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REVIEW

Effectiveness of Non-Pharmacological Interventions for Pain Management After Laparoscopic Cholecystectomy: A Systematic Review and Network Meta-Analysis

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Background: Although non-pharmacological interventions are widely utilized for postoperative pain management, their comparative effectiveness remains unclear. This network meta-analysis (NMA) aimed to comprehensively evaluate the effects of various non-pharmacological interventions on postoperative pain and anxiety after LC, and to identify the optimal intervention through ranking analysis.

Methods: A literature search was executed to identify relevant randomized controlled trials (RCTs) that investigated non-pharmacological interventions for alleviating pain after laparoscopic cholecystectomy (LC). This search encompassed the electronic databases PubMed, Web of Science, Embase, CINAHL, and the Cochrane Library, with the coverage spanning from the inception of each database to January 2025. Two independent reviewers performed literature search, study selection, quality assessment, and data extraction. The Cochrane Risk of Bias 2.0 tool was employed for bias assessment. A Bayesian NMA was conducted, with surface under the cumulative ranking curve (SUCRA) values used to rank intervention effectiveness.

Results: The review identified 15 types of non-pharmacological interventions. The most common among these were acupressure (n=5), massage (n=4), and transcutaneous electrical nerve stimulation (TENS, n=2). The NMA demonstrated that ear acupressure, aromatherapy, and foot baths ranked as the top three interventions for alleviating postoperative pain after LC. Compared with standard care, all three interventions significantly improved pain scores: ear acupressure (standardized mean difference [SMD] = −3.61, 95% credible interval [CrI] −5.71 to −1.50), essential oil therapy (SMD = −2.59, 95% CrI −4.93 to −0.27), and foot baths (SMD = −2.42, 95% CrI −4.67 to −0.19). SUCRA rankings revealed ear acupressure (93.93%) as the most effective intervention, followed by essential oil therapy (80.97%) and foot baths (78.46%). None of the evaluated non-pharmacological interventions demonstrated statistically significant effects on anxiety reduction.

Conclusion: Multiple non-pharmacological interventions can effectively alleviate postoperative pain after LC. However, none of the evaluated interventions produced statistically significant reductions in postoperative anxiety.

Keywords: LC, network meta-analysis, analgesia, non-pharmacological interventions, pain management

Introduction

Laparoscopic cholecystectomy (LC) is the gold standard surgical treatment for benign gallbladder diseases, being widely utilized due to its minimally invasive nature and rapid recovery profile.[1] Although LC significantly reduces postoperative pain compared with conventional open surgery,[2] studies indicate that 17–41% of patients continue to experience substantial pain following LC, with 3.4–7.0% developing persistent pain.[3] The sources of postoperative pain include somatic pain from trocar-related incisions, visceral pain caused by peritoneal distention, and diaphragmatic irritation

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triggered by elevated intra-abdominal pressure and carbon dioxide insufflation.[4,5] The mechanism of shoulder pain following laparoscopic procedures remains incompletely understood,[6] although residual carbon dioxide between the liver and right diaphragm is considered a contributor to diaphragmatic irritation that may lead to referred shoulder pain.[4] Additional explanations include phrenic nerve stimulation caused by carbonic acid generated intraperitoneally from retained carbon dioxide,[6] and some investigators emphasize that visceral pain associated with tissue trauma during cholecystectomy may represent the major component of postoperative discomfort.[7] Without adequate pain management, LC may result in considerable patient discomfort, limited mobility, and impaired respiratory function including restricted deep breathing and coughing. These complications not only compromise early postoperative recovery but may also extend hospitalization duration and increase healthcare costs.[3,8] Effective pain management has been demonstrated to promote early mobilization, improve patient comfort and satisfaction, reduce hospital length of stay, and decrease overall healthcare expenditure.[9] Therefore, optimal postoperative pain control is both a fundamental component of clinical care and a cornerstone of Enhanced Recovery After Surgery (ERAS) protocols, warranting high priority in perioperative management.

Conventional pharmacological approaches, including non-steroidal anti-inflammatory drugs (NSAIDs) and opioids, are the cornerstone of postoperative pain management. However, opioids, even at therapeutic dosages, frequently produce adverse effects including nausea,[10] vomiting,[10] somnolence;[11] severe cases may result in respiratory depression.[12,13] These adverse effects not only increase patient discomfort and treatment complexity—often requiring additional medications to manage side effects—but may also impede recovery. Non-pharmacological interventions provide notable analgesic benefits and offer advantages such as procedural simplicity, affordability, and favorable safety profiles,[14,15] with high acceptance and satisfaction among patients and caregivers.[16,17] Consequently, investigating effective non-pharmacological analgesic interventions as adjuncts or alternatives to pharmacotherapy holds significant clinical importance in optimizing postoperative pain management strategies for LC. The primary objective of non-pharmacological analgesia is to directly reduce pain intensity while empowering patients with enhanced pain control, thereby improving the overall pain experience.[18] Additionally, these interventions are commonly integrated into multi-modal analgesic protocols in combination with pharmacological treatments to achieve synergistic effects, optimize overall pain control, and potentially reduce opioid requirements.[19,20] Identifying effective and safe non-pharmacological analgesic interventions has therefore become a crucial direction in advancing postoperative pain management.

