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REVIEW

Impact of TENS stimulation on acute postoperative pain after abdominal surgery—a pubmed review

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Abstract

Transcutaneous electrical nerve stimulation (TENS) is a technique in which pulsed low-voltage electrical currents are delivered through electrodes applied on the intact skin surface of the painful area of the body, by using a special device in order to stimulate peripheral nerves including those for pain relief. This method is used to manage acute and chronic pain, conditions of nociceptive or neuropathic origin. All clinical trials with TENS for postoperative acute pain were included. Case reports, reviews, protocols, letters to the editor, animal experimental research, guidelines, and ongoing or uncompleted trials were excluded. Two hundred fifty-two articles involving postoperative pain and transcutaneous electric nerve stimulation were identified by applying the aforementioned search strategy which resulted in including 18 articles in the analysis. The number of patients assessed for eligibility in each article varies from a maximum of 800 to a minimum of 3. In 88.89% of the articles the frequency of the TENS applied in the patients was mentioned. In half of the research performed in the selected articles pain was evaluated with the visual analogue scale. Immediate postoperative active mobilization of the patient is a key point of shortening the convalescence period and hospitalisation, the one individual in cause being able to attend work and social activities as soon as possible therefore being able to discover non-invasive, simple to use methods that reduce pain overall and the consumption of pharmaceutical analgesics is mandatory. The TENS technique is a non-invasive, safe, complementary technique used in order to reduce acute postoperative pain and improve pulmonary function, especially deep breathing, facilitating active movement and recovery of the patient and significant morbidity reduction.

Keywords

TENS; Postoperative pain; Abdominal surgery

1. Introduction

Transcutaneous electrical nerve stimulation (TENS) is a technique used to manage acute and chronic pain conditions of nociceptive or neuropathic origin in which pulsed low-voltage electrical currents are applied on the intact surface of the painful area of the body using a special device to stimulate peripheral nerves including those nerves for pain relief [1, 2].

Neuronal stimulation by TENS has been used in the management of various types of pain, such as malignancy related and non-malignant acute or chronic pain, and also the handling of other nonspecific symptoms like nausea or vomiting very often caused by surgical intervention or anaesthesia and intensive care performed procedures.

TENS attracted research attention during the past decades. In addition to being a non-invasive, low-cost pain therapy method, TENS devices are small, portable and easy-to-handle even in home environments. Another fact that makes TENS a proper tool of postoperative pain management is that this non-pharmacological technique has minimal undesirable side effects, compared to the nowadays preferred pain relief approach, the opioid therapy [3].

Previous studies explain and highlight the analgesic benefits of TENS in patients who underwent thoracotomies, abdominal, urogenital, orthopaedic, spine or even aesthetic surgery [4].

The few inconvenient aspects of using TENS units are associated to the local, skin-related, minimal side effects due to the adhesive pads and include redness or irritation. To prevent these unwanted reactions the use of hypoallergenic pads is advised. The electrical impulses that TENS devices produce may cause a tingling, buzzing, or prickling sensation in the aching area. There is some evidence that suggests that TENS can be contraindicated in epilepsy [5], and for patients with a cardiac pacemaker or another type of electrical or metallic implant a careful evaluation should be performed in order to identify any dysfunction [6]. The method's efficacy is linked

to pulse intensity and frequency so that people who use this device for a long time after surgery related acute pain, with the same characteristics of the electrical current, can develop tolerance over time [7].

However, TENS, remains a non-invasive low risks alternative pain therapy, part of a multimodal approach in postoperative pain management by reducing the peripheral nerves' ability to transmit pain signals to the central nervous system.

The scope of this research is to revise the existing literature in order to provide a summary of the up-to-date use of this technique for patients undergoing abdominal wall surgery and abdominal organ surgery.

2. Materials and methods

2.1 Information sources

This systematic review followed the Preferred Reporting Items for Systemic Reviews and Meta-Analyses (PRISMA) guidelines [8]. This study included literature that was included in the PubMed database.

