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Suggested Electroacupuncture for Postoperative Nausea and Vomiting: A Comprehensive Meta-Analysis and Systematic Review of Randomized Controlled Trials

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Statistical Analysis C
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Conflict of interest: None declared

Background: The purpose of this meta-analysis was to evaluate the effectiveness of electroacupuncture in preventing and treating postoperative nausea and vomiting (PONV) after general anesthesia.

Material/Methods: We searched for papers on randomized controlled trials on electroacupuncture for PONV prevention after general anesthesia published in PubMed, Web of Science, and China National Knowledge Infrastructure (CNKI) since October 1, 2016. Primary outcome was incidence of PONV; secondary outcomes were incidence of postoperative nausea (PON) at 6 h, postoperative vomiting (POV) at 6 h, and postoperative antiemetic requirement. Data were combined and analyzed using RevMan 5.4.1 software.

Results: Eight randomized controlled trials, with 899 total participants, were included. Findings showed (1) there was no significant difference in occurrence rate of PONV between electroacupuncture and control groups (OR=0.31, 95% CI [0.06, 1.49], $P=0.14$, $I^2=82\%$); (2) electroacupuncture reduced incidence of PON at 6 h postoperatively, compared with controls (OR=0.43, 95% CI [0.27, 0.67], $P=0.0002$, $I^2=0\%$); (3) compared with control group, electroacupuncture reduced POV incidence 0-6 h postoperatively (OR=0.38, 95% CI [0.23, 0.63], $P=0.0001$, $I^2=0\%$); (4) electroacupuncture group demonstrated a significant reduction in postoperative requirement for antiemetic medications (OR=0.44, 95% CI [0.25, 0.78], $P=0.005$, $I^2=61\%$); (5) one study reported adverse reactions during observation, with 3 patients experiencing pain and itching at acupuncture site and 2 patients refusing a second acupuncture treatment; all symptoms lasted less than 2 h.

Conclusions: Based on current evidence, electroacupuncture significantly reduces the occurrence rate of PON and POV at 6 h after surgery and the use of antiemetic medication postoperatively. However, more high-quality, large-sample randomized controlled trials are needed to further validate its efficacy.

Keywords: Anesthesia, General • Electroacupuncture • Meta-Analysis • Postoperative Nausea and Vomiting

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Background

Postoperative nausea and vomiting (PONV) refers to a series of symptoms such as nausea, retching, and vomiting that occur in a specific period after surgery. It is one of the common complications during the perioperative period, with an incidence rate of approximately 30% [1]. In high-risk individuals, the incidence rate can reach 70% to 80% [2], making PONV the second most common postoperative complication after pain [3]. The exact mechanism of PONV has not been fully elucidated, but current understanding suggests that it is the result of the interaction between various receptors and neurotransmitters in the central and visceral nervous systems [4]. The occurrence of PONV increases the incidence of postoperative complications and prolongs hospital stay [5,6], leading to increased healthcare costs and a significant economic burden on the medical system. Therefore, finding the optimal method for treating PONV following general anesthesia has become an urgent clinical challenge.

In recent years, acupuncture has been widely used as a non-pharmacological therapy for the prevention and treatment of PONV. Some studies have indicated that acupuncture at the Neiguan point (PC6) can effectively prevent the occurrence of PONV [7,8]. Currently, most meta-analyses on intervention measures include acupuncture or transcutaneous electrical acupoint stimulation (TEAS) [9-11]. However, there is a lack of meta-analyses specifically focusing on electroacupuncture for PONV. TEAS is a therapy that combines the theory of meridian acupoints in acupuncture with transcutaneous electrical nerve stimulation (TENS). The main difference between TEAS and electroacupuncture lies in the technique used. Electroacupuncture involves needle insertion into the skin, whereas TEAS applies electrodes on the acupoints, making it a non-invasive procedure. Electroacupuncture refers to a contemporary form of acupuncture in which pulsed current stimulation at varying frequencies and techniques is incorporated to enhance the therapeutic effects. This approach has gained widespread acceptance and is extensively used in clinical practice [12]. Compared with traditional acupuncture, electroacupuncture provides objective and precise control over stimulation parameters, allowing for quantitative, stable, and prolonged stimulation of acupoints. However, there is currently a lack of meta-analyses on the use of electroacupuncture for the prevention and treatment of PONV after general anesthesia. Therefore, we conducted this meta-analysis to evaluate the effectiveness of electroacupuncture in PONV after general anesthesia.

Material and Methods

Inclusion and Exclusion Criteria

Two authors used the following inclusion criteria to assess the articles: The study adhered to the Patient, Intervention, Control, Outcome, and Study Design (PICOS) criteria. It involved patients undergoing surgery under general anesthesia. The intervention consisted of electroacupuncture in conjunction with perioperative conventional therapy. The control group consisted of patients receiving only perioperative conventional therapy. The primary outcome of the study focused on the incidence of PONV. The secondary outcomes included the incidence of postoperative nausea (PON) at 6 h, the incidence of postoperative vomiting (POV) at 6 h, and the postoperative antiemetic requirement. Finally, the study design had to be a randomized controlled clinical trial, with a study period between 2016 and 2023. The exclusion criteria were article categories of comments, case reports, crossover studies, letters, editorials, review articles, meta-analysis, and retrospective studies; studies of animal experiments; and studies that involved data that could not be extracted or that lacked sufficient data. If there was any disagreement about the eligibility of an included article, the disagreement was resolved through a discussion session or by the corresponding author.

Search Strategy

The study protocol was registered with PROSPERO, and the findings have been reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [13]. We conducted a comprehensive search on PubMed, Web of Science, and China National Knowledge Infrastructure (CNKI) to identify relevant studies published from October 1, 2016, to 2023, focusing on the use of electroacupuncture for the prevention of PONV. The search strategy used for PubMed was as follows: (electroacupuncture) AND (postoperative nausea and vomiting OR PONV OR nausea and vomiting postoperative OR vomiting, postoperative OR postoperative emesis OR postoperative vomiting OR emesis, postoperative OR emeses, postoperative OR postoperative emeses OR postoperative nausea OR nausea, postoperative) AND (randomized controlled trial). The search strategy employed for Web of Science and CNKI was: (electroacupuncture) AND (postoperative nausea and vomiting) AND (randomized controlled trial). There were no restrictions based on language, sex, age, or type of surgery. No filters were applied during the search process.

