


## Transcutaneous electrical nerve stimulation for pain treatment after cardiac surgery: a systematic review

### Estimulação elétrica transcutânea para tratamento da dor após cirurgia cardíaca: uma revisão sistemática

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**ABSTRACT | INTRODUCTION:** Sternotomy in cardiac surgery is marked by postoperative pain. Analgesic drugs are widely used to relieve this symptom, however, with several adverse effects that vary according to the drug therapeutic class used. Therefore, the use of Transcutaneous Electrical Nerve Stimulation (TENS) appears as a noninvasive and easily applicable alternative for reducing the use of drugs in patients undergoing cardiac surgery. **OBJECTIVE:** To systematically review the effects of TENS in the treatment of pain in patients in the postoperative cardiac surgery and its repercussion on respiratory parameters. **METHODOLOGY:** Systematic review using the PICO methodology and keywords (TENS, pain, patients in the postoperative, cardiac surgery). Published studies that addressed the effects of TENS on the pain of patients after cardiac surgery were included and, as a secondary variable, its impact on respiratory parameters, published in Portuguese or English, in the years 2008 to 2019. Excluded nonrandomized studies, case reports, clinical observations and reviews. In addition, the Boolean operators “and” and “or” were used. **RESULTS:** The search initially resulted in 265 articles, of which 253 were excluded, 12 articles remained. At the end, 5 articles were included. The search initially resulted in 2165 articles. Of these, 2160 were excluded, of which 5 were selected. The samples ranged from 20 to 120 participants. Of the five studies selected, four demonstrated a reduction in the level of pain after cardiac surgery, varying its application from the first day to the third postoperative day. This reduction in pain favored a decrease in the use of drugs such as morphine. In addition, with the reduction of pain, there was an improvement in ventilatory muscle strength and lung volumes and capacities. **CONCLUSION:** It is concluded that TENS is a non-drug option that can be used as an adjunct in pain reduction and, consequently, improving respiratory muscle strength, lung volume and capacity, among other parameters, in patients undergoing cardiac surgery.

**KEYWORDS:** Thoracic surgery. Transcutaneous electrical nerve stimulation. Pain.

**RESUMO | INTRODUÇÃO:** A esternotomia na cirurgia cardíaca é marcada por dor pós-operatória. Os medicamentos analgésicos são amplamente utilizados para aliviar esse sintoma, no entanto, apresentam vários efeitos adversos que variam de acordo com a classe terapêutica do medicamento utilizado. Portanto, o uso da Estimulação Elétrica Nervosa Transcutânea (TENS) aparece como uma alternativa não invasiva e de fácil aplicação para reduzir o uso de drogas em pacientes submetidos à cirurgia cardíaca. **OBJETIVOS:** Revisar sistematicamente os efeitos da TENS no tratamento da dor em pacientes no pós-operatório de cirurgia cardíaca e sua repercussão nos parâmetros respiratórios. **METODOLOGIA:** Revisão sistemática utilizando a metodologia PICO e palavras-chave (TENS, dor, pacientes no pós-operatório, cirurgia cardíaca). Foram incluídos estudos publicados que abordaram os efeitos da TENS na dor de pacientes após cirurgia cardíaca e, como variável secundária, seu impacto nos parâmetros respiratórios, publicados em português ou inglês, nos anos de 2008 a 2019. Estudos não randomizados excluídos, relatos de casos, observações clínicas e revisões. Além disso, os operadores booleanos “and” e “or” foram utilizados. **RESULTADOS:** A busca resultou inicialmente em 265 artigos, dos quais 253 foram excluídos, restando 12 artigos. Ao final, foram incluídos 5 artigos. As amostras variaram de 20 a 120 participantes. Dos cinco estudos selecionados, quatro demonstraram redução no nível de dor após cirurgia cardíaca, variando sua aplicação do primeiro dia ao terceiro dia de pós-operatório. Essa redução da dor favoreceu uma diminuição no uso de drogas como a morfina. Além disso, com a redução da dor, houve uma melhora na força muscular ventilatória e nos volumes e capacidades pulmonares. **CONCLUSÃO:** Conclui-se que a TENS é uma opção não medicamentosa que pode ser utilizada como adjuvante na redução da dor e, consequentemente, na melhoria da força muscular respiratória, volume e capacidade pulmonar, entre outros parâmetros, em pacientes submetidos à cirurgia cardíaca.

