Electronic Journal of General Medicine
2024, 21(5), em599
e-ISSN: 2516-3507
https://www.ejgm.co.uk/

MODESTUM

Case Report

OPEN ACCESS

Effect of transcutaneous neuromodulation on predictive parameters of extubation failure in severe acute pancreatitis: A case report

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Citation: Hernández-Garcés H, Selva-Sarzo F, Belenguer-Muncharaz A, Fernández-Carnero S, Sánchez-Romero EA, Zaragozá-Crespo R. Effect of transcutaneous neuromodulation on predictive parameters of extubation failure in severe acute pancreatitis: A case report. Electron J Gen Med. 2024;21(5):em599. https://doi.org/10.29333/ejgm/14781

ARTICLE INFO

Received: 10 Nov. 2023

Accepted: 02 May 2024

ABSTRACT

Background: Complications of pancreatitis can lead to admission to the intensive care unit (ICU) with invasive mechanical ventilation. Reducing the duration of mechanical ventilation is challenging for critical care practitioners. Respiratory muscle weakness hinders the weaning process, thereby increasing the duration of mechanical ventilation and hindering pulmonary rehabilitation.

Methods: We evaluated the effect of transcutaneous neuromodulation on predictors of extubation failure. The patient was a 51-year-old male with a history of type 2 diabetes, obesity (body mass index=35), and regular alcohol consumption of 40 g/day. The patient was admitted to ICU with a diagnosis of severe acute pancreatitis and multi-organ failure. Maximum inspiratory pressure (MIP), airway occlusion pressure at 100 ms (P0.1), rapid shallow breathing index (RSBI), and diaphragmatic thickening fraction (DTf) were measured.

Results: The results demonstrated an improvement in all the parameters. Show an increase in MIP from -18 cmH2O to -37 cmH2O and a reduction in P0.1 from -5.7 cmH2O to -3.1 cmH2O. RSBI decreased from 107 to 72, and DTf increased from 20% to 35%. The patient was extubated successfully and discharged to the ward after a 28-day ICU stay.

Conclusions: The application of transcutaneous neuromodulation led to an improvement in the predictive parameters of extubation failure in patients with severe acute pancreatitis, which was ultimately confirmed by ventilatory support not being required after extubation. Transcutaneous neuromodulation application helps improve respiratory parameters and systemic improvement of the patient until he is released from ICU. Transcutaneous neuromodulation should be used in combination with other physiotherapy techniques and should be included in a comprehensive rehabilitation protocol rather than as an isolated therapy.

Keywords: intensive care unit, neuromodulation therapy, transcutaneous, rehabilitation, multiple organ failure, pancreatitis

INTRODUCTION

Prolonged invasive mechanical ventilation (IMV) is required by approximately 15% of patients admitted to the intensive care unit (ICU) and is associated with complications such as ventilator-associated pneumonia, tracheal ischemia, and diaphragmatic dysfunction, and therefore, increased length of stay and mortality [1-3]. As a result, the earliest possible removal of IMV is the principal objective of ICU practitioners [1-4].

Currently, IMV disconnection process begins with a spontaneous breathing trial (SBT), using an oxygen supply without ventilation or low levels of support ventilation, for 30-120 minutes [5]. Some causes of extubation failure are not exclusively related to gas exchange problems but also to mechanical failure due to respiratory muscle weakness induced by the use of IMV [2]. Mechanical failure can be evaluated during SBT, and the following predictors of extubation failure have been identified: a rapid shallow breathing index (RSBI) greater than 105, maximum inspiratory pressure (MIP) of less than -20 cmH2O, and a diaphragmatic thickening fraction (DTf) of less than 30% [6].

Diverse approaches have been proposed to prevent or minimize this weakness of the respiratory musculature, principally respiratory physiotherapy (RP) techniques within a pulmonary rehabilitation program, with the objective of improving the strength and resistance of the respiratory muscles [2, 7-10].

The concept of an interactive network between cutaneous nerves, neuroendocrine axis, and immune system has been established [11-14]. Neurocutaneous interactions influence a variety of physiological and pathophysiological functions, including cell growth, immunity, inflammation, pruritus, and wound healing [12]. This interaction is mediated by primary afferent and autonomic nerves, which release neuromediators and activate specific receptors on many target cells in the skin [13]. A dense network of sensory nerves releases neuropeptides, thereby modulating inflammation, cell growth, and immune responses in the skin [14].