Study Selection

Two researchers, Zhenxu Han and Huan Yang, conducted independent reading and screening of the article, extracted the

data, and cross-checked it for any discrepancies. The screening process involved initially reading the title and abstract of the article. After excluding irrelevant articles, the full text was examined to determine whether the inclusion criteria were met. Data were collected using a predefined table that included details such as the first author, country, year, sample size per group, age, patient sex, type of procedure, American Society of Anesthesiologists classification, experimental and control interventions, duration of intervention, outcome, and risk of bias.

Risk of Bias Assessment

The methodological quality of the included studies was evaluated by 2 reviewers (Zhenxu Han and Huan Yang) according to the Cochrane Risk of Bias Assessment Tool provided by Cochrane Reviewer's Handbook 5.3 [14]: (a) selection bias: whether the random allocation method was adopted, type of random allocation method, and type of allocation hiding method was adopted; (b) implementation bias: whether a blinding method was applied on implementers and participants; (c) measurement bias: whether the blinding method was implemented in the outcome evaluation; (d) follow-up bias: whether there was a loss to follow-up or withdrawal and type of analysis method used; (e) report bias: whether there was a selective reporting of results; and (f) other bias: whether there were other sources of bias.

Statistical Analysis

Meta-analysis was conducted using RevMan 5.4.1 software, developed by the Cochrane Collaboration in Oxford, UK. For categorical variables, odds ratios (OR) with 95% confidence intervals (CI) were used. These variables included the incidence of PONV, incidence of PON at 6 h, incidence of POV at 6 h, and the requirement for postoperative antiemetic medication (including only events starting from 0). The χ^2 test and I^2 statistics were used to assess and quantify statistical heterogeneity, measuring the extent of variation resulting from differences in study characteristics. In the absence of significant statistical heterogeneity among the results, a fixed-effect model was implemented for the meta-analysis. Conversely, if statistical heterogeneity was present, a random-effects model was used. The significance level for the meta-analysis was set at $\alpha=0.05$. In cases of substantial clinical heterogeneity, sensitivity analysis was performed using the leave-one-out method, and publication bias assessment was conducted for outcomes that included 10 or more studies.

Subgroup Analysis

To examine the impact of anesthesia mode and the presence or absence of intraoperative antiemetics on the efficacy of electroacupuncture, subgroup analyses were conducted:

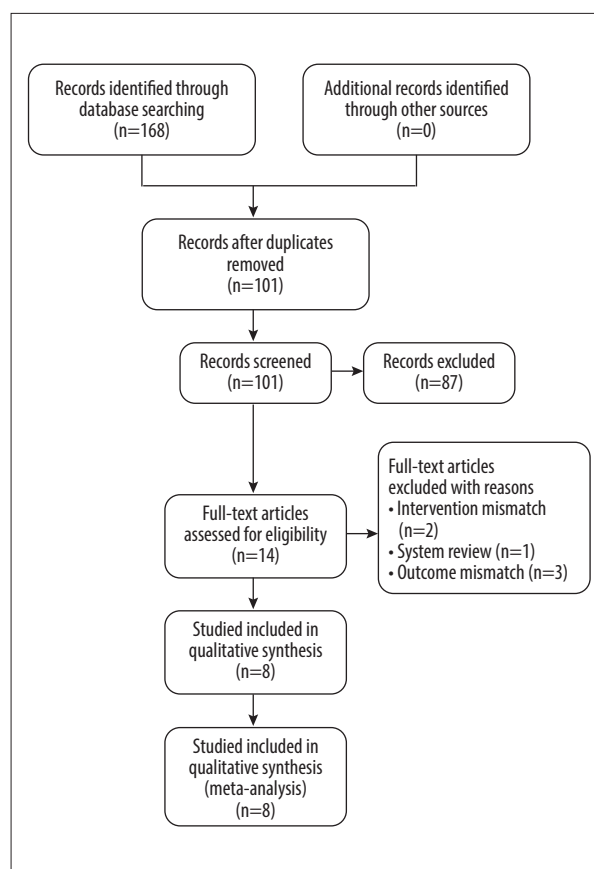


Figure 1. PRISMA flowchart.

- Incidence of PONV: Total intravenous anesthesia vs intravenous inhalation combined anesthesia; continuous wave vs disperse-dense wave;
- PON at 0-6 h: Intraoperative adjunctive antiemetic vs no intraoperative adjunctive antiemetic; continuous wave vs disperse-dense wave;
- POV at 0-6 h: Intraoperative adjunctive antiemetic vs no intraoperative adjunctive antiemetic; continuous wave vs disperse-dense wave;
- Antiemetic requirement: Intraoperative adjunctive antiemetic vs no intraoperative adjunctive antiemetic; continuous wave vs disperse-dense wave.

Results

Study Selection Process

Initially, we retrieved a total of 68 articles, and after conducting a hierarchical screening process, 8 randomized controlled trials [15-22] were included. The selection process is illustrated in Figure 1.

Table 1. Characteristics of the included studies.

Authors, years	Country	Sample size	Type of surgery	ASA
Chen 2018	China	20/20	Total knee arthroplasty	I-II
Fang 2022	China	40/40	Laparoscope surgery	II-III
Li 2017	China	20/20	Laparoscopic gynecological surgery	I-II
Park 2022	Korea	35/29	Thyroidectomy	I-II
Qu 2020	China	47/23	Laparoscopic cholecystectomy	I-II
Praveena 2016	Malaysia	32/32	Transabdominal hysterectomy	I-II
Tong 2022	China	107/34	Breast conserving surgery	I-II
Zhu 2022	China	299/101	Laparoscopic gynecological surgery	I-II

Table 2. Details of interventions.

