Application and efficacy of transcutaneous electrical acupoint stimulation (TEAS) in clinical practice: A systematic review

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A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation; D – writing the article; E – critical revision of the article; F – final approval of the article

Abstract

Transcutaneous electrical acupoint stimulation (TEAS) is an emerging therapeutic approach that combines the effects of transcutaneous electrical nerve stimulation (TENS) with acupuncture point stimulation. Due to its noninvasive nature, it possesses relative advantages over traditional acupuncture and needle-based electrostimulation. Despite the large number of randomized clinical trials (RCTs) describing the effectiveness of TEAS in different applications, its role and mechanism are still not fully understood. The aim of this study was to systematically compare and summarize the latest studies examining a variety of TEAS applications in clinical practice. Databases, including Medline (PubMed), Cochrane Library and Google Scholar were searched without any time restrictions (as of March 2021). The analysis was performed according to the Cochrane Collaboration criteria. Out of 637 studies, only 22 RCTs were selected. Nine studies evaluated the impact of TEAS on nausea and vomiting (NV), showing beneficial effects compared to standard therapy. Eight RCTs examined the effectiveness of TEAS in pain management, reporting pain alleviation described using the visual analog scale (VAS) and lowering of total opioid doses. Improvement of postoperative recovery, in vitro fertilization and pregnancy outcomes, as well as display of cardioprotective properties were found to positively correlate with TEAS. As a noninvasive modality with advantages over classical acupuncture and needle-based electrostimulation, TEAS may be a valuable tool in clinical practice, particularly for pain and NV management. However, considering the methodological quality of the RCTs, rigorous large-scale clinical trials are required to evaluate the clinical utility of this method.

Key words: systematic review, randomized controlled trials, TEAS, clinical practice, transcutaneous electrical acupoint stimulation
Introduction

Over the last 1,000 years, acupuncture has remained a crucial component of Traditional Chinese Medicine. Originally, it was performed by applying specialized acupuncture needles into specific loci on the body, known as meridians. However, during the last several decades, the technique of acupuncture has evolved, and currently, a modified form called transcutaneous electrical acupoint stimulation (TEAS) has garnered widespread interest. The TEAS is a contemporary therapeutic method combining stimulation of acupuncture points and transcutaneous electrical nerve stimulation (TENS). Consequently, the essence of TEAS is the stimulation of sensory nerve endings along acupuncture meridians through the application of low-voltage electrical current. The modality exerts its biological effects through various molecular pathways, including the release of endogenous opioids. Hence, the results of recent studies reveal a broad spectrum of both therapeutic and prophylactic applications of TEAS in clinical practice. The TEAS remains a widely used tool with a variety of uses, including recovery of gastrointestinal function, reduction of the occurrence of postoperative cognitive dysfunction, nausea and vomiting relief, enhancement of immune function, protection of organ function, acceleration of postoperative recovery, reduction of systolic blood pressure in patients with hypertension, and enhancement of patients’ degree of overall comfort. This technique has also been proven helpful in alleviating inflammation and cancer-related pain. Moreover, TEAS has found a clinical application in treating various kinds of reproductive disorders, such as polycystic ovary syndrome (PCOS), pain induced by oocyte retrieval, diminished ovarian reserve, embryo transfer, and oligospermia. Its promising potential is predominantly reported in pain prevention, obstetrics and anesthesiology. Moreover, further analysis of the literature shows that TEAS may be utilized as a standalone therapy or as an adjuvant to established therapies, which could positively impact the quality of patient care. Furthermore, unlike traditional acupuncture, TEAS utilizes electrodes that are fixed to the skin through a patch, making the method noninvasive and, above all, safe for the patient. To date, its usage has been reported in both children and adolescents. Furthermore, the therapy has the advantage of being easy to use and requires minimal training for physicians, technicians and patients. As a noninvasive acupuncture strategy, TEAS can even be performed at home by patients themselves without a prescription. Both patients and caregivers could participate in the clinical application of TEAS after a short but accurate training. However, despite many clinical applications, there are some limitations of TEAS. Firstly, there is a significant amount of conflicting data in the literature regarding the effectiveness of the technique. Moreover, limited access to electrostimulators for patients has also been reported to be a challenge. In addition, the lack of TEAS-trained health personnel is a significant issue that needs to be addressed. Growing research on the application of TEAS in evidence-based practice emphasizes the need to systematize the current evidence. Therefore, we conducted a systematic review of randomized clinical trials (RCTs) evaluating the possible applications of TEAS in clinical practice and reviewed the benefits in the reported indications.