**PALAVRAS-CHAVE:** Cirurgia torácica. Estimulação nervosa elétrica transcutânea. Dor.

## Introduction

Patients undergoing cardiac surgery experience several procedures that generate pain. Presence of drains, tubes and, especially, sternotomy are the main causes of postoperative pain<sup>1</sup>. This symptom is a physiological condition that demonstrates competence of the central nervous system, as it alerts for protection and affects physical and behavioral responses<sup>2</sup>. Nociceptive pain occurs in these individuals due to surgical aggression on muscles and bones<sup>3</sup>. Due to pain, the patient tends to adopt a more superficial pattern, which causes a decrease in lung volumes and capacities.

The term nociception is related to the recognition of painful signals by the nervous system, which formulates information related or not, to the injury<sup>2</sup>. That is, pain directly affects one of the defense mechanisms of the human body through these nociceptors<sup>2</sup>. Due to pain, the patient does not have an effective cough, as it is a defense mechanism of the lower airways, there is an increased risk of pulmonary infections and an increase in hospital stay<sup>4</sup>.

These numerous cardiovascular surgeries are responsible for postoperative pulmonary complications, and postoperative pain is one of the main associated factors<sup>5</sup>. Pain is related to an effective decrease in physical exercises and a significant decline in cough effectiveness due to fear of pain due to increased intrathoracic pressure<sup>6</sup>.

Drug use in postoperative cardiac surgery patients is routine, and opioid analgesics are the most widely used, however, have a range of adverse effects such as hypotension, urinary retention and constipation, as well as respiratory depression, nausea, vomiting, and others, which may compromise postoperative recovery<sup>7</sup>. Evidence shows that the combined use with non-steroidal anti-inflammatory drugs can reduce morphine consumption, however, these

agents are not free of undesirable effects, including the inhibition of platelet aggregation, which may cause hemorrhages. There are also reports of the use of local anesthetics that block the stress response associated with surgical procedures, however, their cardiotoxicity is a major concern, as it endangers the patient's life<sup>8,9</sup>.

In this scenario, transcutaneous electrical nerve stimulation (TENS) is considered an alternative treatment because it acts noninvasively and is easily applied, acting through sensory stimulation, generating therapeutic effects from the combination of frequency and wavelength<sup>9,10</sup>. Thus, it is necessary to conduct a survey of scientific evidence about the use of TENS, aiming at a reduction of painful complications after cardiac surgery and its impact on ventilatory parameters.

The effect of TENS is based on the theory of door control that modulates pain by activating the descending inhibitory pathways<sup>11</sup>. It also promotes the release of endorphins, serotonin and analgesic hormones, thus decreasing cytokine levels<sup>12</sup>. TENS is an extremely safe and viable method, making it possible to apply it daily with minimal adverse effects<sup>13</sup>.

The present study aimed to systematically review the effects of TENS in the treatment of pain in patients in the postoperative of cardiac surgery and its repercussion on respiratory parameters

## Materials and methods

This is a systematic review and the guiding question of this study was: "What are the effects of TENS as a form of treatment for pain and on ventilatory parameters in patients undergoing cardiac surgery?". The research was structured based on the PICO<sup>14</sup> strategy (Chart 1).

Chart 1. PICO research strategy

Acronym	Description	Definition
P	Patient	Patients undergoing cardiac surgery (coronary artery bypass grafting and valve replacement)
I	Intervention	Application of transcutaneous electrical stimulation
C	Control	Patients who did not receive the intervention (TENS)
O	Outcomes	Pain and ventilatory parameters

The following databases were systematically searched: Pubmed, SciELO (Scientific Electronic Library Online), LILACS (Latin American and Caribbean Literature in Health Sciences) and Science Direct. The keywords were used: Thoracic Surgery, Cardiac Surgery, Transcutaneous Electric Nerve Stimulation, Pain, ventilatory parameters, lung capacity, tidal volume, muscle strength; synonyms and related words added by the Boolean operators "AND" and "OR", according to the Health Sciences Descriptors (DeCS). The search was carried out from September to November 2019.