Authors, years	Time point	Time of treatment	Acupoints	Frequency
Chen,2018	Once daily for 7 consecutive days	30 min	ST34*, SP10*, SP9*, ST36*, ST40*, GB40* (on the operation side)	2 Hz/100 Hz disperse-dense wave; 2~5 mA, intensity of tolerable level
Fang 2022	Thirty min prior to the end of the operation	30 min	Neimadian1 and ST361	2 Hz/100 Hz disperse-dense wave; 1mA
Li 2017	24h before surgery	30 min	Bilateral PC6* and ST36*	20-100 Hz dense-disperse mode; intensity of tolerable level
Park 2022	1 h before and 6 h after surgery	30 min	ST36* and PC6*	25 Hz, continuous wave type, 6-8V
Qu 2020	30 min before surgery and 4, 22, 34, 46h after surgery	30 min	ST36*, PC6*, ST37*	10 Hz 5mA
Praveena 2016	Intraoperatively till the end of the surgery	149.06±42.64 min**	PC6* and LI4*	2 Hz, continuous wave, level 1
Tong 2022	Day before operation;day of operation;both day before operation and the day of operation	30 min	HT7*, PC6*, GV29*, DU20*; bilateral LI 4*, PC 6*, and ST 34*	2 Hz, continuous wave type; intensity of tolerable level
Zhu 2022	The day before surgery; 30 min before surgery; both the day and 30 min before surgery	30 min	PC6* and ST36*	20-100 Hz dense-disperse mode; intensity of tolerable level

* Electroacupuncture points; ** started intraoperatively till the end of the surgery.

Study Characteristics

The characteristics of the included studies are presented in **Tables 1-3**. These 8 studies investigated the impact of electroacupuncture and standard care on PONV following general anesthesia. In all the studies, the interventions consisted of electroacupuncture along with routine perioperative care

in the experimental group, while the control group received only routine perioperative care. Opioid analgesics were administered in all studies. Two studies employed additional antiemetic drugs during the surgery [18,19]. Six of the studies were conducted in China, 1 in Korea, and 1 in Malaysia. A total of 899 participants were included in these 8 studies, with 600 individuals receiving electroacupuncture intervention. In

Table 3. Description of acupoints.

Acupoints	Detailed location
Yintang, GV29	In the forehead, where the middle of the two eyebrows
Baihui, DU20	On the head, 5 cun straight upward from the center of the front hairline
Shenmen, HT7	Ulnar end of distal palmar transverse stripe, radial margin of ulnar carpal flexor tendon
Chize, LU5	In front of the elbow, across the elbow, in the radial margin of the biceps tendon depression
Neiguan, PC6	On the anterior side of the forearm, 2 cun (about 5 cm) proximal to the palmar wrist crease, between the tendons of the palmaris longus and flexor carpi radialis muscles
Hegu, LI4	On the dorsum of the hand, between the first and second metacarpal bones, at the midpoint of the second metacarpal bone and close to its radial border
Liangqiu, ST34	2 cun above the base of the patella, between the lateral femoral muscle and the rectus femoris tendon
Xuehai, SP10	2 cun above the medial end of the patellar base, where the medial femoral muscle rises
Yinlingquan, SP9	In the depression between the lower edge of the medial tibial condyle and the medial edge of the tibia
Zusanli, ST36	3 cun or four finger breaths distal to the base of patella and one finger breadth lateral to the anterior border of the tibia
Shangjuxu, ST37	6 cun below Dubi (ST35), on the line between the Dubi ST35 and Jiexi (ST41)
Fenglong, ST40	8 cun above the tip of the outer ankle, the outer edge of the tibialis anterior muscle
Neimadian	On the medial side of the lower leg, 7 cun above the medial malleolus, 0.5 cun posterior to the tibia
Qixu, GB40	Anteriorly below the outer ankle, in the lateral depression of the extensor digitorum longus tendon

5 studies [15,16,18-20], preoperative electroacupuncture interventions were used, while 3 studies [15,17,21] used intra-operative electroacupuncture interventions, and 3 studies [16,20,22] used postoperative electroacupuncture interventions. Two studies [16,18] used measurement tools to assess the severity of PON and POV, 1 study used the visual analog scale (VAS) score, and the other 2 studies used the 4-point Likert-type severity scale [18].

Study Quality

Among the 8 studies included, 4 studies [15,18,19,21] provided descriptions of allocation concealment methods and used blinding techniques. All 8 studies reported comprehensive information on random sequence generation, and 4 studies [15,18,19,21] provided detailed explanations of allocation concealment methods. The risk of bias is presented in **Figure 2**.

Incidence of PONV

A total of 4 randomized controlled trials [16,20,21,22] reported on the occurrence of PONV in 254 total patients, with 142

patients receiving electroacupuncture and 112 patients not receiving it. The study results revealed no significant difference in the incidence of PONV between the electroacupuncture group and the control group. (OR=0.31, 95% CI [0.06, 1.49], $P=0.14$, $I^2=82\%$; **Figure 3**).

Incidence of PON at 6 h

A total of 4 randomized controlled trials [15,17-19] reported the incidence of PON at 6 h in a total of 645 patients, with 458 patients receiving electroacupuncture and 187 patients not receiving it. The study results indicated that the electroacupuncture group exhibited significant improvement in reducing the incidence of PON at 6 h, compared with the control group (OR=0.43, 95% CI [0.27, 0.67], $P=0.0002$ $I^2=0$; **Figure 4**).

Incidence of POV at 6 h

A total of 3 randomized controlled trials [15,18,19] reported the incidence of POV at 6 h in a total of 581 patients, with 426 patients receiving electroacupuncture and 155 patients not receiving it. The study findings demonstrate that electroacupuncture

A



B

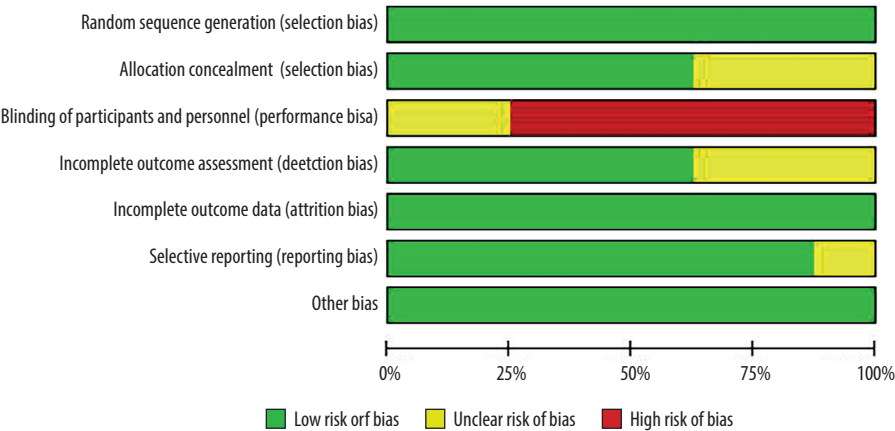


Figure 2. (A, B) Quality assessment of included studies.