2.2 Eligibility criteria

We included all clinical trials describing TENS for postoperative acute pain developed in adults after classic or laparoscopic abdominal surgery. This included abdominal wall surgery (hernias) and abdominal organs surgery: liver, stomach, bowel, gallbladder, pancreas, spleen, appendix, rectum, and anus. Adult patients were considered as aged 18 years old or above. There were no restrictions on gender, race, education, or socioeconomic status. Considering the language limitations of the study investigators, only studies available in English were retained.

Case reports, reviews, protocols, letters to the editor, animal experimental research, guidelines, and ongoing or uncompleted trials were excluded. Paediatric research was ruled out. Research with the aim to improve palliative care, chronic pain, pocket pain, and posttraumatic pain management were excluded. Specialty surgery of the head (brain, face), neck (thyroid, throat), thoracic (cardio, pulmonary, breast), orthopaedic (including amputations or the result of amputation: phantom limb pain) or plastic surgeries (liposuction) were not considered. Urogenital procedures for both males and females (gynaecology & obstetrics procedures), neurosurgery, or neuro block investigations were also eliminated.

2.3 Search strategy

The PubMed database was searched for relevant articles using the following research query ("Pain, Postoperative" (Mesh)) AND "Transcutaneous Electric Nerve Stimulation" (Mesh). The search was undertaken on 05 August 2022 and included papers published from 01 January 2000 to date.

2.4 Data collection

Data were extracted using the download feature of PubMed.

All the literature retrieved from the PubMed database was downloaded into a Microsoft Office Excel File.

Furthermore, the data was standardized based on PRISMA guidelines7 in an Excel file. The data extraction form ensured the extraction of pertinent data to provide a comprehensive synthesis of the literature regarding social media analysis of medical information usage. As per the PRISMA guidelines, data was extracted from each article that met the inclusion criteria regarding participants and interventions [8].

2.5 Data analysis

Article titles were screened for inclusion in the first round of screening. The studies identified as eligible in the first screening round were included in the second round of abstract and full-text screening. The resources available at the Iuliu Haţieganu University of Medicine and Pharmacy Cluj-Napoca were used to retrieve the full text of the articles that passed the title and abstract screening. If no university access to the full text was available, an e-mail request to the corresponding author was sent by presenting the researchers and their research and asking for a copy of the full text.

Qualitative, quantitative, and mixed-method data that met the inclusion criteria for the review, including methodological rigor, credibility, and quality standards as outlined, were described, and synthesized using narrative synthesis. This approach was used to synthesize the evidence relevant to the research questions, summarizing and explaining the findings of included studies. Results were presented as a percentage and associated 95% confidence intervals (95% CI) using an exact method for qualitative variables. Comparisons between groups on qualitative variables were done using Z-test for proportions at a significance level of 5%. The sample sizes were summarized as the median and interquartile range (IQR = (Q1–Q3). The comparison of the sample sizes used in interventional and observational studies was tested using the Mann-Whitney test. The significance level of 5% was used in the statistical analysis, and any p-value less than 0.05 was considered statistically significant.

Preliminary synthesis results in an initial description of the included study, incorporating outcome statistics against research question. As patterns across the study results emerged from the preliminary synthesis, reviewers interrogated the data to identify and gain an understanding about any factors that may explain differences in direction and/or effect. The narrative synthesis of evidence was reported, highlighting the key outcomes. In order to avoid potential biases, key points of difference between studies.

3. Results

Two hundred fifty-two articles involving postoperative pain and TENS were identified by applying the aforementioned search strategy which resulting in including 18 articles in the analysis (Fig. 1).

Out of the 18 articles included, 2 (χ^2 = 9.39, p = 0.002) were published before 2012, while during the recent years it seems to have been an increase in the interest on this topic, as 44.44% (95% CI (0.22–0.69)) of the studies were published starting 2019 till date.