Established non-pharmacological analgesic modalities include ear acupressure,[21] essential oil therapy,[22] foot baths,[23] acupressure,[21] massage therapy,[24] and transcutaneous electrical nerve stimulation (TENS).[25] These interventions have demonstrated positive effects in alleviating postoperative pain, reducing medication dependence, and enhancing overall surgical recovery outcomes, A systematic review and meta-analysis also reported that non-pharmacological strategies effectively relieve pain in cardiac surgery patients while maintaining procedural simplicity and a low incidence of adverse effects.[26] However, current clinical guidelines lack specific recommendations for optimal non-pharmacological approaches to postoperative analgesia following LC. Furthermore, no studies have systematically compared the efficacy and safety of these interventions for LC-related postoperative pain management, creating substantial uncertainty and challenges in clinical practice.

This study utilized a network meta-analysis (NMA) to evaluate the effects of various non-pharmacological interventions on postoperative pain and anxiety following LC. The primary outcome of this study was the pain score. The secondary outcomes included patient anxiety scores. This study aimed to elucidate the clinical efficacy of non-pharmacological approaches in LC pain management. Additionally, we sought to provide evidence-based guidance for developing non-pharmacological analgesic protocols.

Methods

This study was conducted and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) extension for NMA (PRISMA-NMA) guidelines,[27,28] with complete details provided in Supplementary Table S1. The search strategy and analytical protocol for this systematic review and NMA were prospectively registered with the International Prospective Register of Systematic Reviews (PROSPERO) under registration number CRD42025634377.

Literature Search Strategy

A comprehensive literature search was conducted across five major databases (PubMed, Web of Science, Embase, CINAHL, and the Cochrane Library). The search aimed to identify clinical studies investigating non-pharmacological interventions for postoperative pain relief following LC. The search encompassed all available literature from database inception through January 2025. Both Medical Subject Headings (MeSH) terms and free-text words were employed, for example: ((("preemptive" OR "preoperative" OR "perioperative") AND ("analgesia*" OR "pain" OR "analgesic*")) OR ("preemptive analgesia" OR "preoperative analgesia" OR "perioperative analgesia")) AND ("Laparoscopic Cholecystectomy"). Reference lists of relevant systematic reviews were manually searched to identify additional eligible studies. The complete search strategy is detailed in Supplementary Table S2.

Study Selection

Literature management was performed using EndNote software. Two independent reviewers (Ting Lei and Yaping Xie) conducted study screening and data extraction according to predefined inclusion and exclusion criteria. Discrepancies were resolved through discussion with a third investigator (Junjie Wang). Screening was not blinded to authors, institutions, or journals. Inclusion criteria were established based on the PICOS framework: (1) Population (P): adult inpatients aged ≥18 years undergoing elective LC; (2) Intervention (I): non-pharmacological analgesic interventions including ear acupressure, essential oil therapy, massage therapy, acupressure, foot baths, and TENS; (3) Comparator (C): standard care; (4) Outcomes (O): postoperative pain assessed using Visual Analogue Scale (VAS) or Numerical Rating Scale (NRS), and postoperative anxiety evaluated using State-Trait Anxiety Inventory (STAI), or Beck Anxiety Inventory; (5) Study design (S): Only randomized controlled trials (RCTs) were considered for inclusion in this network meta-analysis.

Exclusion criteria comprised: (1) patients with chronic pain history (excluding gallstone-related pain); (2) patients requiring conversion from LC to open cholecystectomy; (3) pregnant or lactating women; (4) duplicate publications; (5) conference abstracts or study protocols; (6) studies with inaccessible full text despite author contact attempts.

Risk of Bias Assessment

Two reviewers (Ting Lei and Yaping Xie) independently evaluated risk of bias using the Cochrane Risk of Bias tool version 2.0 (ROB 2.0). This approach follows recommendations from the Cochrane Handbook version 5.1.0. Assessment domains included bias arising from randomization process, deviations from intended interventions (effect of assignment to intervention), deviations from intended interventions (effect of adhering to intervention), missing outcome data, measurement of outcomes, selective reporting of results, and other sources of bias. Each domain was classified as "high risk," "some concerns," or "low risk." Results were cross-verified, with disagreements resolved through discussion with Junjie Wang.

Data Extraction

Two reviewers (Ting Lei and Junjie Wang) independently extracted key data elements, followed by cross-verification. Discrepancies were resolved through consultation with a third reviewer (Yaping Xie). Extracted information included first author, country, publication year, study design, participant characteristics (age, sample size, gender distribution), detailed intervention descriptions, and outcome measures (pain and anxiety scores). All outcome measures represented the difference between pre- and post-intervention NRS or VAS scores. Pain was assessed using numeric rating scales (NRS) or visual analogue scales (VAS), with higher scores indicating more severe pain. Anxiety was assessed using the State-Trait Anxiety Inventory (STAI), where higher scores reflect more severe anxiety. When differences were not reported in the original studies, they were calculated using formulas specified in the Cochrane Handbook.[29] If key summary data were missing, we tried to reconstruct standard deviations from other reported dispersion statistics (such as standard errors, 95% confidence intervals, or interquartile ranges) using standard formulas. If this still could not be reliably reconstructed, we attempted to contact the corresponding authors. Studies with missing dispersion data were retained in the qualitative synthesis but excluded from the quantitative analysis for that specific outcome.