### Eligibility Criteria

Studies published in randomized controlled trials that addressed the effects of TENS in the treatment of pain and its impact on ventilatory parameters, available in English, Portuguese or Spanish, published between 2008 and 2019 with the aim of updating the topic were included. Nonrandomized studies, case reports, clinical observations and reviews were excluded.

### Data Extraction

The articles collected through the searches in the databases were selected by tracking the titles (first stage), abstracts (second stage) and full reading (third stage). Then, an exploratory reading of the selected studies was carried out and, later, selective and analytical reading. The data extracted from the articles were systematized: authors, title, magazine, year, summary and conclusions, in order to enable the obtaining of information relevant to the research.

The selection process, data extraction from articles and identification of methodological aspects was carried out by two independent reviewers. When there was any disagreement between them, the reviewers read the entire article again for reassessment. If the disagreement persisted, a third independent reviewer evaluated and made the final decision. The research followed the items of the PRISMA<sup>15</sup> protocol for systematic reviews.

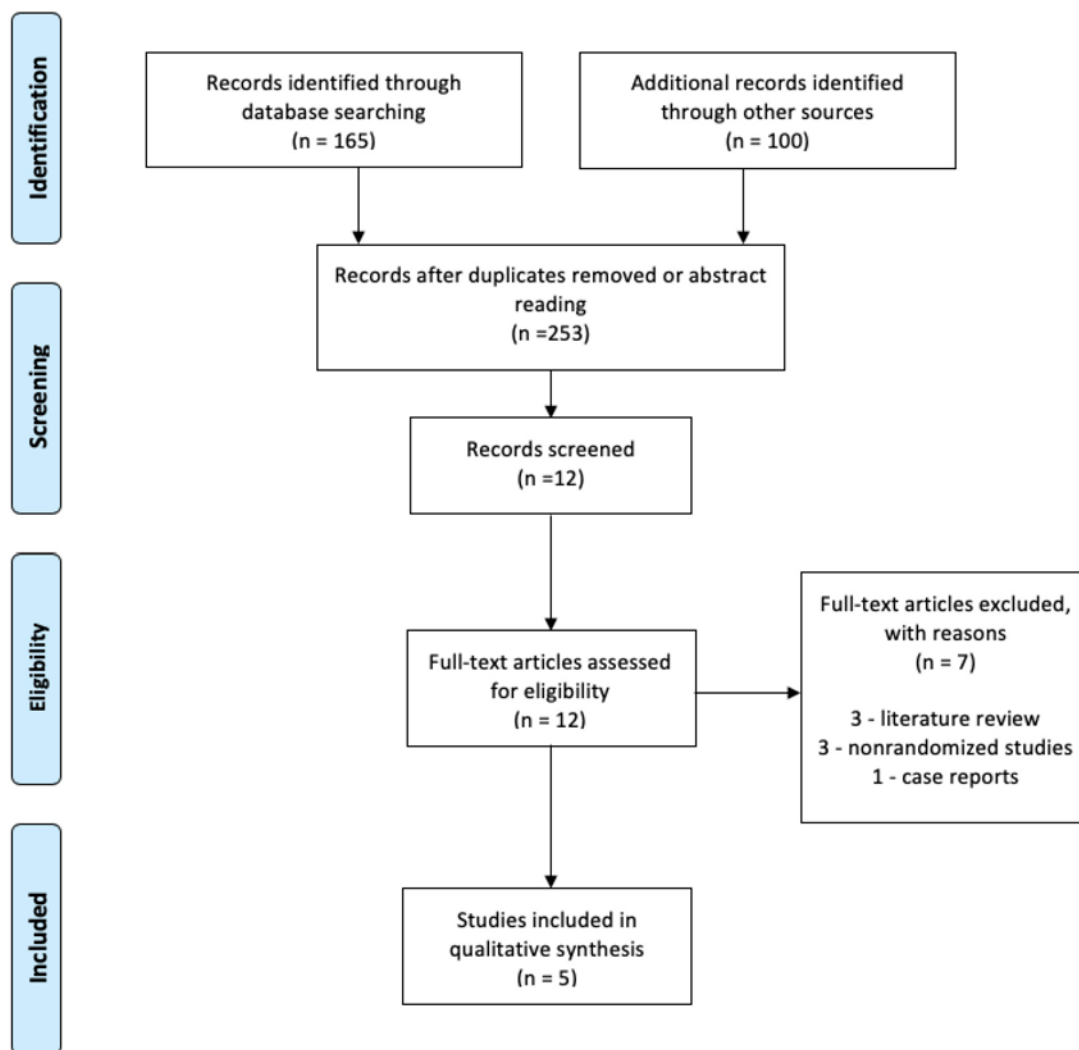
### Methodological quality assessment

The methodological quality of the studies was assessed according to the criteria of the PEDro scale, which scores 11 items, namely: 1- Eligibility criteria, 2 - Random allocation, 3 - Hidden allocation, 4 - Baseline comparability, 5 - Blind subjects, 6 - Blind therapists, 7 - Blind evaluators, 8 - Adequate follow-up, 9 - Intention to treat analysis, 10 - Comparisons between groups, 11 - Point estimates and variability. Items are scored as present (1) or absent (0), generating a maximum sum of 10 points, with the first item not counting.

## Results

Twelve articles were found after reading the summary and titles, of which only 5 were selected through the inclusion criteria. Those who did not use physiotherapy as their main treatment focus or articles with literature review design (3), nonrandomized studies (3), or case reports (1) were also excluded from the study. The flowchart present in figure 1 shows all the criteria and databases used to select the articles.