Recent biological and medical studies on the use of magnetic nanoparticles have tended to evaluate their effects on tissues, cells and biomolecules [15]. It has been shown that magnetic compounds activated by external magnetic fields further improve the biological properties of cells [16].

Transcutaneous neuromodulation using tape containing magnetic particles (TCMP) is based on an adhesive elastic bandage containing magnetic nanoparticles that cannot create magnetic fields until the bandage comes into contact with electromagnetic fields such as those generated by living organisms [11, 17].

In internal medicine, external magnetic fields interact with nanoparticles which can associate or interact with tissues, cells, or biomolecules [18]. However, owing to their small size, they do not exhibit any magnetization unless they are in an external magnetic field [19]. TCMP uses the same methodology in cases, where the magnetic nanoparticles are activated upon contact with electromagnetic fields of the epidermis [11, 17].

The magnetic field acts as a vehicle to induce ion flow and does not stimulate the nerve tissue itself [19]. However, once ion flow is generated in epidermal cells, the mechanism of electrical and magnetic stimulation at the neural level is the same, resulting in depolarization of the axon and initiation of the action potential [20]. Moreover, epidermal cells, especially Langerhans cells, which induce ion flow, act on the lymphatic system and are innervated by the sympathetic autonomic nervous system [21, 22].

Studies have investigated the effect of transcutaneous neuromodulation using TCMP on the modulation of peripheral vascularization and low back pain [17]. It has been shown to have a systemic effect, thereby influencing the autonomic nervous system [11].

This physiological baseline led us to believe that TCMP could have beneficial effects in patients who have developed respiratory muscle weakness and may therefore facilitate IMV disconnection process and help improve health.

The application of TCMP can help improve predictive parameters for extubation failure in patients with severe acute pancreatitis.

CASE PRESENTATION

Patient's Relevant Demographic Details & Medical History

We present the case of a 51-year-old white male patient with a history of type 2 diabetes, obesity (body mass index=35), and regular alcohol consumption of 40 g/day. This document was written following CAse REport (CARE) guidelines [23] for case reports.

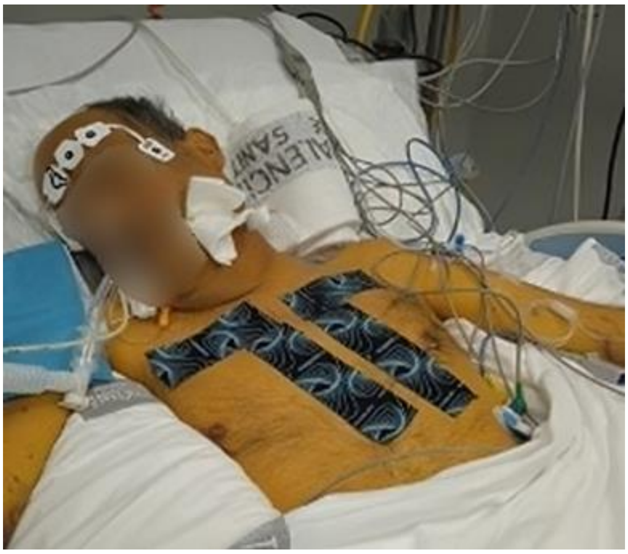

Figure 1. Application of transcutaneous neuromodulation using a TCMP in intubated ICU patient (reprinted with informed consent and permission of the patient)

Symptoms & Signs

The patient presented to the emergency department with abdominal pain radiating to his back, nausea, vomiting, and breathlessness. Blood analysis showed amylase and lipase levels of 493 and 1,584 UI/L, respectively. He was admitted to ICU with a diagnosis of severe acute pancreatitis, development of multiorgan failure with acute kidney failure (glomerular filtration rate of 38), hemo-dynamic instability requiring noradrenaline vasopressor support, and hypoxemic respiratory failure requiring initiation of noninvasive mechanical ventilation. Ultrasonography and computed tomography did not reveal cholelithiasis or other complications. The triglyceride level was 775 mg/dL.

Treatment or Intervention

Two days after the patient's admission to ICU, he required orotracheal intubation and IMV, which was used for 13 days, four of which had muscle relaxation due to an intra-abdominal pressure above 25 mmHg. Over the course of 13 days, the patient was on IMV; organ failure progressively resolved, and respiration improved. Transcutaneous neuromodulation using TCMP (Magnetic Tape®, S.L., Valencia, Spain) was applied to the anterosuperior region of each hemithorax to coincide with the great vessels, lymph nodes, and cutaneous innervation of the thorax (**Figure 1**).