Data Synthesis

A Bayesian NMA was performed using the gemtc package in R software (version 4.4.3). Continuous variables (pain and anxiety scores) were pooled as standardized mean differences (SMDs) with 95% credible intervals (CrIs). Between-study heterogeneity was evaluated using the between-study variance (τ^2) and the I^2 statistic from random-effects models. I^2 values of approximately 25%, 50%, and 75% were interpreted as indicating low, moderate, and high heterogeneity, respectively. Network diagrams were constructed to provide visual representation of available evidence across intervention comparisons. For networks containing closed loops, inconsistency was evaluated using node-splitting methodology, comparing direct and indirect evidence; P-values >0.05 indicated acceptable consistency. Random-effects models were fitted using Markov chain Monte Carlo (MCMC) algorithms with 10,000 burn-in iterations, 50,000 sampling iterations, and thinning interval of 10. Model convergence was confirmed when Gelman-Rubin statistics for all four independent chains were <1.01. To further explore potential sources of heterogeneity and assess the robustness of the findings, we conducted sensitivity analyses excluding trials judged to be of lower methodological quality (ie, with a high overall risk of bias) and performed a predefined subgroup analysis stratified by the presence versus absence of background pharmacological analgesia across trial arms. Results were presented in league tables showing pairwise comparisons between interventions. We used surface under the cumulative ranking curve (SUCRA) values to quantify ranking probabilities, where values range from 0–100% with higher values indicating greater probability of optimal effectiveness.

Results

Literature Selection Process and Results

The systematic search strategy yielded 5,724 potentially relevant records, comprising 891 from PubMed, 1,275 from Embase, 2,790 from the Cochrane Library, 377 from Web of Science, and 391 from CINAHL. After removing 1,781 duplicates using EndNote, 3,943 unique studies remained for screening. After screening titles and abstracts, 3,818 studies were excluded, and 125 proceeded to full-text review. During full-text screening, we excluded 98 studies for the following reasons: ineligible populations (n=8), inappropriate interventions (n=22), incompatible outcomes (n=35), and unsuitable study designs (n=33). Ultimately, 21 RCTs involving 2,695 patients undergoing LC were included for analysis (Figure 1).[30–50]

Characteristics of Included Studies

All 21 included studies were RCTs evaluating pain outcomes (n = 19) and anxiety outcomes (n = 7). A total of 2,695 patients were randomized to intervention groups (n = 1,719) or control groups (n = 1,047). The included studies exhibited a broad geographical distribution, encompassing multiple countries. Specifically, Turkey contributed the largest number of studies (n=10), followed by Iran (n=6). Single studies were identified from Russia, Brazil, Denmark, South Korea, and China. All control groups received standard care. Participant ages ranged from 40 to 60 years. These studies evaluated 15 distinct non-pharmacological analgesic interventions for postoperative pain management following LC. Among these, six studies (28.57%, n = 621 participants) investigated acupressure, while four studies (19.05%, n = 621 participants) examined massage therapy. The included trials spanned from 2008 to 2024. Pain assessment was the most frequently evaluated outcome (19 studies; n = 2,162 participants), followed by anxiety assessment (7 studies; n = 784 participants). Detailed baseline characteristics of the included studies are presented in Table 1 and Table S3.

Risk of Bias Assessment

Study quality was evaluated using the ROB 2.0 tool. The bias assessment revealed that 19.47% of studies (4 trial) raised some concerns, 76.19% (19 trials) demonstrated low risk of bias, and 4.76% (1 trial) exhibited high risk of bias (Supplementary Figure S1).

