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Review article

Hyperventilation and electroconvulsive therapy: A literature review

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A R T I C L E I N F O

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A B S T R A C T

Background: Hyperventilation has been proposed as an augmentation strategy in electroconvulsive therapy (ECT) in accordance with its proconvulsant effect.

Objective: This study reviews the existing literature on the application of hyperventilation in ECT, its efficacy, and tolerance.

Methods: A systematic search was performed in PubMed and EMBASE databases. Search terms ('electroconvulsive therapy' and 'hyperventilation', 'ventilation', 'hyperoxygenation', 'hyperoxia', 'hypocapnia') were used to retrieve works from 1966 to June 2016. Works that described hyperventilation manoeuvres in ECT settings and their clinical repercussion were included in the review.

Results: A total of 17 observational and experimental studies were selected. An important heterogeneity in study designs, samples and ECT conditions, was detected. Findings support a positive influence of hyperventilation on seizure duration, which is the main study variable across different works. Effects of hyperventilation on seizure threshold and quality parameters have been less thoroughly studied. Systematic recording of clinical outcomes and adverse effects of hyperventilation is uncommon.

Conclusions: The literature suggests that hyperventilation may be an effective and safe technique to enhance ECT, but many aspects remain to be studied. Further investigations, especially controlled clinical trials, are necessary and should result in a specific and reliable hyperventilation protocol for ECT settings.

1. Introduction

Electroconvulsive therapy (ECT) is a safe and established technique, which includes highly protocolized procedures [1,2]. The usual respiratory care can be completed in about 10 min. Once anaesthesia and neuromuscular blocker are administered, respiratory function must be artificially secured [3]. Poor ventilation may cause hypercapnia, which has been associated with hypertension, tachycardia, somnolence, delayed recovery from anaesthesia, and a higher prevalence of agitation and headache [3–5]. Furthermore, incidence of oxygen desaturation after a single ECT session can occur, especially in obese patients and in prolonged seizures [6,7] or when previous ventilation has been insufficient [8,9]. Lastly, as some respiratory complications might occur [10] and cardiac disturbances are relatively common in ECT, especially in elderly and multi-pathological patients [11], a good oxygenation is also needed to withstand the brief stress to the heart that follows electrical stimulation. Hence, monitoring and ensuring proper ventilation assistance throughout the ECT procedure, along with surveillance of vital signs, are recommended by clinical guidelines [1,12].

However, ventilation also has a role in enhancing ECT efficiency through an increase in seizure length and an improvement in other quality parameters [13]. To overcome the rise in seizure threshold that occurs during the course of ECT [14], it is usually necessary to gradually increase the electrical dose, which in turn has been associated with undesirable effects such as amnesia or confusion [15]. Thus, dose optimization in the delivered stimulus is suitable for all ECT patients. Several proconvulsant strategies have been proposed: concomitant use of methylxanthinic drugs (caffeine, theophylline) [16], opioids (remifentanil) [17], flumazenil [18], choice for certain anaesthetics (etomidate, ketamine) [19], changes in electric parameters [20], sleep

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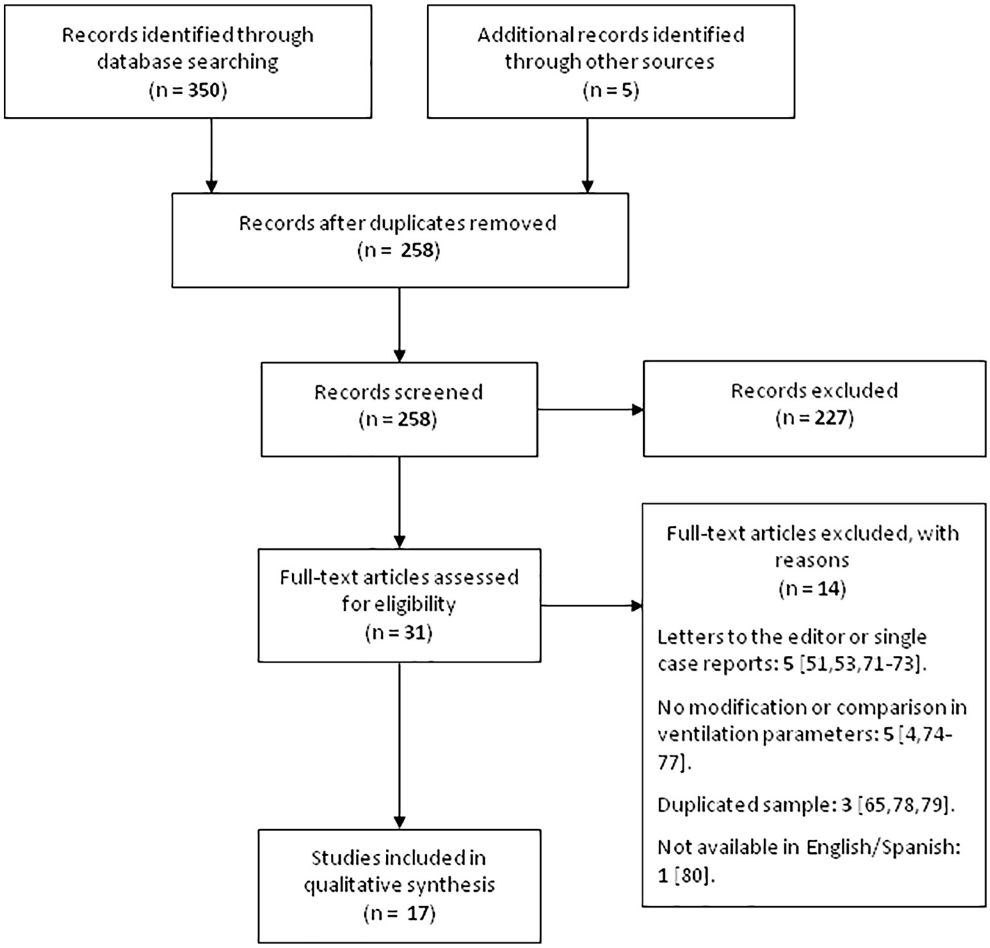