SBT was carried out using the Puritan Bennett™ 980 ventilator (Medtronic, Dublin, Ireland), placing the patient in pressure support ventilation (PSV) mode with a maximal inspiratory pressure (MIP) of seven cmH2O and positive end-expiratory pressure (PEEP) of zero cmH2O.

Outcomes

Measurements were taken before TCMP application 30 min prior to SBT (t1), five minutes after application (t2), and one hour after application (t3). A comparison of the measurements taken at t1 and t2 show an increase in MIP from -18 cmH2O to -37 cmH2O and a reduction in airway occlusion pressure (P0.1) from -5.7 cmH2O to -3.1 cmH2O. RSBI decreased from 107 to 72, and DTf increased from 20% to 35% (**Figure 2** and **Figure 3**).

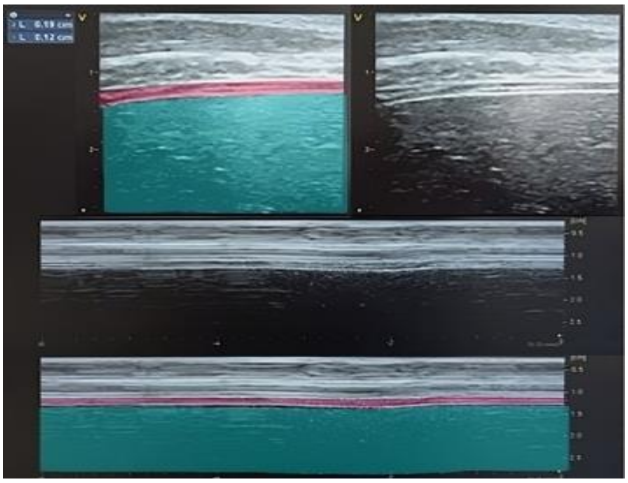

Figure 2. Ultrasound performed before application of TMP (rapid shallow breathing index & diaphragmatic thickening fraction observed by t1-weighted ultrasonography by M-mode [highlighted in red-diaphragm muscle & blue-liver]) (Source: Authors' own elaboration)

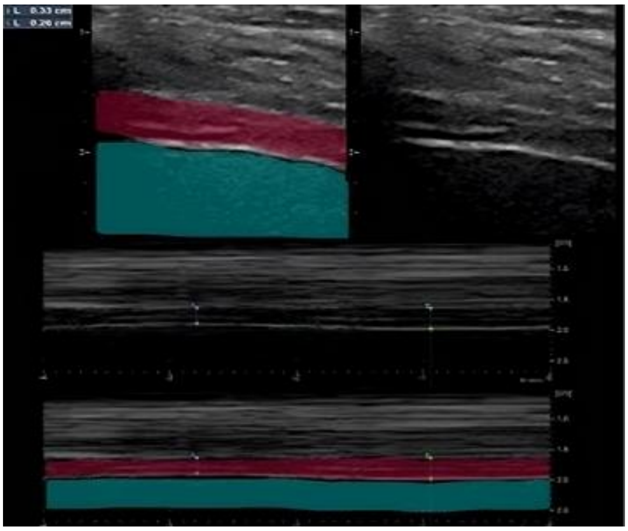

Figure 3. Ultrasound performed after application of TMP (rapid shallow breathing index & diaphragmatic thickening fraction observed by t1-weighted ultrasonography by M-mode [highlighted in red-diaphragm muscle & blue-liver]) (Source: Authors' own elaboration)

Minor differences were observed between the measured values obtained at t2 and those obtained one hour after TCMP application at t3 (**Figure 4**).

Two hours after the start of SBT, the patient was extubated, and prophylactic non-invasive ventilation (NIV) was administered for 24 hours. After this time, NIV could be removed without the need for reintubation. The patient was discharged to the hospital ward after a 28-day stay in ICU.

The application of TCMP changed the measured values until they were far below the cutoff values proposed as predictors of failure.