As per surgery chosen, a third of the articles (33.33%, 95% CI (0.14–0.59)) were looking at TENS application for inguinal

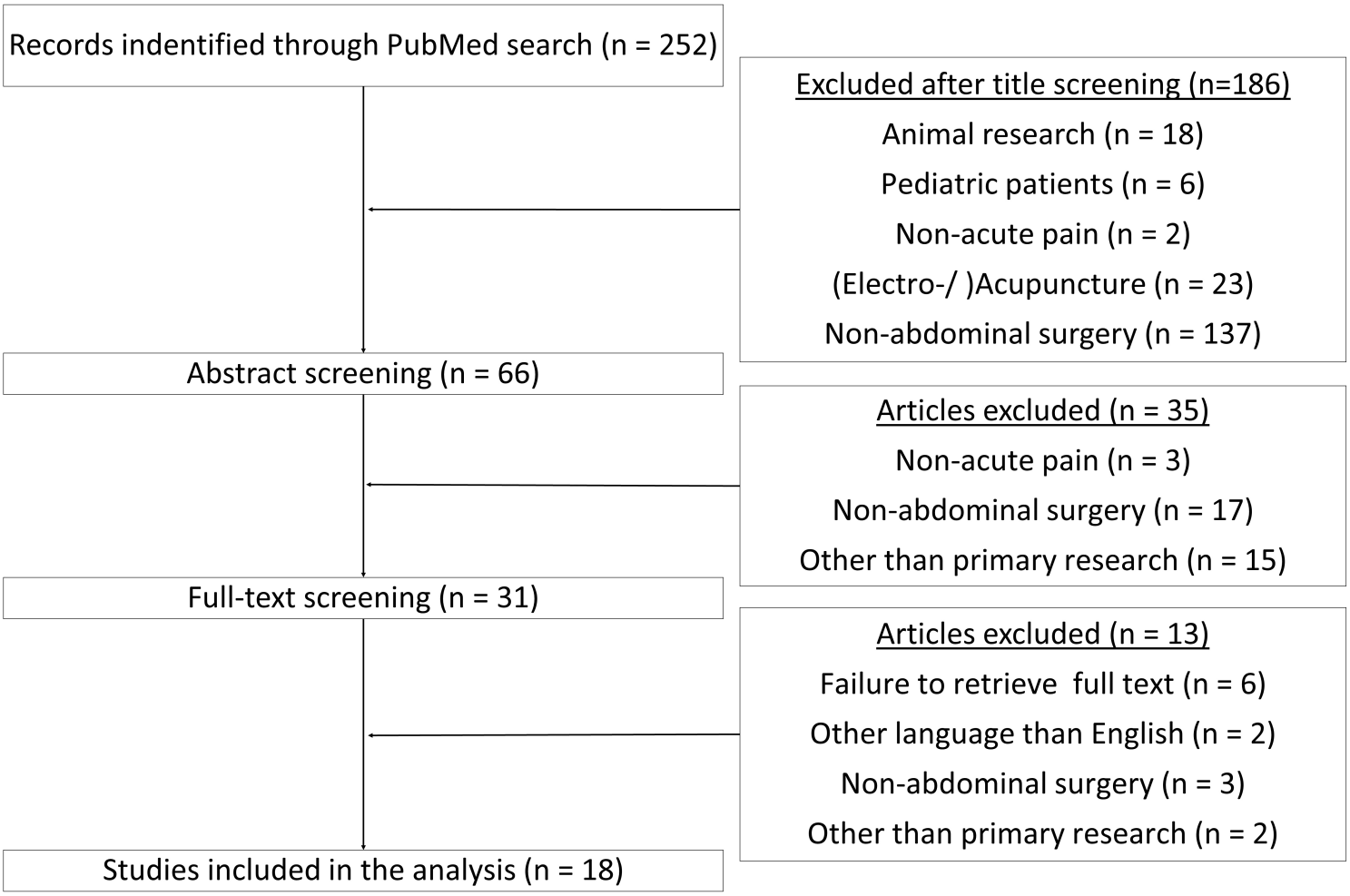

FIGURE 1. PRISMA flowchart for TENS-related publications.

