages) may influence effectiveness; early application is generally recommended for optimal results.
Acupuncture technique	Acupuncture is a therapeutic technique that involves the insertion of fine, sterile needles into specific acupoints for PM.	Endogenous Opioid Release: Acupuncture stimulates specific acupuncture points, leading to the release of endogenous opioids (e.g., endorphins) in the central nervous system. Neurotransmitter Modulation: It influences neurotransmitters that modulate pain perception and inflammation. Improved Blood Flow: Acupuncture may enhance circulation to the surgical area, promoting healing and reducing pain.	– Acupuncture significantly reduces postoperative pain scores. – Meta-analyses indicate that acupuncture effectively reduces opioid requirements post-surgery.	– Patient Selection: Suitable for patients undergoing LG surgeries who are open to complementary therapies. – Training Requirements: Practitioners must be trained in acupuncture techniques to ensure safety and efficacy. – Timing of Treatment: Optimal results are often achieved when acupuncture is administered preoperatively or immediately after surgery.
TENS	TENS is a non-invasive PM technique using low-voltage electrical currents.	TENS works by delivering electrical impulses through the skin to stimulate peripheral sensory nerves. It activates the descending inhibitory pathways in the central nervous system, which helps modulate pain perception and reduce discomfort. The stimulation can inhibit pain signals transmitted to the brain, providing analgesic effects without pharmacological interventions.	– TENS reduces postoperative shoulder pain in patients undergoing laparoscopic surgeries. – TENS decrease in VAS scores at 2, 4, and 8 hours post-surgery.	– Proper placement of electrodes is crucial for effective treatment; they should be positioned near the area of pain (e.g., scapular region for shoulder pain). – Individual patient tolerance to electrical stimulation should be assessed to adjust intensity settings appropriately. – TENS may not be suitable for all patients; contraindications include certain skin conditions or pacemakers.
Massage therapy	Manual manipulation	Physiological Effects: Massage therapy promotes relaxation by stimulating the parasympathetic nervous system, which helps decrease stress hormones and increase endorphin levels. Pain Modulation: It may enhance local blood circulation, reduce muscle tension, and promote lymphatic drainage, all of which contribute to pain relief. Psychological Benefits: The tactile stimulation from massage can also improve mood and reduce anxiety through the release of oxytocin.	– Massage therapy significantly reduces postoperative pain levels.	– Individualization of Treatment: Massage therapy should be tailored to each patient's needs and preferences, considering factors such as pain tolerance and anxiety levels. – Training for Practitioners: Healthcare providers administering massage should be adequately trained to ensure safety and effectiveness. – Contraindications: Care must be taken in patients with certain conditions (e.g., fractures or skin infections) where massage may not be appropriate.
Physical Activities	Through exercise	Increased Circulation: Physical activities promote blood flow, which aids in reducing inflammation and enhancing tissue healing. Muscle Strengthening: Engaging in light exercises helps maintain muscle tone and strength, preventing atrophy during recovery. Pain Gate Control Theory: Physical activity can stimulate endorphin release, which may help mitigate pain perception. Improved Respiratory Function: Activities like deep breathing exercises enhance lung	– Early mobilization reduces postoperative pain scores and improves overall recovery times. – A systematic review supports the efficacy of pelvic floor exercises in reducing discomfort after gynecological procedures.	– Individualized Exercise Plans: Tailoring physical activity recommendations based on patient-specific factors (age, comorbidities) is essential for safety. – Gradual Resumption of Activities: Patients should be advised to start with light activities and gradually increase intensity based on their comfort levels. – Monitoring for Adverse Effects: Healthcare providers should monitor

	function and reduce the risk of complications such as pneumonia.	patients for any signs of complications or increased discomfort during physical activities.

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