Objectives

The aim of this systematic review was to compare and summarize the findings of TEAS trials across various medical indications and provide an evaluation of its effectiveness in comparison to placebo or standard therapy.

Materials and methods

Databases

Medline (PubMed), Cochrane Library and Google Scholar databases were searched without any publication date restrictions (publication date: from inception to March 2021). Articles published after March 2021 were not included in this review due to either their publication date being beyond the custom time range or not meeting custom criteria. Although the search strategy had to be altered to meet limitations of each database, the following phrases were searched invariably: “transcutaneous electrical acupoint stimulation” OR “TEAS”. The aforementioned terms were searched in titles and abstracts in order to initially qualify the research for a systematic review. Subsequently, the papers were thoroughly analyzed and assessed according to the Cochrane Collaboration criteria and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).

Criteria of inclusion and exclusion

For the purpose of evaluating the efficacy and efficiency of TEAS, we included only RCTs in which the TEAS treatment group received either standalone TEAS treatment or where it was an adjuvant to standard therapy and was compared to a) a control group (not receiving TEAS and/or standard therapy) or b) a placebo group (receiving sham TEAS and/or standard therapy). Moreover, the participants had to be randomly assigned to the appropriate group, irrespective of age, sex, ethnicity, place of residence, underlying disease, or comorbidities. It is worth noting that not all of the analyzed RCTs contained information about each of these patient characteristics. Furthermore, this systematic review only considered research assessing transdental nerve stimulation in points typical for acupuncture, regardless of length, voltage or acupoint chosen for TEAS therapy.
The following studies were excluded from the analysis: 1) not stating inclusion or exclusion criteria; 2) evaluating the effectiveness of traditional acupuncture, electroacupuncture (with the use of needles) or transdermal nerve stimulation in loci other than acupuncture points; 3) assessing the efficacy and effectiveness of TEAS without comparison to a control group; 4) applying any – even minimal – voltage in either the control or placebo group; 5) evaluating TEAS in places other than acupuncture points; 6) conducted on a pediatric population; and 7) conducted on animals.

**Data extraction and assessment of the risk of bias**

One author (RK) conducted an initial analysis followed by a detailed review of studies. The 2nd author (SA) verified the research included in the systematic review. Any discrepancies were critically discussed and revised. The primary analysis of RCTs comprised of assessing their 1) validity; 2) type; 3) means of randomization; 4) description of all medical procedures among participants (e.g., type of anesthesia, form and dosage of medication); 5) means of arranging experimental control and placebo groups; and 6) tools (e.g., scales, computer programs) used to extract and present the results. The next phase of analysis involved a detailed assessment of the test group, in particular 1) sample size; 2) acupuncture points applied with precise names and locations; 3) voltage (mA), frequency (Hz) of applied current and length of therapy (s or ms); and 4) exact moment of initiation of treatment (e.g., 30 min before the general anesthesia). At the same time, in the placebo/control group assessment, the following was examined: 1) sample size; 2) location of sham electrodes; and 3) type of intervention.

**Results**

A total of 22 RCTs (Fig. 1, Table 1) that met the inclusion criteria were selected from 637 studies. Almost all of the studies were conducted in Asia (China in particular). The included RCTs focused mainly on assessing the efficacy and effectiveness of TEAS in preventing nausea and vomiting (NV) and pain alleviation. However, some studies examined other indications for TEAS therapy. The RCTs were significantly diversified in terms of the sample size, although most of them had a small experimental TEAS and control/placebo groups. Among the analyzed RCTs, only a few were based on a sample of female participants only.