hernia surgical treatment. The use of TENS for pain management on abdominal surgeries was a topic of investigation for 27.78% (95% CI (0.11–0.54) of the articles considered in this study. Within this research the definition of abdominal surgery was open inguinal hernia repair, laparoscopic cholecystectomy, laparoscopic umbilical/ventral/incisional hernia repair, and laparoscopic hiatal hernia repair or a midline incision for a diagnosis of stomach or colorectal cancer [9]. Three ($\chi^2 = 6.72$, $p < 0.01$) article investigate the use of TENS on cholecystectomy. The remaining 4 articles look at colon, gastrointestinal, pancreatic surgeries and haemorrhoidectomy.

Eighty-three percent of the articles ($\chi^2 = 6.72$, $p = 0.01$) are randomized trials. A third of the articles (33.33%, 95% CI (0.14–0.59)) of the articles' methodology is single blind while four ($\chi^2 = 4.50$, $p = 0.03$) are double blind. A placebo-control method was used in 38.89% (95% CI (0.18–0.64)) of the articles.

The number of patients assessed for eligibility in each article varies from a maximum of 800 [10] to a minimum of 3 [11], with a mean of 136.89 ± 43.05. Out of the eligible patients, the number of patients randomized narrowed to a mean of 122.25 ± 48.58. The TENS groups have a mean size of 58.76 ± 33.91 patients.

In 88.89%, $\chi^2 = 9.39$, $p < 0.001$, of the articles the frequency of the TENS applied in the patients was mentioned. Out of them in 4 articles ($\chi^2 = 4.5$, $p = 0.03$) for the TENS group was used a 100 Hz frequency, in 3 article ($\chi^2 = 6.72$, $p < 0.001$) for the test group was used a frequency of 80 Hz and in 3 other articles (16.67%, 95% CI (0.04–0.42)) it was used a frequency of 100 Hz alternating every 3 seconds with a frequency of 2 Hz. In 2 research articles (11.11%, 95% CI (0.02–0.36)) was included the review was used a frequency of 150 Hz and a pulse width of 75 μs. The pulse duration was described by 72.22% (95% CI (0.45–0.89)) of the articles included with a median of 200 μs (Q1–Q3 (100–250)) (Table 1).

Four articles (22.22%, 95% CI (0.07–0.48)) describe the amplitude of the TENS applied. The location where TENS was applied was mentioned in 5 articles (27.77%, 95% CI (0.11–0.55)). The duration of the application for the 3 articles mentioning this criteria was 30 minutes.

Through half (55.56%, 95% CI (0.31–0.78)) of the research performed in the selected articles pain was evaluated with the visual analogue scale and in 4 cases 22.22%, 95% CI (0.07–0.48), pain was evaluated while resting, after walking and when standing up from the bed. Results of 11 research papers demonstrated that TENS was efficient to reduce post operative pain intensity, while the rest of the papers have not included in their significant findings any remarks to respect to (Table 1).

TABLE 1. Articles included in the review.