**Figure 1.** Flowchart for obtaining randomized clinical trials based on TENS for pain management and ventilatory parameters after cardiac surgery



The methodological quality assessed using the PEDro scale is shown in Chart 2. The five studies included in this systematic review discuss the use of TENS after cardiac surgery, and a summary of the methods used, and clinical outcomes are presented in Table 1.

**Chart 2.** Methodological Quality Assessment of the Studies included in this review using the Pedro Database Scale.

		LIMA,et al 16., 2011	GREGORINI et al17., 2010	LUCHESA et al18., 2009	JUNIOR et al19, 2008	OZTURK et al20, 2016
01	The eligibility criteria have been specified.					
02	Subjects were randomly assigned to groups.	✓	✓	✓	✓	✓
03	The allocation of the subjects was secret.					
04	Initially, the groups were similar with regard to the most important prognostic indicators.		✓		✓	
05	All subjects participated blindly in the studies.					
06	All therapists who administer the therapy did so blindly.	✓		✓		✓
07	All evaluators who measured at least one key result, did so blindly.					
08	Measurements of at least one key result were obtained in more than 85% of the subjects initially distributed by the groups.	✓	✓	✓	✓	✓
09	All subjects from whom measurements of results were presented received the treatment or control condition according to the allocation, or when this was not the case, the data was analyzed for at least one of the key results by "intention of treatment".					
10	The results of inter-group statistical comparisons have been described by at least one key result.	✓	✓	✓	✓	✓
11	The study presents both precision measures and measures of variability for at least one key result.	✓	✓	✓	✓	✓
<b>Pontuation</b>		5/10	5/10	5/10	5/10	5/10

In their research, conducted in 2009, Luchesa et al.<sup>18</sup> demonstrated the efficacy of TENS in analgesia, although no statistically significant differences were found regarding respiratory function. In contrast, in a study by Ozturk et al.<sup>20</sup>, a significant reduction in morphine consumption was reported in a patient-controlled analgesia protocol. However, when comparing the groups, no significant differences in analgesia were found between the control group and the TENS group. The other authors<sup>16,17,19</sup> found positive results with the use of electrostimulation promotes improvement in muscle strength, lung volumes and capacities, as shown in table 1.