In terms of randomization, from a total of 22 analyzed studies, only a few were appropriately conducted. For instance, most of the excluded studies included participants randomized using incorrect baseline information, multiple randomizations being performed for the same participant or a lack of double-blinding, which might have impacted the observed outcomes.

**Effectiveness of TEAS in preventing NV**

Yang et al. compared the effectiveness of TEAS with dexamethasone (Acu group), dexamethasone with tropisetron (Trp group), and dexamethasone only (Dxm group) in counteracting postoperative nausea and vomiting (PONV) 24 h after surgery. Compared to standalone glucocorticosteroid therapy, the Acu group presented a significantly lower risk of PONV (p = 0.048, odds ratio (OR) = 0.389, 95% CI: 0.170–0.891). Simultaneously, the authors did not show any difference in the reduction of PONV between the Acu group and Trp group (p = 0.857). The same study showed no difference between all of the groups in demand for anti-emetics (Acu group: 10%, 95% CI: 1–19%; Trp group: 8%, 95% CI: 0–15%; Dxm group: 14%, 95% CI: 4–24%). Similarly, Liu et al. have shown the benefits of TEAS therapy in reducing PONV incidence 24 h after operation. Authors have noted 14/48 (30%) PONV in the TEAS group and 31/48 (65%) in a standard therapy group. The attained relation was statistically significant (p < 0.05). At the same time, the TEAS group received fewer anti-emetics than the control group (p < 0.05). Zheng et al. also observed a reduction of PONV in the first 24 postoperative hours among patients receiving TEAS (5/30, 17%) in comparison to the control group (14/30, 47%). The correlation was statistically significant (p < 0.05). Xu et al. reported a possible efficiency in PONV prevention on the day after surgery, comparing the TEAS group to the non-TEAS group (nausea: 33% compared to 58%, p = 0.008; vomiting: 22% compared to 41%, p = 0.025). On the other hand, Ho et al. demonstrated that the occurrence of PONV was only slightly lower in the TEAS group compared to traditional therapy (9/25 (36%) compared to 11/25 (44%), respectively), and the relationship was not statistically significant.
<table>
<thead>
<tr>
<th>Study</th>
<th>Publication year</th>
<th>Country</th>
<th>Study type</th>
<th>Acupuncture points</th>
<th>Characteristics of the study participants</th>
<th>Clincal indication</th>
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</thead>
<tbody>
<tr>
<td>Xie et al.</td>
<td>2017</td>
<td>China</td>
<td>Single-blind RCT</td>
<td>Hegu (LI4), Neiguan (P6), Zusanli (ST36)</td>
<td>72 participants, active acupuncture group: 70 mA, 4 Hz, 6 days; control group: 70 mA, 2 Hz, 2-10 days</td>
<td>TEAS combined with palonosetron for chemotherapy-induced NV</td>
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<td>Yang et al.</td>
<td>2015</td>
<td>China</td>
<td>Prospective double-blind RCT</td>
<td>Neiguan (P6)</td>
<td>50 participants, active acupuncture group: 65 mA, 2 Hz, 2-10 days; control group: no electrical stimulation</td>
<td>TEAS combined with palonosetron for chemotherapy-induced NV</td>
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<td>Xu et al.</td>
<td>2012</td>
<td>China</td>
<td>Prospective randomized study</td>
<td>Neiguan (P6)</td>
<td>65 participants, active acupuncture group: 48 mA, 2-100 Hz, 30 min before induction of anesthesia and lasted up to 24 h postoperatively; control group: no treatment</td>
<td>TEAS on PONV in patients after infratentorial craniotomy</td>
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<td>Liu et al.</td>
<td>2008</td>
<td>China</td>
<td>Prospective randomized study</td>
<td>Neiguan (P6)</td>
