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REVIEW

Pulmonary hypoinsufflation in patients with pleural effusion, advantages and disadvantages of respiratory therapy with EzPAP®: an integrative review

Pulmonary hypoinsufflation in patients with Pleural effusion, Advantages and Disadvantages of Respiratory Therapy with EzPAP®: an Integrative Review

Brenner Dias Rocha[a*], Pâmella Soares de Sousa[b], Erikson Custódio Alcântara[b]

[a] Pontifícia Universidade Católica de Goiás – PUC-GO, Goiás, Brasil.

[b] Universidade Estadual de Goiás – UEG, Goiás, Brasil.

* Correspondence: eriksonalcantara@hotmail.com

ABSTRACT

To analyze how advantages and disadvantages of respiratory therapy with EzPAP® in patients functionally diagnosed with pulmonary hypoinflation. Methods: in this integrative review, conducted from March to May 2020, searches were performed in the Pubmed, CAPES and MedLine databases, in the period 2000-20. The selected descriptors were: Ezpap, atelectasis and pulmonary function, present in the Health Sciences Descriptors (DeCS). A total of 12 articles were evaluated, of which 9 studies were selected to compose the review. Results: The indication of EzPAP® is a therapeutic alternative for lung expansion in patients with Pleural Effusion, in the presence of loss of lung volumes and resources, a device that allows to offer inspiratory flow and positive end-expiratory pressure, which enables reversal of areas previously collapsed, stimulating the reabsorption of pleural fluid by the lymphatic system and restoring adequate function to hypoinflated and atelectatic lungs. Conclusion: There is an indication for the use of EzPAP® for the treatment and correction of atelectasis and pulmonary hypoinflation if necessary with pleural effusion, mainly to correct hypoxemia and reduce dyspnea.

RESUMO

Analisar as vantagens de desvantagens da terapia respiratória com EzPAP® em pacientes diagnosticados funcionalmente com hipoinsuflação pulmonar. Métodos: nesta revisão integrativa, conduzida nos meses de março a maio de 2020, fez-se buscas realizadas nas bases de dados Pubmed, CAPES e MedLine, no período de 2000-20. Os descritores selecionados foram: Ezpap, atelectasia e função pulmonar, presentes nos Descritores em Ciências da Saúde (DeCS). Foram avaliados um total de 12 artigos dos quais 9 estudos foram selecionados para compor a revisão. Resultados: A indicação do EzPAP® mostra-se uma alternativa terapêutica para expansão pulmonar nos indivíduos acometidos por Derrame Pleural, na presença de perda de volumes e capacidades pulmonares, dispositivo que permite oferecer fluxo inspiratório adicional e pressão positiva expiratória final, que possibilita reversão de áreas previamente colapsadas, estimulando a reabsorção do líquido pleural pelo sistema linfático e devolvendo a função adequada à pulmões hipoinsuflados e atelectasiados. Conclusão: Há indicação do uso do EzPAP® para tratamento e correção de atelectasia e hipoinsuflação pulmonar em indivíduos com derrame pleural, sobretudo para corrigir hipoxemia e diminuir a dispneia.

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Pleural effusion; Atelectasis, Ezpap, Pulmonary Function.

Introduction

Restrictive Ventilatory Disorder (RVD) is defined by a reduction in total lung capacity. It is measured by spirometry in the presence of a normal FEV_1/FVC ratio with reduced Forced Vital Capacity (FVC) and the presence of an evident cause for restriction[1].

FVC dysfunction is classified as mild with 60-80%; moderate 41-59%, and severe ≤ 40% of predicted. These intervals should be used for the physical therapist to determine the functional diagnosis of pulmonary hypoinflation[1,2].

The accumulation of fluid in the pleural cavity is one of the main determining factors for restrictive lung disease, especially in patients whose fluid volume is moderate to large. The reduction in lung volumes occurs due to mechanical compression caused by the presence of fluid volume in the pleural space, causing a decrease in residual volume and lung compliance, which has functional repercussions in the individual who has dyspnea, hypoxemia, and reduced quality of life[3].