**Table 1.** General data on included randomized controlled trials using TENS after cardiac surgery (to be continued)

Author/ Year	Sample	Study design	Mean age	Objective	Intervention	TENS protocol	Results
LIMA, et al <sup>16</sup>	20	Clinical trial, randomized and controlled	40 a 60 years	To analyze the effectiveness of TENS on pain and respiratory muscle strength in the 1st POD after CABG.	Control group: usual routine of analgesic and hospital physiotherapy. TENS Group: same treatment as the control group plus TENS (30 minutes, three times a day, 3 hours apart each application).	The frequency used in TENS was 80 to 110 Hz, with pulse width between 50 and 80 µs. The intensity of stimulation was modified according to the report of patient, being adjusted based on a feeling of intense paresthesia that did not cause discomfort, being increased during application.	It was effective in reducing pain, increasing respiratory muscle strength and decreasing analgesic request in the 1st POD. The same did not occur in the Control Group.
GREGORINI et al <sup>17</sup>	25	Prospective, randomized clinical trial	59,9 ±10,3	To evaluate the effectiveness of short-term TENS on pain, respiratory muscle strength, lung volume and capacity in the 3rd POD of cardiac surgery.	Control group: application of placebo TENS by modifying the device parameters to prevent its analgesic effect. TENS Group: TENS application for 4 hours, without other analgesic treatment in the last 8 hours after the intervention.	Current pulse at 80 Hz (hertz), pulse duration of 150 ms (microseconds) and dose in milliampères (mA), adjusted at a sensitive threshold.	It was effective in reducing pain at rest and cough; improved respiratory muscle strength, lung volume and capacity.
LUCHEHA et al <sup>18</sup>	30	Blind controlled and randomized experimental clinical trial with cross-sectional, prospective design	61,66 ± 9,48	To evaluate the effectiveness of TENS in reducing pain and improving lung capacity in postoperative CABG patients.	Control group: application of placebo TENS (without use of electric current). TENS Group: 2 daily applications (50 minutes each) of TENS from 1st to 5th POD (started 24 hours after surgery) All received medication analgesia according to the protocol of the surgical team.	Frequency at 80 Hz with square wave, biphasic, symmetrical in pulses of 125 µs. The current intensity (mA) was delimited according to the sensitivity of each patient.	It was effective in reducing pain levels in the TENS group when compared to the control group; however, although it improved respiratory function, this difference was not statistically significant.



**Table 1.** General data on included randomized controlled trials using TENS after cardiac surgery (conclusion)

Author/ Year	Sample	Study design	Mean age	Objective	Intervention	TENS protocol	Results
JUNIOR et al <sup>19</sup>	45	Prospective and randomized study	41 a 77 years	To evaluate the effectiveness of short-term TENS on pain, pulmonary function and muscle electrical activity in the 3rd POD of cardiac surgery.	Control group: application of placebo TENS by modifying the device parameters to prevent its analgesic effect. TENS Group: TENS application for 4 hours, without other analgesic treatment in the last 8 hours after the intervention.	During the 4-h treatment period, pulse duration was kept constant (150 ms) at a wave frequency of 80 Hz and a duty cycle (on:off time) of 330y33 ms	It was effective in significantly reducing spontaneous and cough-induced postoperative pain, as well as increasing pulmonary ventilatory function and electrical activity of the trapezius and pectoralis major muscles.
OZTURK et al <sup>20</sup>	120	Randomized, controlled prospective study	18 a 65 years	To compare the effectiveness of TENS with parasternal blockade using levobupivacaine in postoperative pain during the first 24 hours after cardiac surgery.	Control group: patient-controlled analgesia (IV morphine) after ICU admission. TENS group: protocol of the control group plus intermittent TENS (1 hour of stimulation with 1 hour of rest for 24 hours). Parasternal block group: protocol of the control group plus parasternal block (25mL levobupivacaine and 25mL saline). TENS and control groups received saline instead of levobupivacaine. Control and block groups received placebo TENS (no analgesic effect).	Therapeutic TENS unit produced an asymmetrical square biphasic waveform at a frequency of 100 pulses/s and a pulse width of 100 $\mu$ s.	There was a significant reduction in morphine consumption in the TENS and parasternal block groups, with lower consumption in the latter. Although lower VAS scores were found in the TENS group than in the control group, this difference was not significant. Only the parasternal block group had a significant reduction in pain scores.

TENS: Transcutaneous Electrical Nerve Stimulation; VAS: Visual Analog Scale; CABG: coronary bypass artery grafting; POD: postoperative day; IV: intravenous; ICU: Intensive Care Unit.

## Discussion

Based on the results obtained in this systematic review, it can be observed that the application of TENS, in the postoperative period of cardiac surgery, is effective in reducing pain and, as a consequence, improves ventilatory parameters such as tidal volume and vital capacity.