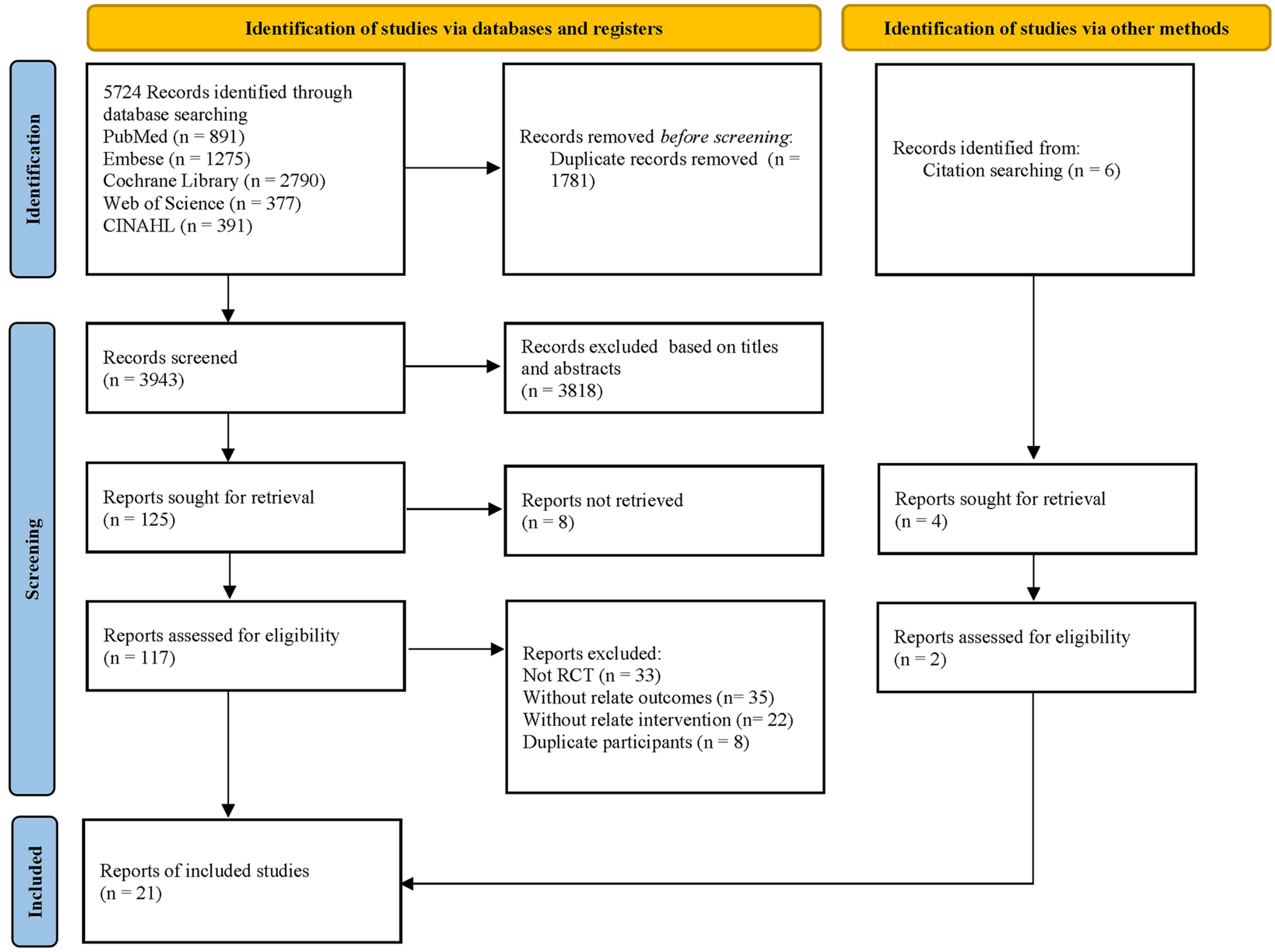

Figure 1 Literature selection flowchart.

NMA of Pain Outcomes

Twenty-one trials incorporating 15 interventions were included in the NMA of pain outcomes. The network diagram for pain outcomes is presented in Figure 2A. Given the presence of closed loops, inconsistency testing was conducted, revealing no significant inconsistency (Supplementary Figure S2). The forest plot of relative effects (Figure 2B)

Table 1 Characteristics and Quality Assessments of the Included Studies

Author, Year	Country	Patient	Intervention Measure	Sample Size	Age/Years	Sex Ratio (M/F)	Pain	Anxiety	Pain Measurement Time
Topdemir, 2021[30]	Turkey	LC	Acupressure	44	47.61 ± 9.94	10/34	VAS	NR	After intervention 0.5h
			Reiki	44	49.95 ± 9.74	12/32			
			Routine Nursing	44	46.91 ± 10.65	14/30			
Goktas, 2022[50]	Turkey	LC	Health Education	30	47.70 ± 9.55	10/20	VAS	STAI	After surgery 24h
			Routine Nursing	30	50.63 ± 10.50	10/20			
Toğaç, 2020[31]	Turkey	LC	Health Education	62	48.61 ± 13.84	12/50	VAS	STAI	After surgery4h
			Routine Nursing	62	48,82 ± 13,46	12/50			
Soylu, 2021[32]	Turkey	LC	Acupressure	26	NR	NR	VAS	STAI	After surgery4h
			Routine Nursing	27	NR	NR			
Nechay, 2021[33]	Russia	LC	ERAS	88	48.8±15.3	32/ 56	VAS	NR	After surgery6h
			Routine Nursing	101	54.4±14.6	42 /59			

(*Continued*)

Table 1 (Continued).

Author, Year	Country	Patient	Intervention Measure	Sample Size	Age/Years	Sex Ratio (M/F)	Pain	Anxiety	Pain Measurement Time
Çankaya, 2018[34]	Turkey	LC	Massage	44	48.45±14.80	10/34	NRS	NR	After intervention 10min
			Routine Nursing	44	51.38±13.88	13/31			
Silva, 2012[35]	Brazil	LC	TENS	21	52 ±14	2/19	VAS	NR	After intervention 0.5h
			Routine Nursing	21	44 ± 16	1/20			
Graversen, 2013[36]	Denmark	LC	Music	40	50 (35–57)	12/28	VAS/ NRS	NR	After surgery 3h
			Routine Nursing	35	44 (36–58)	8/27			
Zohourparvaz, 2023[37]	Iran	LC	Routine Nursing	36	48. 78 ± 12.06	6/29	VAS	STAI	After intervention4h
			Acupressure	36	45.78± 12.06	6/27			
			Ear Acupressure	36	44.69± 12.26	11/22			
KILINÇ, 2022[38]	Turkey	LC	Acupressure	64	47.76±12.24	15/49	VAS	NR	After surgery 12h
			Routine Nursing	64	48.04±12.50	13/51			
Kheradkish, 2024[39]	Iran	LC	Acupressure	42	46.71 ± 10.31	NR	VAS	NR	After surgery 0.5h
			Routine Nursing	39	45.08 ± 7.29	NR			
Gürçayir, 2022[40]	Turkey	LC	Footbath	54	NR	13/41	VAS	STAI	After surgery 2h
			Routine Nursing	54	NR	15/39			
Artıklar, 2023[41]	Turkey	LC	Breathing And Coughing Exercise	35	52.03 ± 5.0	17/18	NPS	NR	After surgery 2h
			Breathing And Coughing Exercise And Oxygen Therapy	35	52.49 ± 5.28	17/18			
			Routine Nursing	35	51.46 ± 5.41	17/18			
Abbasnia, 2023[42]	Iran	LC	Health Education	49	41.02 ± 10.19	6/43	VAS/ MPQ	STAI	After surgery 4h
			Routine Nursing	47	46.79±11.99	11/36			
Saremirad, 2022[43]	Iran	LC	Breathing Exercises	42	NR	23/19	NPS	NR	After surgery 4h
			Routine Nursing	41	NR	19/22			
Lee, 2021[44]	Korea	LC	Essential Oil	23	47.78±11.72	13/10	NRS	NR	After surgery 24h
			Routine Nursing	23	57.96±12.91	14/19			
Duran, 2024[45]	Turkey	LC	Massage	29	NR	15/14	VAS	NR	After intervention0.5h
			Routine Nursing	30	NR	12/18			
Mottahedi, 2023[46]	Iran	LC	Massage	46	44.59 ± 10.91	14/36	VAS	NR	After intervention20min
			TENS	46	42.07 ± 11.73	19/287			
			Routine Nursing	46	42.91 ± 11.50	10/36			
Wang, 2023[47]	China	LC	Routine Nursing	21	57.75 ± 11.64	10/11	VAS	NR	After surgery 6h
			Acupuncture	21	56.60 ± 11.76	8/13			
Sadati, 2013[48]	Iran	LC	Health Education	50	46.8±10.6	0/50	VAS	STAI	After surgery 24h
			Routine Nursing	50	46.8±10.6	0/50			
Koraş, 2018[49]	Turkey	LC	Massage	85	NR	24/61	VAS	STAI	After intervention2h
			Routine Nursing	82	NR	26/56			