The EzPAP® is a non-invasive, portable, low-cost respiratory physiotherapy device that provides inspiratory pressure and flow. In the EzPAP® device, atmospheric air joins the flow of external oxygen, coming from a gas cylinder, favoring the fusion of gases inside the device, increasing the pressure and velocity of the inspiratory flow by up to four times[4]. It is an alternative for the treatment of atelectasis and pulmonary hypoinflation, as it provides an increase in functional residual capacity, vital capacity, and improvement in the ventilation/perfusion ratio and, consequently, functional improvement in patients[5].

Considering the prevalence (12%)6 of restrictive lung diseases in hospitalized patients and a greater negative impact as age advances, it was felt the need to carry out an integrative review on the application and effects of EzPAP®, observing beneficial and therapeutic effects in this profile of individuals affected by pleural effusion, to observe the reach of the proposed therapeutic targets.

The objective is to analyze the advantages and

disadvantages of respiratory therapy with EzPAP® and functional repercussions in patients with a diagnostic hypothesis of pulmonary hypoinflation resulting from pleural effusion.

Methods

This is an integrative review of the literature, understood as a method that allows the exposure of evidence about clinical practices in the health care context, in terms of individuals with Pleural Effusion. Initially, the theme was identified and the guiding question of the study was elaborated; inclusion and exclusion criteria were established; a search was carried out in the scientific literature; the information of interest to the researchers was defined, followed by interpretation. The literature review will be presented in Table 1 and commented on during the study.

The guiding question of the study was: *What are the advantages and disadvantages of respiratory therapy with EzPAP® and the effects on conditions of lung hypoinflation caused by pleural effusion?*

Searches were performed in PubMed, CAPES, and Medline databases in the period 2000-20. The selected descriptors were: Ezpap, atelectasis, and pulmonary function, present in the Health Sciences Descriptors (DeCS).

Inclusion criteria for selection were: original articles controlled clinical trials, and retrospective studies, published in Portuguese, English, Spanish, Italian, or German available in the selected databases. Repeated articles, publications that were not allocated in databases, articles that mix several respiratory therapies without a clear definition of the outcome, articles without a clear description of the methodology, contradictory results, and course conclusion works were excluded.

A total of 12 articles were evaluated, of which 9 studies were selected to compose this review. Table 1 shows the distribution of articles in the databases and the combination of descriptors.

The studies obtained from the databases selected according to the descriptors, in health Ezpap AND atelectasis AND Pulmonary Function, were: CAPES, PubMed, and MedLine, with 1, 6, and 2 studies being selected from each database, respectively.

Results

There is a higher prevalence of studies related to the therapeutic use of EzPAP® in the postoperative period of thoracoabdominal surgery, especially about the reversal of pulmonary atelectasis, common in thoracic and abdominal surgical and postoperative procedures. Table 1 shows the studies found in the databases by the selected descriptors.

Table 1. Synthesis of selected studies with their respective objectives and results.