PMID	Publication Year	Surgery	Patients recruited (TENS group)	TENS Frequency (Hz)	Pulse duration	Amplitude (mA)	Duration (minutes)	Location	Pain evaluation	TENS' influence
14622666	2003	Abdominal surgery	44 (33)			3–57				↓[4] pain intensity during walking
18387854	2008	Inguinal Hernia	45 (20)	100	100 μs	9–18	30		NRS[2]	↓[4] pain intensity and analgesic consumption
22311059	2012	Laparoscopic cholecystectomy	51 (21)	150	75 μs				VAS[1]	↓[4] pain, complains of nausea and emesis
22672211	2013	Inguinal Hernia	4 (4)	60	200 μs			T 8–9		↓[4] local and regional pain
24901753	2014	Abdominal surgery or laparoscopic surgery	62 (19)	1–250	100 ms				VAS[1]	↓[4] postoperative pain and improve pulmonary functions
24439637	2014	Pancreatic	86 (25)	80				T 5–9	VAS[1]	
26541070	2015	Colon	83 (24)	80				T10–L1	VAS[1]	↓[4] pain
25675068	2015	Inguinal Hernia	3 (3)							
29454480	2018	Abdominal surgery	169 (82)	100–200	120–200 μs		30–60			
28071133	2018	Haemorrhoidectomy	89 (41)	2–100	0.25 ms	0.06–2.30			VAS[1]	↓[4] pain and anxiety
31358034	2019	Abdominal surgery	800 (400)	5–100						
31169066	2019	Abdominal surgery	158 (32)	2–100	0.25 min	12	30			↓[4] pain and analgesic consumption
30072277	2019	Inguinal Hernia	70 (29)	100	100 μs				VAS[1]	↓[4] postoperative pain
33006195	2020	Cholecystectomy	10 (10)	80	250 μs				VAS[1]	
32564661	2020	Cholecystectomy	167 (26)	150	75 μs				VAS[1]	↓[4] pain
33495134	2021	Gastrointestinal	311 (154)	2–100	0.2–0.6 ms				VAS[1]	
33309784	2021	Inguinal Hernia	156 (40)	100	200 μs			T12–L3	VAS[1]	↓[4] postoperative pain and analgesic use
35743988	2022	Inguinal Hernia	156 (40)	100	200 μs			T12–L3	SF-36[3]	

VAS[1] = visual analogue scale; NRS[2] = Numerical Rating Scale; SF-36[3] = 36-Item Short Form Survey Instrument; ↓[4] = decrease; TENS = Transcutaneous electrical nerve stimulation.

4. Discussion

Immediate postoperative active mobilization of the patient is a key point of shortening the hospital length of stay and the recovery period, so the individual to resume their routine as soon as possible. Therefore being able to discover a non-invasive, easy to use method that reduces the overall pain and the consumption of pharmaceutical analgesics is mandatory. Our systematic review regarding the role of TENS on acute postoperative pain showed that complementary use of intermittent TENS to chemical analgesia was found to significantly relieve pain intensity during major postoperative activities such as gait speed and vital capacity when compared to the use of pharmacologic analgesia alone and place effect of this technique. Furthermore, pain intensity scale at rest was not influenced by TENS and because of that we sustain the hypothesis that pain at rest has different mechanisms than active movement pain. Many previous studies suggest that a substantially reduction in hyperalgesia does not influence the reduction of intensity of pain at rest [12].

Wang *et al*. [13] demonstrated the fact that intermittent, high intensity transcutaneous acupoint electrical stimulation (TAES) was far more efficient than low intensity TAES used with controlled analgesia, electrodes been placed at the key acupoints of the nondominant hand compared to both sides of the surgical incision. Research has highlighted that acupuncture can help gastrointestinal function haemostasis through a variety of unknown mechanisms. Acupuncture can stimulate gastric peristalsis by up-regulating the vagal nerve impulses, inhibiting gastric peristalsis through the somatosensory-nucleus tractus solitarius pathway, and reduces hyperalgesia using peripheral and central opioid receptors, and releasing endogenous opioids [14]. As per Wen-Jing Li *et al*. [15], patients pre-treated with TAES, that underwent gastrointestinal surgery under general anaesthesia, recovered gastric and intestinal mobility faster than the control group. The incidence of nausea, vomiting and high scale postoperative pain also significantly reduced due to stimulating the production of substance P brain-gut peptide.

There are some positive effects of TENS on spirometry breath function, but only demonstrated in thoracic surgery patients' population [16]. More specific, forced vital capacity, Forced Expiratory Volumeand pressure of oxygen were increased and pressure of carbon dioxidedecreased due to the use of high intensity TENS compared to the placebo group, even though placebo TENS has also positive effects on reducing postoperative pain. The functional pulmonary benefits have not been seen as much in abdominal surgery patients, but the positive effects on pain management and walking function are sustained by many articles [17, 18].

Discussing surgical interventions on the digestive system, the most documented studies of TENS were for cholecystectomies, inguinal hernia repairs and haemorrhoidectomies.