Abbreviations: LC, Laparoscopic Cholecystectomy; VAS, Visual Analog Scale; NRS, Numeric Rating Scale; MPQ, McGill Pain Questionnaire; STAI, State-Trait Anxiety Inventory; ERAS, Enhanced Recovery After Surgery; TENS, Transcutaneous Electrical Nerve Stimulation; NR, Not Report.

demonstrated significant pain improvement with three interventions compared with standard care. Ear acupressure showed the largest effect (SMD = −3.61, 95% CrI −5.71 to −1.50), followed by essential oil therapy (SMD = −2.59, 95% CrI −4.93 to −0.27) and foot baths (SMD = −2.42, 95% CrI −4.67 to −0.19). SUCRA rankings indicated that ear acupressure achieved the highest probability of being the most effective intervention for pain reduction (SUCRA = 93.93%), followed by essential oil therapy (SUCRA = 80.97%) and foot baths (SUCRA = 78.46%). Comprehensive pairwise comparison results are provided in Supplementary Table S4. No statistically significant differences were observed between Reiki and massage therapy, music therapy, foot baths, or breathing exercises.

NMA of Anxiety Outcomes

Seven trials involving four interventions were included in the NMA of anxiety outcomes. The network diagram for anxiety is shown in Figure 3A, with no closed loops identified. The forest plot of relative effects (Figure 3B) revealed that, compared with standard care, acupressure, health education, foot baths, massage therapy, and meditation did not demonstrate statistically significant improvements in anxiety scores. Detailed pairwise comparison results are presented in Supplementary Table S5.