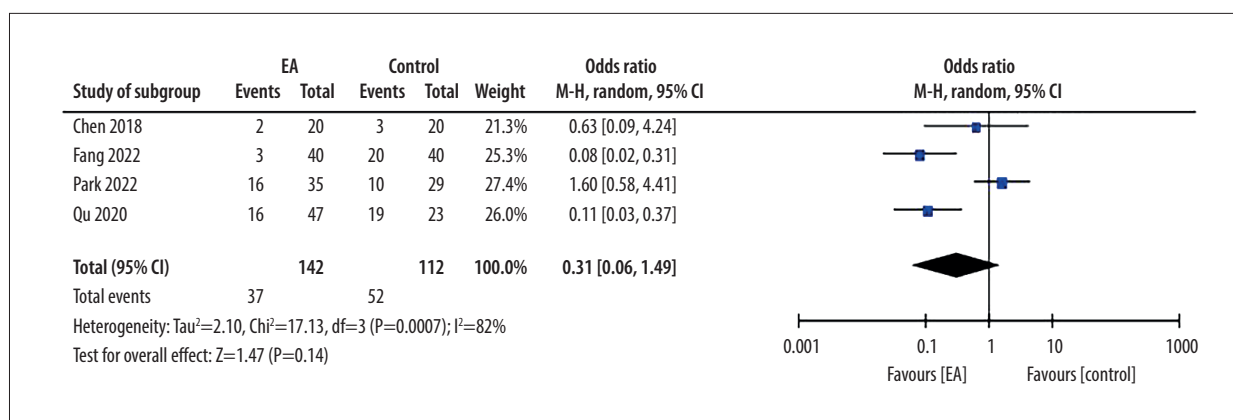


Figure 3. Forest plot showing incidence of postoperative nausea and vomiting.

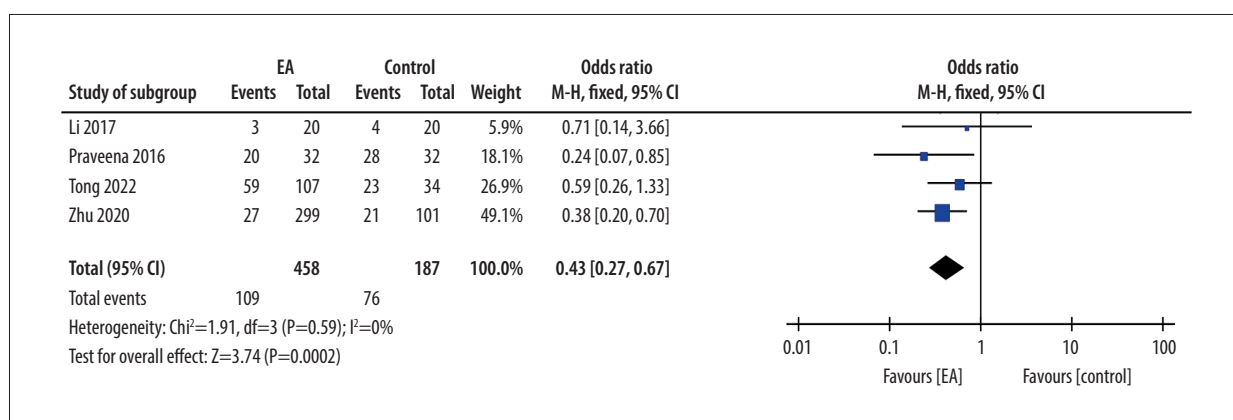


Figure 4. Forest plot showing incidence of postoperative nausea and at 6 h.

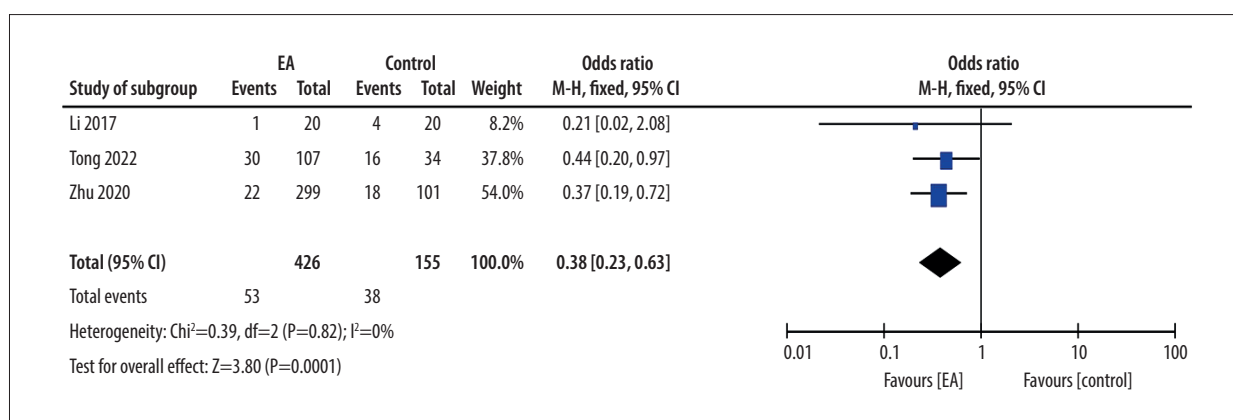


Figure 5. Forest plot showing incidence of postoperative vomiting at 6 h.