<td>48 participants, active acupuncture group: 30 mA, 2-100 Hz, 30 min before and after operation; control group: no treatment</td>
<td>TEAS for preventing PONV after laparoscopic cholecystectomy</td>
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<td>Zheng et al.</td>
<td>2008</td>
<td>China</td>
<td>RCT</td>
<td>Hegu (LI4), Neiguan (P6), Zusanli (ST36)</td>
<td>30 participants, active acupuncture group: 25 mA, 2-100 Hz, 30 min before leaving PACU and at 24 h after surgery; control group: no treatment</td>
<td>TEAS for transverse abdominal plane block for postoperative analgesia in abdominal surgery</td>
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<tr>
<td>Ho et al.</td>
<td>1990</td>
<td>Taiwan</td>
<td>Double-blind randomized clinical trial</td>
<td>Neiguan (P6)</td>
<td>25 participants, active acupuncture group: 25 mA, 2-100 Hz, 3-15 min; control group: no treatment</td>
<td>TEAS for transverse abdominal plane block for postoperative analgesia after ureteroscopic lithotripsy</td>
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<tr>
<td>Zhan and Tian</td>
<td>2020</td>
<td>China</td>
<td>Single-blind RCT</td>
<td>Zusanli (ST36)</td>
<td>30 participants, active acupuncture group: 25 mA, 2-100 Hz, 2-15 min; control group: usual care group</td>
<td>TEAS and postoperative analgesia after ureteroscopic lithotripsy</td>
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<tr>
<td>Tu et al.</td>
<td>2019</td>
<td>Taiwan</td>
<td>Double-blind randomized clinical trial</td>
<td>Shenyu (BL23), Yinlingquan (SP9)</td>
<td>60 participants, active acupuncture group: 60 mA, 2-100 Hz, 3-15 min; control group: no treatment</td>
<td>TEAS at the acupuncture points for postoperative analgesia in patients under mechanical ventilation</td>
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<tr>
<td>AminiSaman et al.</td>
<td>2018</td>
<td>Iran</td>
<td>Double-blind randomized clinical trial</td>
<td>Hegu (LI4), Zusanli (ST36)</td>
<td>25 participants, active acupuncture group: 25 mA, 2-100 Hz, 3-15 min; control group: no treatment</td>
<td>TEAS at the acupuncture points for postoperative analgesia in patients under mechanical ventilation</td>
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<td>Study</td>
<td>Country</td>
<td>Publication year</td>
<td>Study type</td>
<td>Interventions</td>
<td>n (TEAS)</td>
<td>n (control)</td>
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<td>Yeh et al.26</td>
<td>Taiwan</td>
<td>2018</td>
<td>randomized clinical trial</td>
<td>Electroacupuncture (BL57, EX–UE2)</td>
<td>39</td>
<td>41</td>
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<tr>
<td>Liu et al.28</td>
<td>China</td>
<td>2015</td>
<td>randomized blind controlled trial</td>
<td>Electroacupuncture (LI4, EX–B2, PC6, GB20, GB40, BL10, BL2, EX–HN4)</td>
<td>46</td>
<td>46</td>
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<tr>
<td>Chen et al.29</td>
<td>China</td>
<td>2015</td>
<td>prospective triple-blind randomized placebo-controlled trial</td>
<td>Optimal intensity was set to initiate visible slight twitching of the surrounding muscle.</td>
<td>114</td>
<td>115</td>
</tr>
<tr>
<td>Lan et al.21</td>
<td>China</td>
<td>2012</td>
<td>RCT</td>
<td>Electroacupuncture (P6, LI4, ST36, GB31, EX–HN1)</td>
<td>30</td>
<td>30</td>
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<tr>
<td>Wang et al.27</td>
<td>USA</td>
<td>1997</td>
<td>prospective double-blind randomized placebo-controlled trial</td>
<td>Electroacupuncture (GV20, EX–HN3, ST36, PC6)</td>
<td>25</td>
<td>25</td>
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<tr>
<td>Yu et al.36</td>
<td>China</td>
<td>2020</td>
<td>prospective double-blind randomized placebo-controlled trial</td>