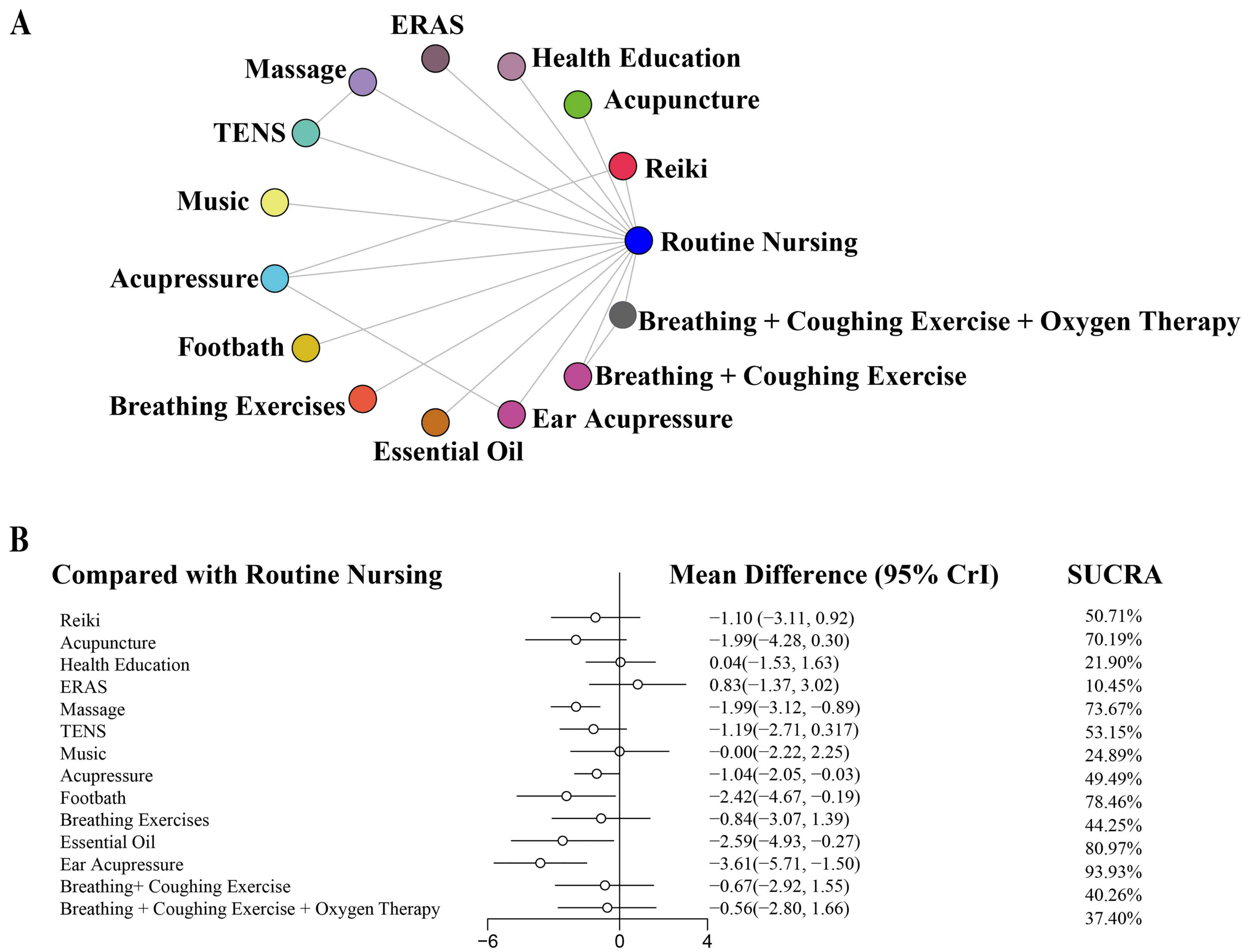

Figure 2 (**A**) Network geometry of non-pharmacological interventions for postoperative pain; (**B**) Forest plots and SUCRA rankings of non-pharmacological interventions for postoperative pain.

Abbreviations: ERAS, Enhanced Recovery After Surgery; TENS, Transcutaneous Electrical Nerve Stimulation; CrI, Credible Interval; SUCRA, Surface Under The Cumulative Ranking Curve.

Subgroup Analyses

Subgroup analyses were conducted to determine whether background analgesic use influenced pain and anxiety outcomes (Table 2). The main analysis (n = 17) identified ear acupressure as the most effective intervention overall (SUCRA = 93.93%). In the nine studies without interference from background analgesics, ear acupressure maintained its therapeutic superiority, with a SUCRA value of 97.63%. In the eight studies where this confounder was not controlled and ear acupressure was not included, massage ranked as the most effective intervention (SUCRA = 83.45%). For anxiety outcomes, both the main analysis (n = 8) and the subgroup without background analgesic influence (n = 7) suggested that health education may be the most effective approach.

Sensitivity Analyses

Sensitivity analyses supported the robustness of the findings (Table 3). For both pain and anxiety outcomes, the relative ranking of interventions remained stable Minor fluctuations in point estimates were observed for anxiety but did not alter the overall conclusions, confirming the reliability of the network meta-analysis.

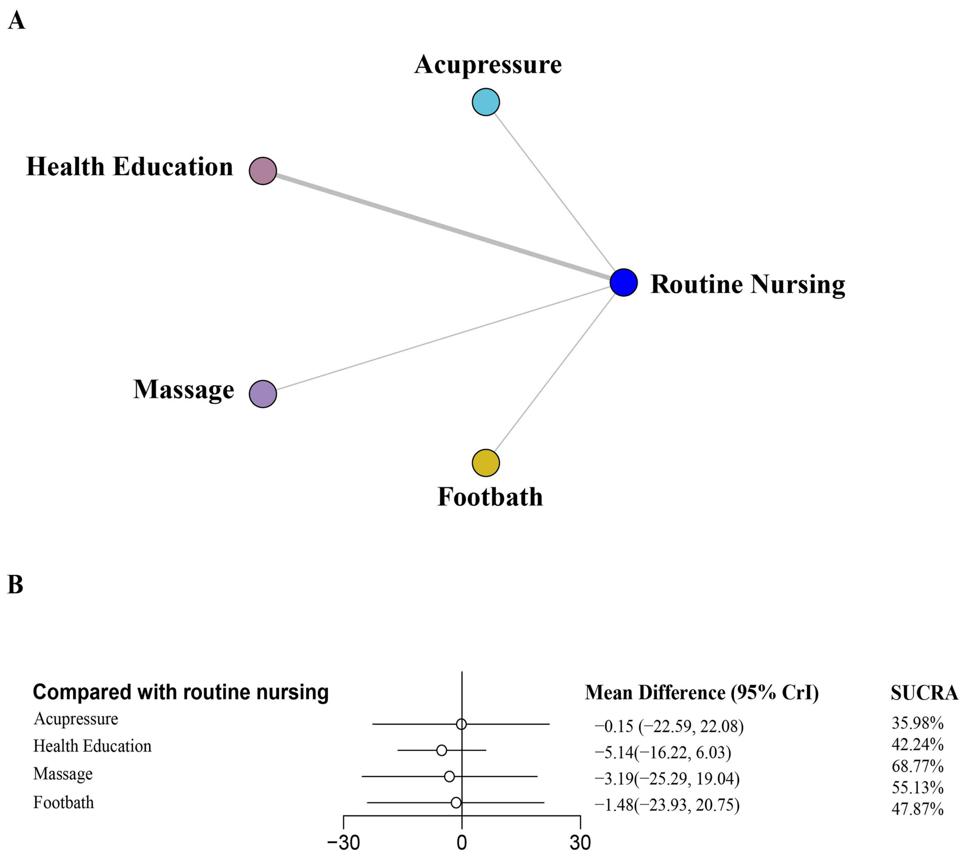

Figure 3 (**A**) Network geometry of non-pharmacological interventions for anxiety; (**B**) Forest plots and SUCRA rankings of non-pharmacological interventions for anxiety.
Abbreviations: CrI, Credible Interval; SUCRAc, Surface Under The Cumulative Ranking Curve.