Inguinal herniorrhaphy is one of the most common surgeries performed across the world and the high incidence of chronic pain represents a considerable therapeutic problem because it is more often seen than hernia recurrence itself. As per Guilherme *et al*. [19], almost 30% of the patients suffer from chronic pain one year after the surgery and a percentage of 6–20% has reported pain interference in daily basis activities [20]. In the majority of the cases, the pain felt is described as neuropathic, a burning, foreign body sensation in the groin or genital area, occuring mostly from iatrogenic nerve damaging or postoperative inflammatory reactions around the ilioinguinal, ilio hypogastric or genital branch of the genitofemoral nerve. The possible risk factors described included age under 40 years old, female gender, genetics, previous inguinal surgeries [21, 22]. Ultrasound guided permanent neurostimulation implant was extremely efficient in reducing pain at 12-month follow-ups and foreign body sensation (mesh) was also diminished.

Laparoscopic and open inguinal hernia approach are still under debate. Laparoscopic techniques such as transabdominal pre-peritoneal or laparoscopic totally extraperitoneal proved their superior benefits in small, uncomplicated inguinal hernias. The main question remaining: which open approach technique is the most suitable from the subjective, less pain causable point of view.

Some studies on the TENS pain management in major pancreatic resections investigated the high frequency usage of this technique as a complementary pain-relieving transition from epidural anaesthesia to general induced analgesia after surgery. Even though, concerning intensity, higher amplitude voltage provides the best analgesic effect, Bjersa *et al*. [23] were not able to detect significant benefits of using TENS beyond the end of epidural analgesia in postoperative period after extensive surgical procedures because such body stress requires complex and multimodal pain relief management. The results presented were enforced by research on patients with various thoracic surgery procedures (thoracotomies) that advocate the advantages of TENS in pain management after minor surgery. Pads were placed as close as possible to the incision line, as well as dermatome correspondent on patient's back but no differences have been found in applying dermatome located spots compared to the real benefits of acupuncture key points positioning in gastrointestinal and gynaecological surgery [21, 23].

Concerning the role of TENS in decreasing pain after open lower abdomen surgical procedures such as colon resections some studies suggest that pain was appreciated lower by patients during the first day after epidural analgesia termination. Eventhough the number of subjects recruited was not as high as expected, so the results were underpowered but sustained by a considerable amount of articles on nonpharmacological methods that help pain and overall postoperative care period [23]—reduced usage of analgesic medication, and reduced pain during walking, deep breathing and other activities [20, 22].

The TENS battery-operated gadgets administer alternating current to the painful location through electrodes placed on the skin. Adjustable parameters of pulse frequency and pulse intensity are associated with TENS effectiveness. Both high frequency (HF) and low frequency (LF) TENS produce effects at the stimulation point. HF TENS decreases substance P, which is elevated in the neurons of the dorsal root ganglia of injured animals [24]. Blocking peripheral opioid receptors inhibits LF TENS from producing analgesia, but not HF TENS [25]. Thus, TENS may also modify the excitability of periph-

eral nociceptors in order to decrease afferent input to the central nervous system.

In mice lacking -2a-adrenergic receptors, neither LF nor HF TENS produces analgesia. Blocking peripheral -2 receptors, but not spinal or supraspinal -2 receptors, reduces TENS-induced analgesia [26], indicating a role for peripheral -2a-adrenergic receptors in TENS-induced analgesia. In addition, application of systemic phentolamine to inhibit -adrenergic receptors reduces the decrease in cold allodynia induced by LF TENS [27]. This adrenergic action may have an influence on the autonomic nervous system. Blood flow rises with LF TENS at intensities that cause motor contractions; higher than 25% over the motor threshold [28]. Consequently, part of the analgesic effects of TENS are mediated through adrenergic receptors in the periphery.