<td>Electroacupuncture (GV20, EX–HN3, ST36, PC6)</td>
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<td>Study</td>
<td>Publication year</td>
<td>Country</td>
<td>Study type</td>
<td>Acupuncture points</td>
<td>Characteristics of the study participants</td>
<td>Clinical indication</td>
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<td>intervention group/control/placebo/other group</td>
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<td>Chi et al.</td>
<td>2019</td>
<td>China</td>
<td>prospective randomized trial</td>
<td>Zusanli (ST36)/Sanyinjiao (SP6)/Neiguan (PC6)/Quchi (L111)</td>
<td>26 (TEAS)/ind**/2/10/30 min before the epidural</td>
<td>TEAS for improving postoperative recovery, reducing stress and inflammatory responses</td>
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<td>in the same place as in the intervention group but with no stimulation</td>
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<tr>
<td>Li et al.</td>
<td>2019</td>
<td>China</td>
<td>single-center prospective trial</td>
<td>Neiguan (PC6)/Ximen (PC4)</td>
<td>61 (TEAS)/ind**/4/20/30 min before anesthesia</td>
<td>cardioselective effect of TEAS on perioperative elderly patients with coronary heart</td>
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<td>induction until the end of surgery</td>
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<tr>
<td>Bai et al.</td>
<td>2018</td>
<td>China</td>
<td>prospective randomized trial</td>
<td>Hegu (LI4)/Neiguan (PC6)/Lieque (LI7)/Chia (L5)/Futu (L18)/Renying (ST9)</td>
<td>37 (TEAS)/6–15/2/10/30 min before anesthesia</td>
<td>TEAS on the stress response during extubation after general anesthesia in elderly</td>
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<td>patients with coronary heart disease</td>
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<td>Qu et al.</td>
<td>2017</td>
<td>China</td>
<td>prospective randomized trial</td>
<td>Xuehai (SP10)/Diji (SP8)/Taichong (LR3)/Zusanli (ST36)/Zigong (EX–CA1)/Guanyuan (RN4)/Neiguan (PC6)/Zhongwan (RN12)</td>
<td>108 (TEAS–2)/1/111 (TEAS–100)/114 (TEAS–2/100)/2/100/30 min respectively at 24 h before TVOR and 2 h before ET</td>
<td>TEAS improves the outcomes of IVF</td>
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<tr>
<td>Zheng et al.</td>
<td>2015</td>
<td>China</td>
<td>randomized controlled study</td>
<td>Guanyuan (RN4)/Zhongzi (RN3)/Sanyinjiao (SP9)/Zigong (EX–CA1)/Tianhu (ST25)/Shenyu (BL23)/Yaoyangguan (DU3)/Mingmen (DU4)</td>
<td>56 (TEAS)/2–25/2/lasted for 30 min and was given once a day, after 3 courses, the treatment continued during the ovulation cycle until the day of egg retrieval</td>
<td>TEAS on ovarian reserve of patients with diminished ovarian reserve in in vitro</td>
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<td>fertilization and embryo transfer cycles</td>
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<td>Jones and Ngai</td>
<td>2014</td>
<td>Australia/China</td>
<td>randomized placebo-controlled crossover design</td>
<td>Neiguan (PC6)</td>
<td>10 (acu-TENS)/ind**/2/45 min before exercise/10 (placebo)</td>
<td>similar to the acu-TENS protocol but without electrical output from the TENS unit</td>
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<td>acu-TENS lowers blood lactate levels and enhances heart rate recovery after exercise</td>
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<tr>
<td>Ngai and Jones</td>
<td>2013</td>
<td>China</td>
<td>double-blind randomized crossover study</td>
<td>Feishu (BL13)</td>
<td>9 (acu-TENS)/the highest tolerable intensity but short of pain/2/45 min</td>
<td>electrodes applied in the same place as in the intervention group but with no stimulation</td>
</tr>
</tbody>
</table>