Fig. 1. Flow diagram of reviewed articles. Detail of the screening procedure and main reasons for study exclusion.

deprivation [21] or hyperventilation itself [1]. All of them can decrease the seizure threshold and therefore the electric dose necessary to obtain the convulsion [22,23].

Evidence from epilepsy studies [24] and experimentation on animal models [25] indicate that both hyperoxia and hypocapnia increase the duration of seizures and cause a synergistic effect when occurring concurrently. In humans undergoing ECT, this seizure lengthening has already been suggested in primitive works when hyperoxygenation was performed, albeit without assessment of carbon dioxide pressure [26,27].

Nevertheless, even today, clinical guidelines do not thoroughly address the issue of ventilation management in ECT. Pre-oxygenation is used in order to achieve an intrapulmonary oxygen reserve and extend the duration of safe apnoea. Although pre-oxygenation and hyperventilation are widely recommended as a part of ECT protocol, it is not usually specified how to optimally perform ventilation manoeuvres to improve ECT sessions.

As a main aim for the present work, we review the existing literature concerning the application of hyperventilation in ECT settings to elucidate aspects of its proconvulsant efficacy and clinical effects and tolerability in observational and experimental studies.

2. Material and methods

Literature regarding hyperventilation in ECT sessions during the last 50 years (1966–2016) was screened for systematic review. A citation search was conducted in June 2016 in *PubMed* and *EMBASE* databases by combining 'electroconvulsive therapy' with the following search terms: 'ventilation', 'hyperventilation', 'hyperoxygenation', 'hyperoxia', and 'hypocapnia'. All suitable publications in English and/or Spanish were extracted. The distinction between hyperoxygenation and hyperventilation (which should involve a state of hypocapnia and hyperoxia) is not always clear throughout the literature, so both terms have been included.

In addition, references of the selected articles on ECT anaesthesia and augmentation strategies [22,23,28,29], and of specialized textbooks were also reviewed and their relevant cross-references were searched manually. Data of one of the retrieved citations were obtained directly from the author as the full-text version was unavailable [30]. No search of unpublished data was performed.

A first screening, by close reading of abstracts, was independently performed by two of the authors. A consensus of which references identified were suitable for the review was reached by the authors. For those cites, the complete articles were assessed for eligibility.

Articles were eligible for inclusion provided that they (1) referenced ECT in human subjects (regardless of psychiatric diagnosis), (2) described hyperventilation, as measured by changes in CO_2 or O_2 pressure or unmeasured but with a description of hyperventilation in the airway technique, and (3) specified their clinical repercussion (e.g. blood pressure, heart rate or other cardiovascular variables, seizure duration, stimulus intensity, postictal suppression index and other seizure quality parameters, side effects).

Exclusion criteria were: (1) letters to the editor or single case reports; (2) no modification in ventilation parameters; (3) duplicated samples and results previously described in earlier works on the same topic; (4) full-text articles not available in English or Spanish.

Clinical data extracted from the eligible articles were: study population, study design, hyperventilation procedure, CO_2 target or achieved level, outcome measures, main results, and side effects.

The available studies were limited in number and quality.