The stimulation intensity used is crucial in TENS applications. Applying the maximum tolerable intensity generates hypoalgesia in healthy participants, but lesser intensities are ineffective [29]. In addition to activating a larger number of sensory afferents, it is believed that higher pulse amplitudes engage deeper tissue afferents, resulting in enhanced analgesia. TENS with a high intensity reduces post-operative opioid needs and adverse side effects [30]. TENS systematic reviews continue to include trials with a broad range of intensity settings, despite the fact that researchers have shown the significance of intensity in TENS administration. In reality, as shown below, the use of TENS at insufficient intensities is one of the major causes of contradictory TENS effectiveness reports. Clinicians should thus attempt to use TENS at the maximum acceptable intensity for each patient.

The confluence between acupuncture and TENS is garnering a growing amount of scientific interest. Many research [31] have investigated both electroacupuncture and typical TENS pad electrodes used to acupuncture points. Clinically, TENS applied to these acupoints lowers pain and may be more effective than when administered at non-acupoint sites when assessing pain and pain thresholds to heat and pressure in normal people [32] and in patient populations [33] when compared to sham TENS. Compared to TENS at non-acupoint locations, TENS at acupoint sites decreased opioid use, nausea, and dizziness in hysterectomy patients [34].

Animals and people develop analgesic tolerance after daily administration of LF or HF TENS at the same frequency, strength, and pulse length (*i.e.*, same dosage). In animals, the analgesic tolerance induced by LF TENS results in cross-tolerance at -opioid receptors in the spinal cord, while the analgesic tolerance induced by HF TENS leads in cross-tolerance at -opioid receptors in the spinal cord [35]. Modulation of opioid tolerance-involved pathways pharmacologically prevents the development of analgesic tolerance. Particularly, blocking the ionotropic receptors mediating glutamatergic neurotransmission receptors or cholecystokinin receptors in the spinal cord reduces analgesic tolerance to both low-frequency and high-frequency TENS. Alternating between LF and HF TENS during a therapy session [36] or adjusting the strength of TENS daily [37] may help avoid analgesic tolerance. Hence, animal studies indicate that TENS tolerance may be postponed by pharmacological and non-pharmacological modification of TENS parameters.

Nevertheless, the economic aspect of this method is very important because it requires expensive electric disposable pads and a generous amount of time for medical professionals to educate the patient on every aspect of TENS usage concomitant with adjusting pain medication doses at home [38, 39].

Our research was limited to one database and a significant low number of articles. Firstly, we acknowledge that there is significant research outside the PubMed database which was not comprised in the current review. Secondly, the university's access to the full text article of some articles further limited the available publications that were eligible for inclusion. Beyond the limitations of our research, there are inherited limitations of all the studies taken into account. The lack of control that patients felt over the ability to self-adjust the electrical intensity of TENS, many of them being frightened initially by the increased tingling sensation they felt every time the amplitude was modified. Because of that, the decision to stop pressing the button might have been influenced and therefore it stopped at a lower intensity. Another limitation was the low number of patients recruited and the absence of correct blinding. All of the subjects included in the studies were blinded but the healthcare personnel was not. It would have been a solid strength if all the people involved in teaching the use of this treatment were blinded [40].

5. Conclusions

Transcutaneous electrical nerve stimulating (TENS) is a non-invasive, safe, complementary technique used in order to reduce acute postoperative pain and improve pulmonary function, especially deep breath, facilitating patient active movement and recovery and significant morbidity reduction. Further studies on extensive populations and major abdominal surgeries such as hepato-biliary-pancreatic interventions must be conducted in order to see the substantial effects of TENS as part of a multimodal therapy in paramount surgery patients.

ABBREVIATIONS

TENS, Transcutaneous electrical nerve stimulation; TAES, transcutaneous acupoint electrical stimulation.

AVAILABILITY OF DATA AND MATERIALS

Data analysis shall be provided upon request by the corresponding authors.

AUTHOR CONTRIBUTIONS

RAC and AAC—designed the research study, wrote the draft of the manuscript. AAC and AC—performed the research. RAC—provided help and guidance on the research methodology. SM, ND and DSD—analyzed the data, revised the draft of the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This section is a review that uses already existing published literature and relies on these papers and their ethics approvals and consents.

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CONFLICT OF INTEREST

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