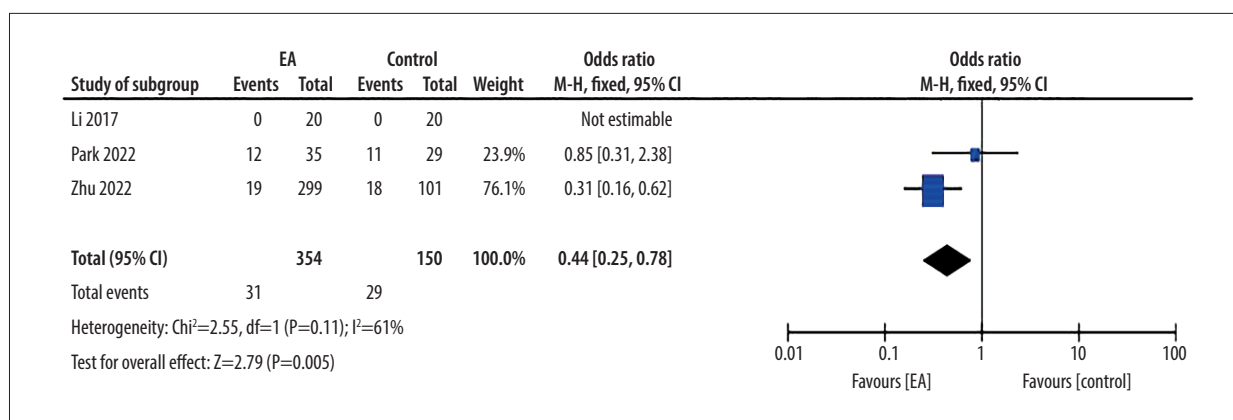


Figure 6. Forest plot showing antiemetic requirement.

significantly reduced the incidence of POV within the first 6 h after surgery, compared with the control group (OR=0.38, 95% CI [0.23, 0.63], $P=0.0001$, $I^2=0\%$; **Figure 5**).

Antiemetic Requirement

A total of 3 randomized controlled trials [16,18,19] reported on the requirement for antiemetic medications in a total of 504 patients, with 354 patients receiving electroacupuncture and 150 patients not receiving it. Compared with the control group, the electroacupuncture group demonstrated a significant reduction in the postoperative requirement for antiemetic medications. (OR=0.44, 95% CI [0.25, 0.78], $P=0.005$, $I^2=61\%$; **Figure 6**).

Subgroup Analysis

Through subgroup analysis, it appeared that the administration of intraoperative antiemetics can influence the efficacy of electroacupuncture, particularly with regard to postoperative antiemetic needs. However, due to the limited number of included articles, the reliability of this result was not high, and further research is required. Regarding the impact of the type of anesthesia used during general anesthesia, based on the restricted number of articles included, we concluded that it had minimal or no effect on the effectiveness of electroacupuncture. Additionally, the waveform of electroacupuncture appeared to affect its therapeutic effectiveness in reducing the incidence of PONV and the requirement for postoperative antiemetic medications, while not significantly impacting other aspects (**Figures 7-10**).

Sensitivity Analysis

For the outcome of the incidence of PONV, the included studies were excluded on a study-by-study basis, and the heterogeneity in the results of the meta-analysis changed after the exclusion of the study Park et al [16]. The forest plot after

exclusion of this study is shown in **Figure 11**. After analysis, it was found that the sex of the patients included in the study [16] was female, whereas the patients included in other studies [20-22] were of both sexes; therefore, the sex of the included patients may be the main reason for the study heterogeneity. However, due to the small number of articles included in the present study, the included articles could not be analyzed in subgroups according to patient sex.

Discussion

Clinical investigations have substantiated that the primary etiology of PONV involves the administration of inhalation anesthesia and opioid analgesics [23]. PONV represents one of the most distressing postoperative symptoms experienced by patients, and inadequate management of PONV leads to prolonged hospital stays and increased healthcare costs [5]. Current clinical strategies for preventing and treating PONV primarily rely on pharmaceutical interventions [24], yet the effectiveness of pharmacological agents in preventing and managing PONV remains unsatisfactory. Reports from certain studies indicate an efficacy rate of only 55.1% for drugs belonging to the ondansetron class [25]. Recent investigations have demonstrated the pivotal role of acupuncture in managing postoperative pain, yielding notable reductions in postoperative pain levels and opioid consumption, thereby mitigating the occurrence of opioid-induced adverse effects, such as nausea and vomiting [26,27]. Both animal and human studies have revealed that preoperative electroacupuncture facilitates an elevation in enkephalin and β -endorphin levels, thereby conferring beneficial analgesic effects [28-30]. Furthermore, additional research has elucidated how acupuncture modulates serotonin and dopamine levels, which are targeted by common antiemetic drugs [31,32], potentially contributing to the suppressive impact of acupuncture on PONV. In comparison with antiemetic drugs, acupuncture offers distinct advantages, including minimal physiological perturbation and a lower incidence of adverse effects [33].