Author/Year	Objective	Type of study	Results
Omar et al, 2015 [7]	Examine the effects of gas flow by Peak Inspiratory Flow (PIP) Peak Expiratory Pressure (PEP), Peak Inspiratory Flow (PIF) Peak Expiratory Flow (PEF), Volume, and PIF/PEF.	Controlled Clinical Trial	O EzPAP® foi associado ao aumento do fluxo e pressão de vias aéreas, também houve aumento do fluxo expiratório. O aumento da PEP foi maior que da PIP. Quando o fluxo inspiratório foi aumentado, houve significante aumento nos valores de PIP, PEP, PFI/PFE e PIF. Não houve mudança significativa no volume inspiratório.
Iberl et al, 2014 [8]	To analyze the therapeutic effects of EzPAP® and its use in patients with Chronic Obstructive Pulmonary Disease (COPD) and severe emphysema.	Controlled Clinical Trial	An increase in time off Non-Invasive Ventilation (NIV) was achieved in dependent patients (n = 9), a median decrease in dyspnea sensitivity by 3.3 points on the BORG scale (BORG of 10), and a median increase in the ability to walk 50.4 m in the 6-minute Walk Test. Median lung function showed an increase in vital capacity by 544 ml. The combination with manual inflation technology led to a decrease in transcutaneous CO_2 measurement by 7.3 mmHg.
Nyland et al, 2016 [9]	To determine whether prophylactic adoption of lung expansion therapy can improve patient clinical and functional outcomes and reduce hospitalization time and associated complications in patients with chest trauma.	Controlled Clinical Trial	The study demonstrates that prophylactic respiratory therapy with MetaNeb or EzPAP® improved the prognosis of these individuals, mitigating adverse events and improving the course of hospital stay.
Rieg et al, 2012 [10]	To compare the effect of standard oxygen delivery by face mask with the delivery of O2, using EzPAP, providing Positive End Expiratory Pressure (PEEP)	Randomized Clinical Trial	There was no difference in SpO_2 between patients selected for EzPAP® and patients in the control group (standard oxygen therapy). However, the need to return to oxygen therapy was lower in the EzPAP® group (EzPAP 25 group versus 41 control

	in post-anesthesia patients who had hypoxemia and inefficient ventilation.		group), as well as the occurrence of post-anesthetic complications (EzPAP 13 group versus 25 control group). It was observed that obese patients and patients with pulmonary disorders such as COPD benefited from the administration of oxygen using EzPAP® and presented higher SpO_2 values, being considered a well-tolerated, effective, and easy-to-operate physiotherapeutic resource.
Rowley et al, 2019 [11]	To identify the therapeutic difference in End-Expiratory Pulmonary Impedance (ΔEELI%) between incentive spirometry and EzPAP®.	Randomized Controlled Clinical Trial	The incentive spirometry and EzPAP® groups demonstrated an increase in ΔEELI% after lung expansion therapies in each of the measures in patients undergoing upper abdominal surgery; an increase for incentive spirometry versus EzPAP®, on the first day postoperatively 16% versus 12%, on the second postoperative day 6% versus 6% and on the 5th day 9% versus 6%. The length of hospital stay and the incidence of postoperative pulmonary complications were similar.
Elliott et al, 2013 [12]	To review the continued use of EzPAP® as an effective therapeutic modality for lung reexpansion.	Retrospective Study	The use of EzPAP® is recommended to promote lung reexpansion in postoperative thoracic surgery patients who present ineffective ventilation, to prevent atelectasis and facilitate the management of tracheobronchial secretions.
Talley et al, 2012 [13]	To analyze the effects of nasal catheter compared to EzPAP® in patients in the immediate postoperative period of laparoscopic abdominal surgery.	Controlled Clinical Trial	An improvement in SpO_2 was demonstrated in the postoperative period with the use of EzPAP® and a reduction in respiratory effort in the first hours. There was no improvement in CO_2 and SpO_2 levels in both groups before the first 4 postoperative hours.
Fassone et al, 2015 [14]	To compare the use of EzPAP® with traditional physical therapy in patients undergoing cardiac surgery.	Controlled Clinical Trial	EzPAP® was associated with a reduction in associated complications (reintubation, hemodynamic lability, or increased respiratory distress) such as a decrease in the number of ICU admissions and the need for reintubation when compared to traditional physical therapy (forced expiration and/or coughing techniques).
Wiersgalla et al, 2002 [15]	To compare EzPAP® with Incentive Spirometry in the correction of atelectasis in the postoperative period of cardiac surgery.	Controlled Clinical Trial	The group that received Incentive Spirometry therapy (n = 20) showed correction of atelectasis areas by 25%, while the EzPAP® group (n = 30) showed improvement of atelectasis by 100%.

Discussion

Pleural effusion is a condition that causes restriction of lung volumes, with reduced lung capacities and often worsening gas exchange. Pulmonary hypoinflation is the most common functional alteration in patients with pleural effusion[16].