DISCUSSION

In the present case, a significant change in the traditional predictive parameters of extubation failure was observed after

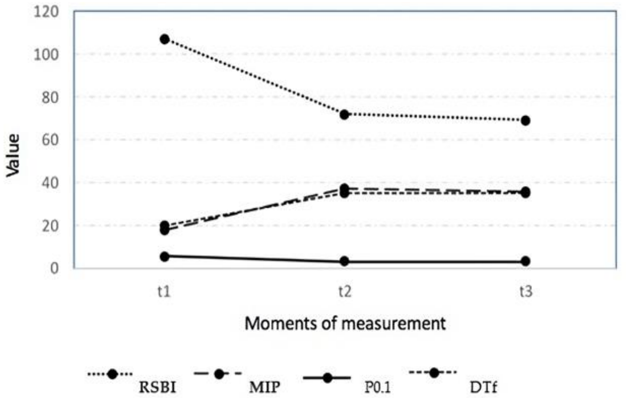

Figure 4. Evaluation of predictive parameters at three moments of measurement (Source: Authors' own elaboration)

Note: RSBI: rapid shallow breathing index; MIP: maximum inspiratory pressure; DTf: diaphragmatic thickening fraction; P0.1: airway occlusion pressure

TCMP application. It remains to be seen whether this effect exists in a wide range of patients.

In the event that it is replicated and confirmed, we believe that TCMP should be used in combination with other physiotherapy techniques and be included in a comprehensive pulmonary rehabilitation protocol, rather than as an isolated therapy.

The measurements taken before and after the application of TCMP are compared.

RP techniques used to date do not appear to have a significant impact when used in isolation or for a short period of time [24]. On the other hand, a combination of RP techniques may have positive repercussions in terms of mortality [25].

Consequently, a priori, it would be difficult to believe that a single pulmonary rehabilitation intervention delivered in isolation could have such striking effects. However, the application of TCMP in our patient changed the values measured until they were far below the cut-off values proposed as predictors of failure.

Although the systemic effects of TCMP appear to have been defined [11, 17], the mechanism by which it may improve the parameters studied remains unclear. The stimulation of the sympathetic nervous system induced by TCMP might be responsible for the changes observed through modulation of the lymphatic system, which in turn acts on the immune system and thus assists in homeostasis recovery [11].

The influence of an interactive network between cutaneous nerves, the neuroendocrine axis, and the immune system[13, 14] seems to be the action pathway of TCMP acting on the primary afferent and autonomic nerves [11].

Human lymph nodes contain sympathetic nerves in their capsule, trabeculae, cortex, medulla, and hilum, both as perivascular and discrete structures [22]. Discrete nerves were observed in relation to T cells and non-T cell-rich areas, such as hilar and capsular connective tissue[13, 14, 22]. The presence of discrete structures suggests neural regulation of structures other than blood vessels and was confirmed by the presence of varicosities in a portion of these nerves[13, 14, 22].

Langerhans cells are located precisely at this level in the skin [22]. Ion flow is induced and innervated by the sympathetic autonomic nervous system in these cells. These observations are of relevance in further understanding the neural regulation of lymph node immune responses and in the development of neuromodulatory immune therapies, leading us to hypothesize that these cells may play a role in the observed effects of TCMP application [22].

Some studies have concluded that magnetic field therapy alleviates pain [26], promotes bone regeneration [27], muscles [15], and nerves [28], improves vascularization of tissues [17], and significantly increases maximal strength and decreases the time to reach maximal strength (peak time) [29]. Furthermore, a recent study related epidermal dysfunction to modifications in the thalamus [28].

CONCLUSIONS

In our patient with severe acute pancreatitis, the application of TCMP led to an improvement in the predictive parameters of extubation failure, which was ultimately confirmed by ventilatory support not being required after extubation.

TCMP should be used in combination with other physiotherapy techniques and should be included in comprehensive rehabilitation protocols.

The application of TCMP described in this report could help improve the expectations and prognosis of pulmonary rehabilitation.

Author contributions: HH-G, FS-S, AB-M, SF-C, EAS-R, & RZ-C: validation & supervision; **HH-G, FS-S, AB-M, & RZ-C:** writing–original draft preparation; **HH-G, AB-M, & RZ-C:** investigation; **FS-S & EAS-R:** conceptualization, methodology, software, formal analysis, resources, data curation, writing–review & editing, & funding acquisition; & **FS-S:** visualization & project administration. All authors have agreed with the results and conclusions.

Funding: No funding source is reported for this study.

Acknowledgments: The authors would like to thank the patient of the report for making this study possible.

Ethical statement: The authors stated that the study was conducted in accordance with the Declaration of Helsinki. Ethics approval was obtained from Hospital Dr Peset with Ethics Approval Number 123/20. Informed consent was obtained from the patient involved in the study. Written informed consent has been obtained from the patient to publish this report.

Declaration of interest: The authors report a potential conflict of interest in the fact that **FS-S** is the developer of the magnetic tape. **FS-S** did not have access to ICU, nor to data collection. The rest of the authors do not present any relationship of any kind with the brand.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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