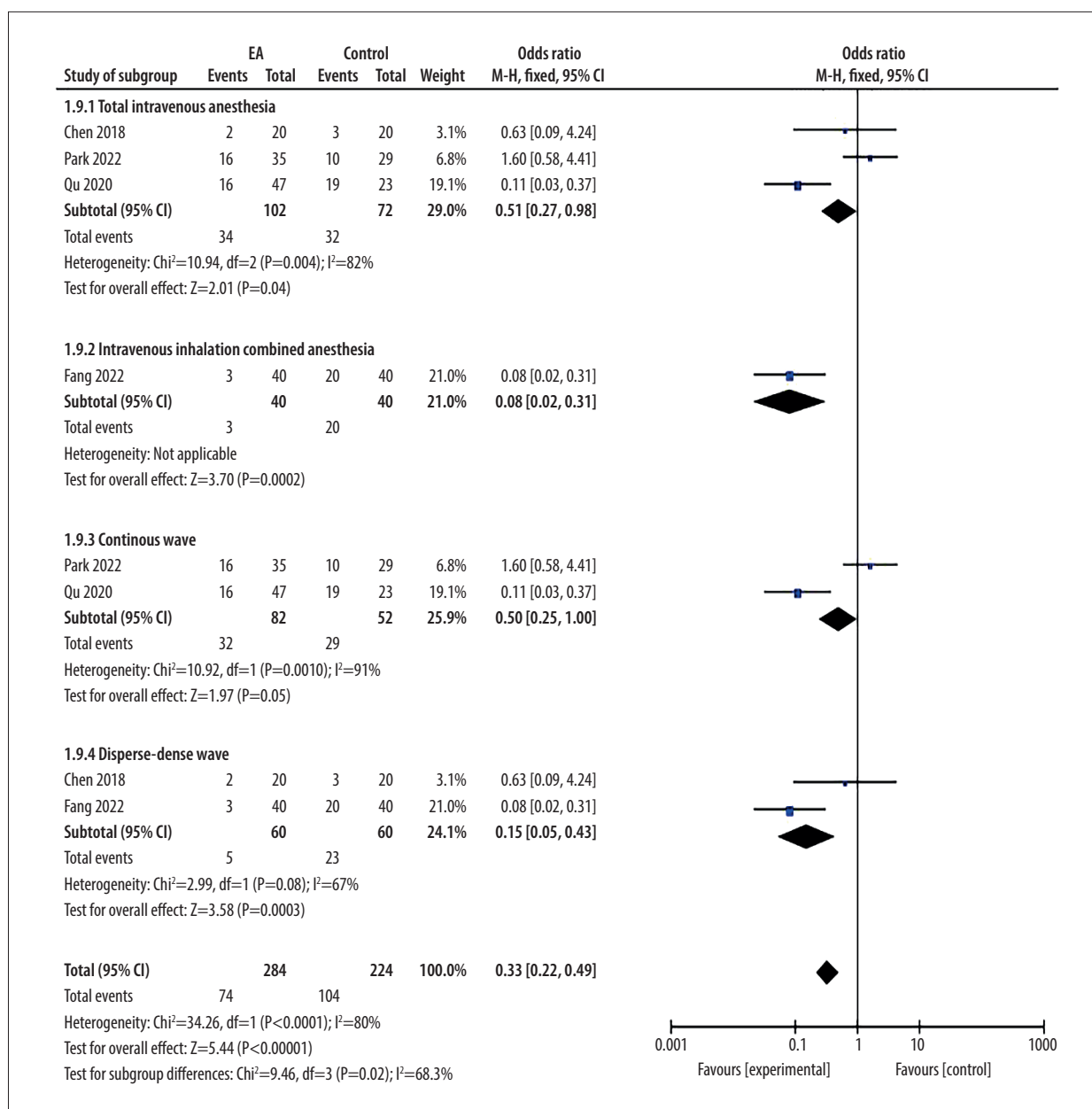


Figure 7. Forest plot showing incidence of postoperative nausea and vomiting. Total intravenous anesthesia vs combined intravenous-inhalation anesthesia. Continuous wave vs disperse-dense wave.

Manual acupuncture, involving manual manipulation of needles to elicit the de qi sensation, represents a therapeutic modality. Electroacupuncture, derived from manual acupuncture, boasts the ability to quantitatively and repetitively administer stimulation, facilitating objective control of the degree of stimuli for quantitative analysis [34]. Furthermore, an investigation examining resting-state fMRI findings revealed distinct enduring effects of manual acupuncture and electroacupuncture on the Zusanli (ST36) acupoint, with electroacupuncture demonstrating a broader range of activation [35]. Therefore, the aim of the present study was to evaluate and investigate

the clinical efficacy of electroacupuncture in mitigating PONV after general anesthesia, with the intention of making a valuable contribution to the existing literature.

This meta-analysis indicated that there was no significant difference in reducing the incidence of PONV between the electroacupuncture group and the postoperative conventional care group. However, the study findings showed statistically significant differences between the electroacupuncture group and the control group in preventing PON and POV at 6 h, as well as reducing the usage of antiemetic medication after surgery.

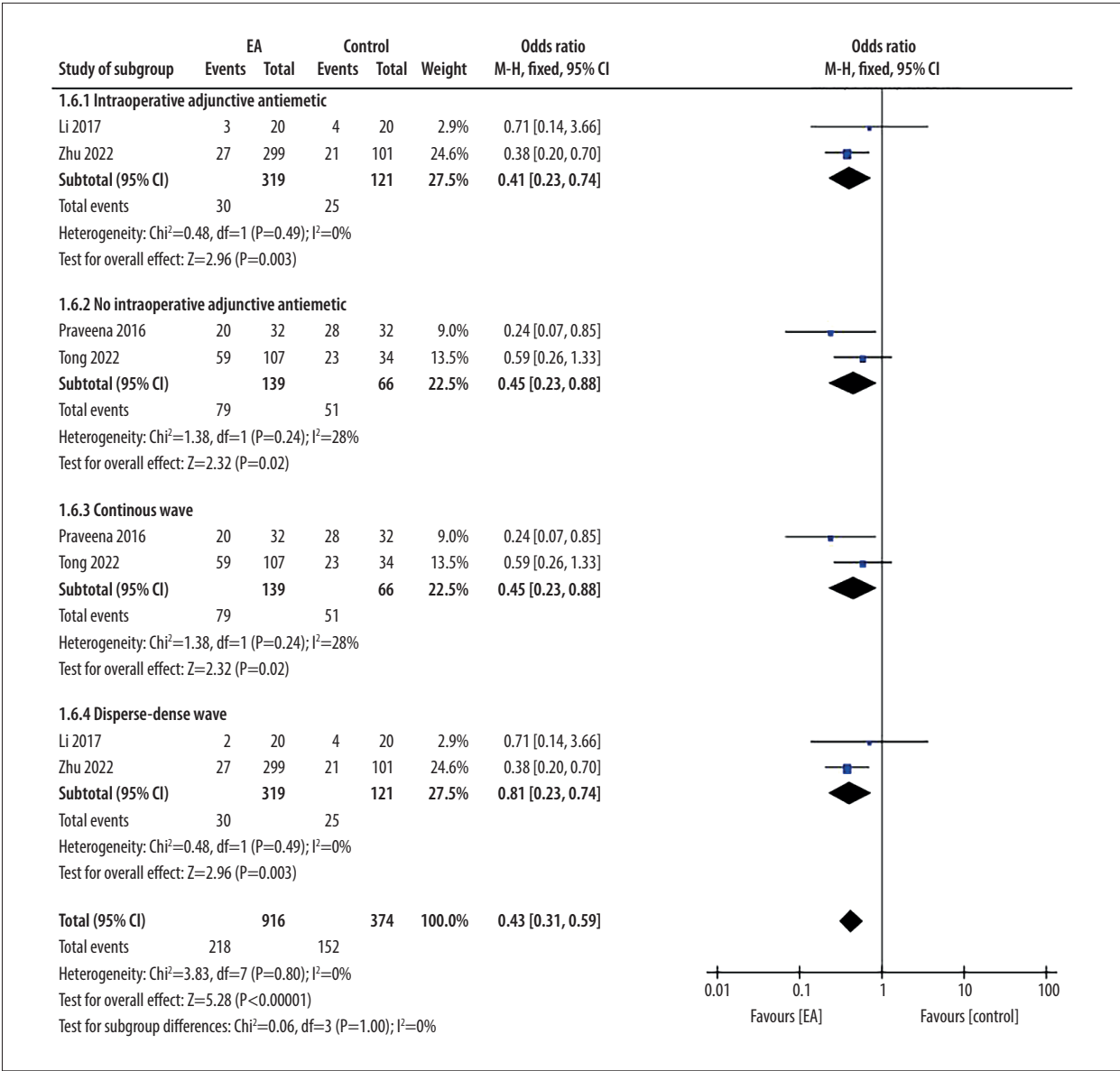


Figure 8. Forest plot showing postoperative nausea at 0-6 h. Intraoperative adjunctive antiemetic vs no intraoperative adjunctive antiemetic. Continuous wave vs disperse-dense wave.