RCT – randomized controlled trial; TEAS – transcutaneous electrical acupoint stimulation; TENS – transcutaneous electrical nerve stimulation; TAP – transverse abdominal plane block; IVF – in vitro fertilization; EAF – electroacupuncture; N/A – not applicable; N/D – no data; POMV – postoperative nausea and vomiting; PACU – post-anesthesia care unit; TVOR – transvaginal oocyte retrieval; ET – embryo transfer; AEC – artificial endometrial cycle treatment; FHP – comforting false Han’s placebo; PCA – patient-controlled analgesia; n* – the number of participants included in the appropriate group; ind** – individually – the highest tolerable level that caused no discomfort for the participants.
Xie et al. evaluated whether a combination of TEAS and palonosetron might alleviate nausea and/or vomiting in patients undergoing intravenous chemotherapy for late-stage liver cancer. Results showed a reduction of NV incidence and nausea intensity, although the correlation was not statistically significant (p > 0.05).23 In conclusion, the majority of the studies showed a positive role for TEAS in the reduction of NV after surgery. However, not all RCTs clearly present significant differences between TEAS and non-TEAS groups in this regard. Table 2 presents a summary of RCTs assessing the effectiveness of TEAS in NV prophylaxis.

### Effectiveness of TEAS in pain alleviation

Tu et al. demonstrated that in comparison to the control group, patients receiving TEAS were characterized by lesser pain, as evaluated using the visual analog scale (VAS) in the 4th (p = 0.01), 12th (p = 0.03) and 24th (p < 0.01) hour after surgery. The same study showed that patients in the TEAS group received fewer analgesics during the first 48 h post-operation compared to the control group (127.14 ±28.46 compared to 415.27 ±86.37, p < 0.01).24 AminiSaman et al. investigated the relationship between TEAS and pain reduction after mechanical lung ventilation. Compared to the control group, the TEAS group was less prone to pain (p < 0.05) and, simultaneously, received fewer analog-sedatives in the postoperative period.25 Similar results were obtained by Yeh et al.26 and Wang et al.27 On the other hand, Liu et al. evaluated whether the use of TEAS could affect the course of anesthesia and analgesia in patients undergoing supratentorial craniotomy. The results showed that in comparison to the control group, the TEAS group received fewer anesthetics during surgery (sufentanil: 95.6 ±21.76 µg compared to 117.7 ±37.95 µg, p < 0.05; propofol: 216.3 ±67.72 mg compared to 234.1 ±71.30 mg). Moreover, the researchers reported a lower pain rate (described using VAS) in the TEAS group on the 1st day after surgery (p < 0.001). Nevertheless, the same study showed that VAS rates were higher in the 2nd and 3rd days following surgery in the TEAS group than in the control group.28 Chen et al. assessed pain levels after the application of TEAS in patients undergoing colonoscopy. Compared to the control group, the TEAS group showed a statistically significant reduction of pain (p = 0.007) after the procedure – in the TEAS group, only 13/114 (11.4%) showed symptoms of pain compared to 29/115 (25.2%) in the control group.29 Furthermore, TEAS, in combination with other therapeutic methods, might have an impact on patient outcomes. Zhan and Tian evaluated whether combining TEAS with transversus abdominis plane block (TAP) impacts postoperative pain alleviation. The study showed that the TAP and TEAS combination significantly reduced pain 24 h and 48 h after an abdominal operation (p = 0.01, p < 0.0001; p = 0.004) compared to the control group. Moreover, the same study demonstrated that in the TAP and TEAS groups, pain levels of VAS were lower than in the standalone TAP group (p = 0.03).30 Lan et al. showed that patients in the TEAS group required lower doses of fentanyl 24 h and 48 h after surgery compared to the control group (respectively: 360 ±117 µg compared to 572 ±132 µg, p < 0.001;
In the study group, the level of pain was lower compared with the control group (p = 0.007).