Discussion

This systematic review and NMA evaluated 15 non-pharmacological interventions for alleviating postoperative pain following LC, with primary focus on short-term changes in pain intensity. The NMA results demonstrated that ear acupressure, essential oil therapy, and foot baths exhibited the most significant analgesic effects following LC. These findings align with a previous meta-analysis confirming the overall analgesic value of non-pharmacological interventions in surgical populations[51] and with evidence from a systematic review showing their efficacy in cardiac surgery patients.[26] Furthermore, the pronounced efficacy of auricular therapy is consistent with a specific study demonstrating that auricular

Table 2 Subgroup Analysis results

Outcome	Subgroup	Number of Studies	Best-Performing Intervention	Worst-Performing Intervention	Key-SUCRA Values
Pain	Overall	17	Ear Acupressure (SD = −3.61,95% CrI = −5.71,-1.50)	Massage (SD = −2.42,95% CrI = - 4.67, −0.19)	Highest: Ear Acupressure 93.93% Lowest: TENS 22.06%
	Accounting for analgesic confounders	9	Ear Acupressure (SD = −3.80,95% CrI = −5.88, −1.82)	Massage (SD = −1.53,95% CrI = −2.98, −0.34)	Highest: Ear Acupressure 97.63% Lowest: Music 21.72%
	Without accounting for analgesic confounders	8	Massage (SD = −2.74, 95% CrI = −5.09, −0.57)	-	Highest: massage 83.45% Lowest: Health Education 22.24%
Anxiety	Overall	8	-	-	Highest: health education 68.77% Lowest: Acupressure 35.98%
	Accounting for analgesic confounders	1	-	-	-
	Without accounting for analgesic confounders	7	-	-	Highest: health education 71.36% Lowest: Acupressure 41.92%

Table 3 Results of Sensitivity Analysis

Outcome	Subgroup	Number of Studies	Best-Performing Intervention	Worst-Performing Intervention	Key-SUCRA Values
Primary analysis	Pain	17	Ear Acupressure (SD = −3.61, 95% CrI = −5.71, −1.50)	Massage (SD = −2.42, 95% CrI = −4.67, −0.19)	Highest: Ear Acupressure 93.93% Lowest: TENS 22.06%
	Anxiety	8	-	-	Highest: health education 68.77% Lowest: Acupressure 35.98%
Sensitivity analysis	Pain	17	Ear Acupressure (SD = −3.61, 95% CrI = −5.71, −1.50)	Massage (SD = −2.42, 95% CrI = −4.67, −0.19)	Highest: Ear Acupressure 93.93% Lowest: TENS 22.06%
	Anxiety	7	-	-	Highest: health education 71.60% Lowest: Acupressure 42.35%

acupuncture significantly reduced ibuprofen requirement after ambulatory knee surgery compared to a control procedure.[52]

Acupressure, originating from traditional Chinese medicine, involves applying gentle finger pressure to specific meridian points on the body to stimulate physiological regulatory processes. Therapeutic effects are achieved through sustained pressure application to the same acupoint.[53] This technique is a non-invasive, cost-effective intervention that avoids skin damage, infection, or bleeding while effectively controlling pain symptoms without significant complications.[54,55] The ear contains numerous meridian connections that converge at key therapeutic points, and stimulation of these auricular points can activate regulatory mechanisms and provide analgesic effects.[56] Zohourparvaz et al[37] demonstrated that both acupressure and ear acupressure effectively reduced shoulder pain following LC, with ear acupressure providing superior and more rapid pain relief. Arumugam et al[57] conducted a meta-analysis of five RCTs involving 451 participants, showing that ear acupressure significantly reduced labor pain compared with standard care. However, research specifically examining ear acupressure for LC-related postoperative pain remains limited, and these findings require cautious interpretation. Additional high-quality RCTs are needed to validate the efficacy of ear acupressure in managing postoperative pain after LC.[58] Consistent with our findings, ear acupressure has been shown to improve heart rate variability, thereby reducing sympathetic nervous system activity, decreasing adrenaline and cortisol secretion, and enhancing relaxation responses, which collectively reduce pain, stress, and anxiety levels.[59] The analgesic mechanisms of acupressure are believed to involve two primary pathways: first, blocking pain signal transmission through neural pathways to the spinal cord and brain; second, stimulating endorphin release, which contributes to pain reduction.[60]

Essential oil therapy uses plant-derived essential oils administered through various routes, including inhalation, topical application, massage, or foot baths. These approaches can alleviate stress, reduce pain, and improve sleep quality. Lee et al[44] investigated essential oil therapy effects on postoperative pain in LC patients, revealing significant differences among intervention, placebo, and control groups. The intervention group demonstrated markedly lower pain scores and required fewer additional pain control measures beyond standard analgesics within 48 hours postoperatively. Bagheri et al[61] reported concordant findings, with intervention group patients inhaling four drops of 2% lavender essential oil in oxygen for 20 minutes, while controls received oxygen alone. Postoperative pain was assessed immediately upon surgical ward transfer and at 2, 6, and 24 hours post-surgery using visual analogue scales. Pain severity was significantly reduced in the intervention group at all four measurement points compared with controls. However, the aromatic properties of essential oils preclude patient blinding, potentially introducing placebo effects that warrant cautious result interpretation. To establish the analgesic efficacy of inhaled essential oil therapy, future research should investigate various essential oil types, different concentration ratios, and multiple outcome measures to determine optimal pain management protocols.