One study included in the analysis reported adverse events. Therefore, electroacupuncture is considered a safe adjunctive therapy for preventing PONV following general anesthesia.

However, our study has several limitations: (1) The number of randomized controlled trials included in this study and the sample size of participants were insufficient to draw specific conclusions. We recommend conducting a multicenter randomized controlled trial with a larger sample to mitigate bias. (2) Additionally, there are certain issues with the reporting of efficacy indicators for the prevention of PONV using electroacupuncture. For instance, variations exist in the timing of PONV observation across different articles, thereby making it challenging to incorporate

certain results into this systematic study and provide a higher level of evidence for clinical trials. (3) Out of the 8 studies analyzed, only 2 studies, involving 128 total patients, were conducted in other countries, with the majority of the study population being from China. This highlights a lack of similar large-scale international multicenter clinical trials. (4) During the sensitivity analysis of the PONV indicator in this study, sex was identified as a significant factor contributing to heterogeneity and influencing the results. However, due to limited relevant studies, subgroup analysis could not be performed. (5) The potential cofounders influencing the efficacy of electroacupuncture were not thoroughly investigated, and variables such as the type of procedure and its duration were not further explored.

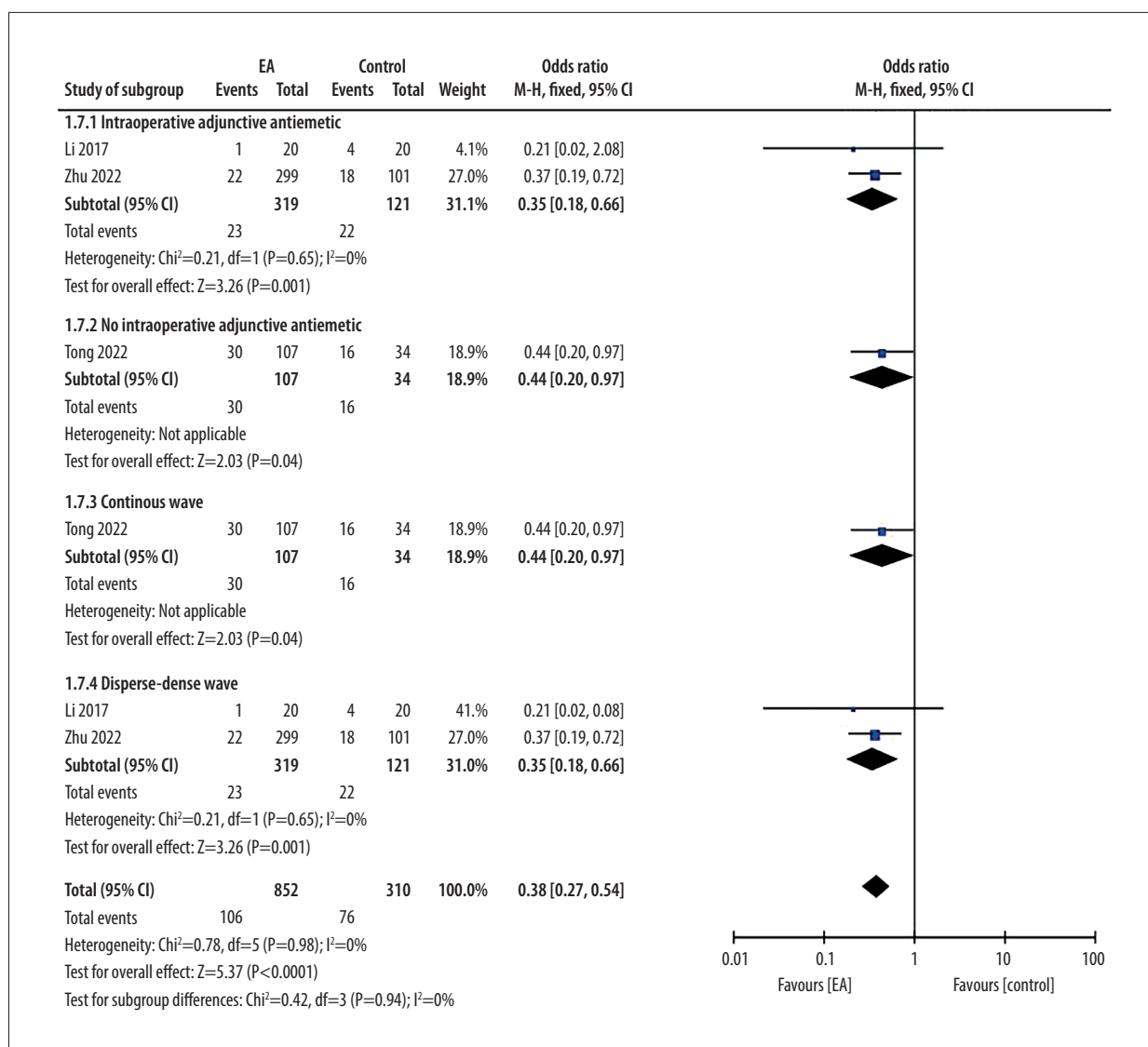


Figure 9. Forest plot showing postoperative vomiting at 0-6 h. Intraoperative adjunctive antiemetic vs no intraoperative adjunctive antiemetic. Continuous wave vs disperse-dense wave.

Conclusions

In summary, we conducted a comprehensive statistical analysis of outcome data regarding the use of electroacupuncture for the prevention and treatment of PONV after general anesthesia. The pooled data from a randomized controlled trial indicate that electroacupuncture significantly reduces the incidence of PON and POV at 6 h after surgery, as well as the antiemetic requirement. However, there is no significant difference between the electroacupuncture group and the control group in terms of the incidence of PONV. Regarding safety, electroacupuncture carries a minimal risk of pain and itching at the needle insertion site. To provide more precise guidance for clinical practice, it is necessary to conduct longer-duration and larger-scale randomized controlled trials to evaluate the

effectiveness and safety of electroacupuncture in the prevention and treatment of PONV.