Indication
- postoperative

Results
- pain after
  - 2020
  - 2018
  - 2018
  - 2012
  - 2012
  - 2015

In both the TEAS treatment and control groups, the levels of markers were elevated (p < 0.05). However, compared to the control group, the concentration of hs-CtNT in the TEAS group on days 1 and 3 was significantly lower (p < 0.05). There was no difference in CRP and CK levels between the groups. Moreover, heart rate (HR) on days 1, 3 and 5 after surgery compared to the day before the surgery was higher in both groups, wherein the increase was lower in the TEAS treatment group.

Effectiveness of TEAS in other indications

Cardioprotection

Li et al. studied the possible protective impact of TEAS on cardiac muscle in patients with diagnosed coronary artery disease qualified for spinal surgery. The cardioprotective effect was evaluated by measuring the level of markers in blood serum, including troponin (high-sensitive troponin T (hs-CtNT)), C-reactive protein (CRP) and creatine kinase (CK), on the 1st, 3rd and 5th day after the surgery. In both the TEAS treatment and control groups, the levels of all of the markers were elevated (p < 0.05). However, compared to the control group, the concentration of hs-CtNT in the TEAS group on days 1 and 3 was significantly lower (p < 0.05). There was no difference in CRP and CK levels between the groups. Moreover, heart rate (HR) on days 1, 3 and 5 after surgery compared to the day before the surgery was higher in both groups, wherein the increase was lower in the TEAS treatment group.

A study by Ngai and Jones confirms the cardioprotective properties of TEAS, as they showed a reduction of low frequency to high frequency (LF/HF) ratio by 0.37 ±0.01 (p = 0.012) compared to the control group. In conclusion, all these studies show the positive impact of TEAS in cardioprotection. Table 4 presents a summary of RCTs assessing the effectiveness of TEAS in other indications.
Postoperative general condition

Chi et al. assessed whether TEAS treatment could affect the general condition of a patient after knee surgery. For this, they used the Quality of Recovery-40 questionnaire (QoR-40). Compared to the TEAS treatment group, the control group scored lower in QoR-40 on the 1st day after surgery, and the relationship was statistically significant (170.9 ± 5.0 compared to 160.1 ± 5.5, p < 0.05, respectively). The same study showed that CRP in the TEAS group was notably lower (p < 0.05). Bai et al. achieved comparable results, showing a statistically significant relationship in QoR-40 score in the TEAS group compared to the control group (176.9 ± 11.1 compared to 164.3 ± 13.7, p < 0.01). Moreover, they showed that patients receiving TEAS less often suffered from cough (10 (27.0) compared to 19 (50.0), p = 0.04) and NV (13 (35.1) compared to 24 (63.2), p = 0.02).9

Yu et al. analyzed the influence of TEAS on the perioperative period in patients after laparoscopy due to gynecological diseases. The study included not only QoR-40 but also Mini-Mental State Examination (MMSE). Compared to the control group, scores in the TEAS group were significantly higher in both scales on day 1 and 2 after surgery (QR-40: 1st day – 166.07 ± 8.44 compared to 175.33 ± 9.66, 2nd day – 187.73 ± 5.47 compared to 191.40 ± 5.74; MMSE: 1st day – 24.60 ± 2.35 compared to 26.10 ± 2.78, 2nd day – 26.53 ± 2.94 compared to 27.83 ± 2.73); in treated group, the incidence of PONV was lower compared with the control group (23.3% compared to 56.7%).

Obstetrics

Qu et al. examined the implication of TEAS on in vitro fertilization (IVF). The authors identified 4 groups: controls and 3 TEAS groups with various frequencies: 2 Hz, 100 Hz, and 2/100 Hz. Compared to all other groups, the number of pregnancies, successful implantations and live births in the 2/100 Hz group was significantly higher (p < 0.05). Zheng et al. showed that TEAS therapy in women with lowered ovarian reserve notably increased the number of pregnancies after IVF in comparison to the control group (respectively: 42.31% (n = 22/52) compared to 21.57% (n = 11/51), p < 0.05).38