Foot baths represent an effective, cost-efficient, and easily implementable non-pharmacological intervention. Nursing staff can administer this treatment to alleviate postoperative pain, reduce anxiety and stress, promote muscle relaxation, and improve sleep quality.[62] Consistent with our findings, existing literature demonstrates that patients undergoing abdominal surgery experience statistically significant pain reduction following foot bathing compared with control groups.[23,63,64] In a study by Soonyoung and Myoungjin,[65] patients in the experimental group who received warm foot baths following hand replantation demonstrated marked decreases in pain intensity. Similarly, Gurccayir et al[40] reported that foot baths effectively reduced both pain and anxiety levels in patients following LC. The analgesic mechanisms of warm foot baths are believed to involve two primary pathways: first, reduction of muscle spasms and metabolic rate coupled with enhanced blood circulation; second, interruption of pain transmission pathways, thereby attenuating pain perception.[66–68]

The subgroup analyses revealed an important pattern in evidence quality. Ear acupressure emerged as the most effective intervention based entirely on high-quality studies that controlled for background analgesic use, strengthening confidence in its observed efficacy. In contrast, massage was ranked most effective only in studies lacking adequate control of confounding, suggesting possible overestimation of its benefits. This contrast highlights the superior methodological rigor underpinning the evidence supporting ear acupressure. Clinically, these findings indicate that non-pharmacological analgesic recommendations should prioritize interventions supported by higher-quality evidence, positioning ear acupressure as a preferred strategy after LC.

This study provides two major innovations. First, it establishes the most comprehensive evidence-integration framework to date by incorporating all available RCTs into a unified NMA, allowing simultaneous comparison of fifteen non-pharmacological interventions and providing a global efficacy ranking. Second, the use of SUCRA values enhances the interpretability of findings by estimating the probability that each intervention represents the optimal choice, offering more clinically actionable insights than traditional meta-analyses.

This study has several notable strengths. First, this is the inaugural application of NMA methodology to comprehensively compare the effectiveness of 15 non-pharmacological interventions for postoperative pain management following LC, providing novel evidence-based insights into this important clinical challenge. Second, we incorporated a comprehensive range of commonly utilized non-pharmacological interventions, facilitating thorough comparative analysis to guide postoperative analgesic strategy selection for LC. Third, we conducted systematic and extensive literature searches across five major databases, spanning from database inception through January 2025, to maximize identification of all relevant research. Furthermore, a notable strength of our analysis is the broad geographical representation of the included studies, which encompassed research from a wide range of countries and regions, including Turkey, Iran, Russia, Brazil, Denmark, South Korea, and China. This diversity enhances the external validity and generalizability of our findings. It suggests that the efficacy of the evaluated non-pharmacological interventions for post-operative pain may be robust across different healthcare settings and patient populations. Moreover, the inclusion of studies from various cultural contexts hints at the potential cross-cultural acceptability of these modalities, which is a particularly valuable attribute for managing a universal experience like pain.

Several limitations warrant acknowledgment. First, due to limited study availability, we did not differentiate between specific acupoint combinations in acupressure and massage interventions, precluding determination of relative efficacy and safety among different acupoint protocols. Second, inclusion was restricted to English-language publications, potentially introducing language bias through exclusion of non-English studies. Third, several included studies featured small sample sizes and brief follow-up periods, potentially limiting assessment of long-term clinical outcomes. Fourth, most included studies were single-center investigations, which may introduce bias and limit generalizability of findings. Fifth, pain was assessed at varying timepoints across trials, creating methodological heterogeneity and limiting precise comparison of analgesic onset and duration. Differences in the intervention sets included in various subgroups further constrained direct comparison under identical conditions, although these differences accurately reflect the stratified evidence levels that currently exist among non-pharmacological modalities.

Conclusions

This network meta-analysis confirmed that auricular therapy, essential oil therapy, and foot baths are effective non-pharmacological options for relieving postoperative pain after laparoscopic cholecystectomy (LC). Auricular therapy demonstrated the strongest overall analgesic effect and may be considered a preferred non-pharmacological component of multimodal analgesia after LC.

Clinical Significance and Practical Value

These findings provide clear evidence-based foundation to guide clinical practice. Incorporating auricular therapy and other non-pharmacological modalities into multimodal analgesia strategies following LC offers patients a safe, effective, and well-accepted analgesic option. This approach not only effectively alleviates patient pain and enhances patient safety, but also reduces opioid consumption, thereby minimizing the incidence of opioid-related adverse effects such as nausea, vomiting, and constipation. These benefits directly contribute to accelerated patient recovery and improved overall quality of care.

Future Research Perspectives

Although this study confirms the overall efficacy of these interventions, key treatment parameters including optimal acupoint combinations, stimulation intensity, frequency, and treatment duration remain unstandardized. Establishing these parameters is critical for advancing the intervention from “effective” to “optimal.” Future research could employ factorial or optimization trial designs to systematically analyze and establish best practice protocols. Large-scale, high-quality multicenter randomized controlled trials are urgently needed to further validate the impact of these therapies on long-term functional recovery, patient satisfaction, and economic benefits, thereby providing high-level evidence to inform clinical guideline development. We also recommend standardizing pain assessment time-points in future studies to facilitate objective comparisons of intervention onset time and duration of effect across different modalities.

In summary, this study establishes the superior position of auricular therapy within non-pharmacological pain management after LC, providing essential theoretical foundation and practical direction for developing safer, more efficient, and patient-centered perioperative analgesic strategies.

Data Sharing Statement

All data generated or analysed during this study are included in this published article and its Supplementary Information Files.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work. Ting Lei contributed to study conception and design, literature search, bias risk assessment, data extraction and analysis, and manuscript drafting. Yanqiong Peng contributed to study conception and design and provided critical manuscript revision. Ting Lei and Yaping Xie contributed to literature search and bias risk assessment. Ting Lei and Junjie Wang contributed to data extraction. Yuanjun Liu contributed to study conception and design. All authors contributed to data interpretation and provided critical manuscript review for publication.

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Disclosure

The authors have no conflict of interest to declare.

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