Data Availability

The article, tables, and figures contain the original contributions presented in the study. Any additional questions should be directed to the corresponding author.

Declaration of Figures' Authenticity

All figures submitted have been created by the authors, who confirm that the images are original with no duplication and have not been previously published in whole or in part.

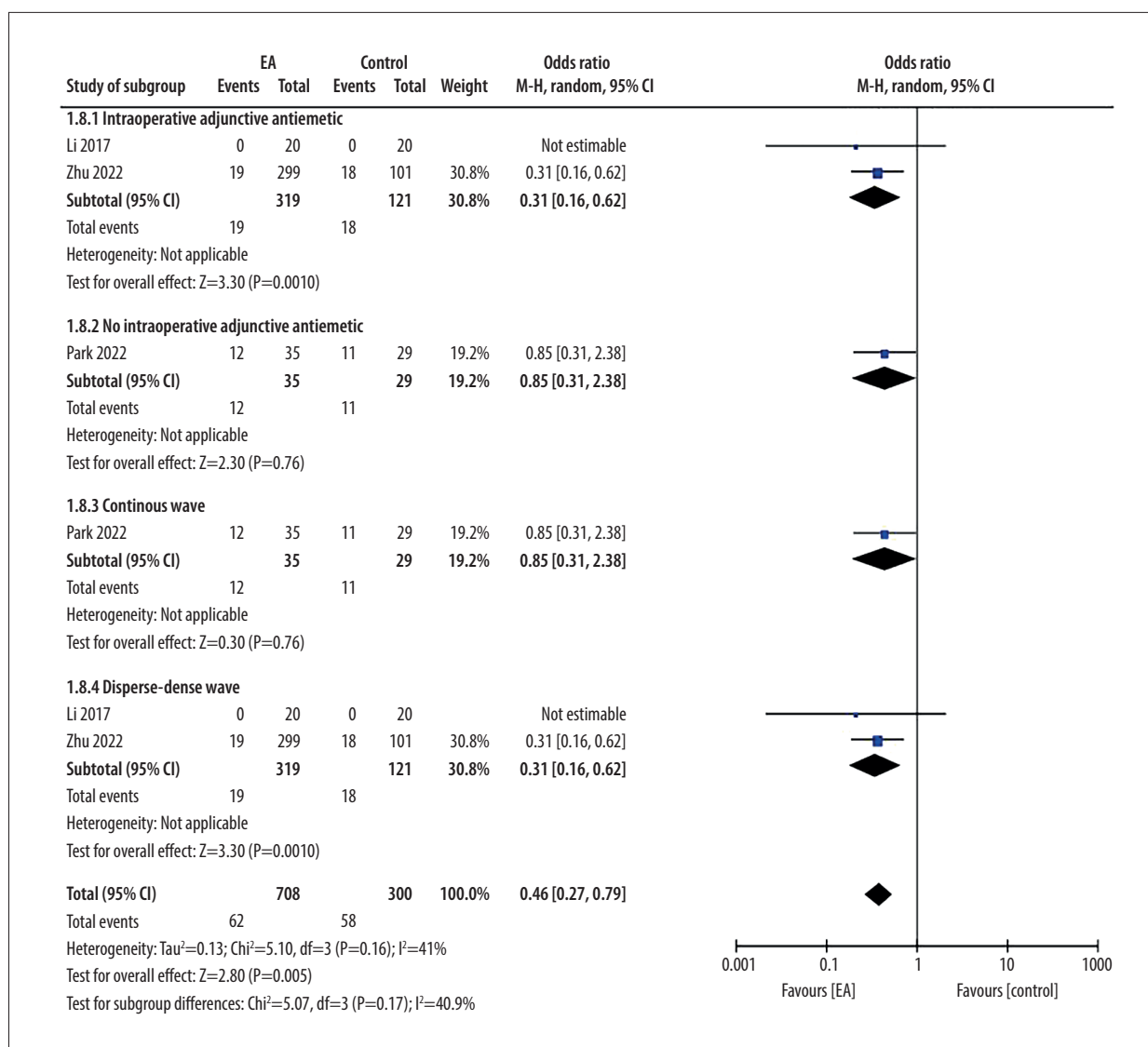


Figure 10. Forest plot showing antiemetic requirement. Intraoperative adjunctive antiemetic vs no intraoperative adjunctive antiemetic. Continuous wave vs disperse-dense wave.

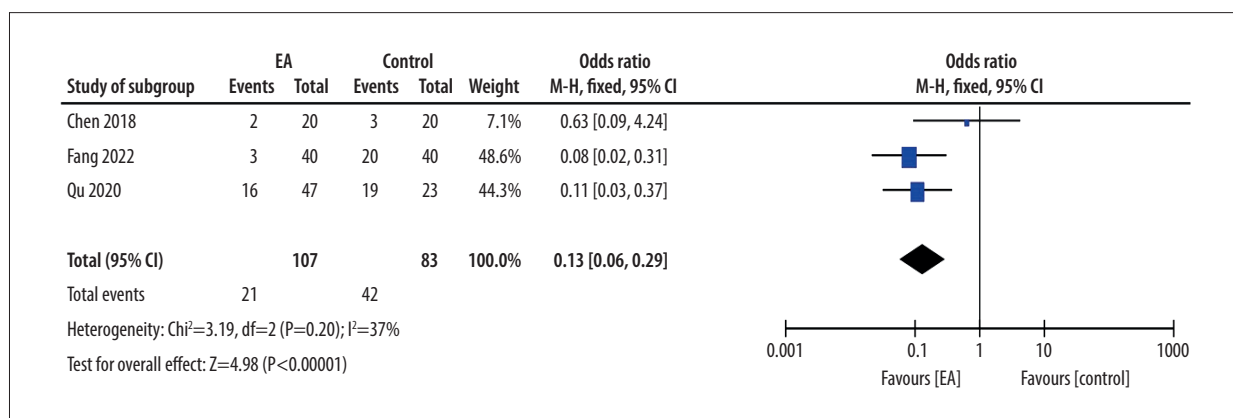


Figure 11. Forest plot showing incidence of postoperative nausea and vomiting after exclusion.

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