Discussion

Our review is the first to identify and analyze TEAS trials in several medical indications, providing an evaluation
of TEAS effectiveness in comparison to placebo or standard therapy. Out of 22 chosen RCTs, 9 studies evaluated the effectiveness of TEAS in the treatment of NV, demonstrating superior clinical outcomes in TEAS-treated patients in comparison to standard therapy. Eight of those studies were focused strictly on the effect of TEAS on pain reduction. The studies showed lower VAS and/or total analgesics doses in the TEAS study group when compared with other study arms. Most of those studies evaluated the effectiveness of TEAS in surgical pain management exclusively. However, there was 1 notable study on the efficacy of TEAS in decreasing pain related to mechanical ventilation.26 Such application of TEAS might be particularly valuable in the face of the coronavirus disease 2019 (COVID-19) global pandemic that is associated with a significant percentage of patients requiring prolonged mechanical ventilation depending on disease severity. Despite ample evidence on the effectiveness of TEAS on both PONV and pain control, there are some studies that show contrasting results. One RCT showed significantly worse outcomes of TEAS compared to control in pain alleviation at days 2 and 3.28 However, this study primarily evaluated the impact of TEAS on anesthetics use, and the modality ended upon culmination of the surgery. Besides the influence of TEAS on pain management, it might have a broadly defined beneficial impact on patients recovering from surgical interventions. Three RCTs demonstrated that patients receiving TEAS scored higher in either QoR-40 or MMSE. Such findings seem to be crucial, as quality of recovery is directly associated with satisfaction and quality of life up to 3 years after surgery.40 Another 3 RCTs display the cardioprotective properties of TEAS by either lowering the HR, reducing the HR normalization time or lowering the LF/HF ratio. Furthermore, the results of 2 RCTs showed improved pregnancy and IVF outcomes after TEAS therapy—an crucial feature given the rising infertility rates worldwide.41

Only one previous systematic review assessed the effectiveness of acupuncture and, as a separate subgroup, acupuncture-related methods in treating postoperative pain. Wu et al. included only 5 studies that compared TEAS with standard treatment. Similar to our results, they found that patients receiving TEAS suffered less pain on the 1st day after surgery, as evaluated by VAS (p < 0.0020). Also, consistent with our findings, they found that the TEAS group required a lower total opioid dose on the 1st postoperative day than the control group (p < 0.001).42

Although the results of these studies are encouraging, they have limitations, primarily with regard to methodology. The biggest concern is insufficient blinding of care providers. In all of the studies that included a placebo group, the care provider knew whether they applied a true or sham treatment modality. A considerable amount of properly executed RCTs are required to establish TEAS as a noninvasive alternative to standard therapy in the aforementioned indications and other ones. To do so, researchers need to adhere to appropriate methods of intervention. Sizeable cohorts including the study group, along with control and placebo arms, as well as proper randomization are necessary. Means of double-blinding should be developed, as informing the research staff might cause bias. For publication purposes, much like the Standards for Reporting Interventions in Clinical Trials of Acupuncture (STRICTA),43 the Consolidated Standards of Reporting Trials (CONSORT) has been developed to avoid unnecessary mistakes and hindering otherwise useful studies from being recreated.44

**Limitations**

We recognize that our review has a number of limitations. Firstly, we only included trials published in English, possibly significantly reducing the database. Even though a substantial effort was put into extracting every available RCT on the subject, we cannot guarantee that the search was all-inclusive. The most significant factor limiting the quality and conclusiveness of this review is selective publishing. Since only 1 included RCT showed a negative outcome of TEAS, RCTs with negative results likely remain unpublished, misrepresenting the outcome of TEAS overall.

**Conclusions**

The results of this systematic review demonstrate TEAS as an emerging, noninvasive modality with distinct advantages over classical acupuncture and needle-based electrostimulation, regardless of its application (as a standalone TEAS therapy or as an adjuvant to standard therapy). Our study suggests this approach may be useful in clinical practice, particularly for pain and NV management. However, considering the methodological quality of most RCTs, rigorous large-scale clinical trials of TEAS are needed to evaluate the clinical utility of this technique.

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