TENS is a non-pharmacological intervention, effective in analgesia of acute and chronic clinical conditions, such as postoperative nociceptive pain, osteoarthritis, diabetic neuropathy and others<sup>19</sup>. Its mechanism of action is related to central and peripheral mechanisms, including the induction of increased beta-endorphins, enkephalin methionine, as well as the activation of different opioid receptors, as well as the modulation of endogenous inhibitory mechanisms in the central nervous system involving receptors GABA and muscarinic. Some effects are also mediated by peripheral adrenergic receptors<sup>19</sup>.

In 2015, another research group conducted studies on patients submitted to posterolateral thoracotomy, demonstrating a reduction in analgesic consumption and a decrease in pain, corroborating the outcomes found by the authors mentioned in this review<sup>20</sup>. With the decrease in pain, the patient tends not to be excessively afraid to take deep breaths or cough, and these factors may favor the improvement of pulmonary function.

According to Lima et al.<sup>16</sup>, after surgery, patients present an involution in respiratory muscle strength, favoring the appearance of pulmonary complications. Thus, they proposed a protocol whose intervention was the use of electroanalgesia together with the standard protocol that was used for the control group, demonstrating the effectiveness of the device in reducing pain and improving muscle strength.

Especially in the article in which Junior et al.<sup>19</sup>, discusses the use of the device, the treatment was performed without group division, thus removing all pharmacological analgesia for 8 hours and analyzing the effect of electroanalgesia without influence of pharmacological treatment on the outcome of these patients. There was a significant decrease in pain, directly influencing cough-related pain, also reflecting better respiratory parameters, such as tidal volume and vital capacity.

As previously discussed, with the decrease in pain, the patient begins to show greater chest expansion, generating increased transpulmonary pressure and increased lung capacity. In addition, electrostimulation may be responsible for generating muscle contraction, increasing strength, making the patient able to perform more vigorous inspirations. This stimulation can occur when high intensity is used. As previously discussed, with the decrease in pain, the patient begins to present greater chest expansion, effectively negating pleural pressure, thus generating an increase in transpulmonary pressure and an increase in lung capacity. In addition, electrostimulation may be responsible for generating muscle contraction, increasing strength making the patient able to perform more vigorous inspirations. This stimulation can occur when high intensity is used. The use of TENS has been encouraged in these audiences, since the use of opioids is related to the development of adverse effects such as extreme drowsiness, nausea, vomiting, cough suppression, and greater difficulty in expectoration<sup>21</sup>.

In contrast, the findings by Ozturk et al.<sup>20</sup> did not show significant analgesia in the group receiving TENS. In this study, there was a division into three distinct groups, where part received parasternal block with levobupivacaine, another group received TENS, and both these groups and the control received patient-controlled analgesia with morphine. It was observed that people who underwent parasternal block had better efficacy in reducing pain compared to the group that used TENS in the management of postoperative pain, and this did not present significant difference statistics and clinic in analgesia when compared to the control group. The frequency and pulse intensity parameters of electrostimulation should be adjusted in order to achieve analgesic efficacy. However, when analyzing the protocol used by Ozturk et al.<sup>20</sup>, it was found that it used a different protocol from the other authors, with different parameters, which may justify the ineffectiveness of electroanalgesia in this intervention.

Given the findings reported in this systematic review with local improvement of pain in which stimulation is applied, it can be inferred that the patient's general well-being can be inferred, also reflecting in the parameters of cough and mobility and reducing drug consumption, protecting subjects the individuals from any adverse effects of such use.



The limitations found in the clinical trials used refer to the heterogeneity of the protocols used, such as intensity and time of application. Despite this, the application of TENS to patients in the postoperative period of cardiac surgery should be encouraged, aiming at reducing pain and greater adherence to the proposed treatment. Studies with the application of this instrument for a longer period and with more closed protocols should be encouraged.

## Conclusion

According to studies, electroanalgesia through TENS has reduced pain in individuals undergoing cardiac surgery. In addition, it was possible to notice that there are improvements in respiratory parameters, such as improved volume and lung capacity.

## Author contributions

Cordeiro ALL participated in study conception and design, analysis and interpretation of data, writing and review and approval of the final draft. Oliveira AP, Cerqueira N, Oliveira A, Miranda I participated in study conception and design and in the writing of the manuscript.

## Competing interests

No financial, legal or political competing interests with third parties (government, commercial, private foundation, etc.) were disclosed for any aspect of the submitted work (including but not limited to grants, data monitoring board, study design, manuscript preparation, statistical analysis, etc.).

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