The indication of EzPAP® appears to be a therapeutic alternative for lung expansion, due to the loss of lung volumes and capacities in the postoperative period of the chest and abdomen, or as a prophylactic measure. The device offers additional inspiratory flow and positive end-expiratory pressure[10], which makes it possible to reverse hypoinflated and/or collapsed areas by allowing a longer expiratory time[8], reducing the Pendelluft effect due to inequalities in the time constant of the alveolar units.

Intra and postoperative factors

General anesthesia influences the repercussions on pulmonary function, regardless of age or weight of the individual, by relaxing the respiratory muscles and causing a change in pleural pressure compliance. This factor contributes to gravitational collapse, promoting the formation of atelectasis by reducing functional residual capacity and increasing intraoperative shunt, resulting in hypoxemia[17].

Chung et al.[18] found that being overweight is also an intraoperative and postoperative complicating factor, especially in the formation of atelectasis and hypoinflated lung areas. The findings of this study are similar to those of Talley et al.[13], who observed the presence of ventilatory and respiratory dysfunctions in obese patients undergoing laparoscopic abdominal surgery, given that the management of the abdominal cavity and abdominal circumference generates compression of the lung parenchyma. because the abdominal contents cephalosate the diaphragm[19]; it was found in this study that EzPAP® was more favorable in

this population than oxygen therapy by nasal catheter, ensuring a significant increase in peripheral oxygen saturation (SpO_2) together with a reduction in ventilatory effort and carbon monoxide retention.

The evolution of medical procedures for thoracic and cardiac surgery cannot be ignored, but pulmonary complications of multifactorial origins are frequent. It is worth mentioning the surgical incisions of the median sternotomy type, the use of cardiopulmonary bypass (CPB) which, in turn, induces an increase in endothelial permeability, increased fluid in the interstitium; which contributes to the formation of pulmonary atelectasis[20], increased pulmonary shunt and changes in gas exchange, above all, increased risk of diaphragmatic dysfunction[21].

Wiersgalla et al.[15] evaluated the use of EzPAP® in individuals in the postoperative period of coronary bypass heart surgery (myocardial revascularization), which showed the effectiveness of the device when compared to incentive spirometry, demonstrating an improvement of 100% of atelectasis on chest radiography. The group that received treatment with incentive spirometry presented correction of atelectasis in only 25%. However, there are limitations in this study, the sample size (N=50) is just one variable to assess the outcome. While in the study by Fassone et al.[14], the effectiveness of traditional respiratory physiotherapy (forced expiration and/or coughing techniques) was evaluated when compared to EzPAP® in patients after cardiac surgery; the EzPAP® device excelled in reducing the need for intensive care and decreasing the rate of re-intubation.

Factors associated with the functionality of the respiratory system

Dyspnea is a limiting factor and is frequently present among patients with pleural effusion, resulting from compression of the lung parenchyma together with mechanical changes in the respiratory muscles and rib cage. This biomechanical disorder of the respiratory system results from the advancement of pleural effusion, which alters the lung length-tension relationship. This factor has a direct impact on ventilatory efficiency and gas exchange. The greater the volume of the pleural effusion, the greater the compression on the lung, with worse functionality, commonly expressed by ventilatory failure[22].

For Omar et al.[7], the use of EzPAP® increased the expiratory flow, and the increase in PEP, resulting in a significant increase in the expiratory time, essential for the treatment and reversal of atelectasis and pulmonary hypoinflation. The impact on lung function was in the optimization of gas exchange, there was no effect on mucociliary clearance when indicating this device.

Benefits were pointed out in the application of EzPAP® in chronic obstructive patients; Iberl et al.[8] conducted a study with 30 patients who presented with postoperative hypoxemia. In the group that included high-risk individuals, postoperative hypoxemia, such as chronic obstructive, obese, and heart failure patients, there was an improvement in spirometric measurements with an average increase in the tidal volume of 544 ml, a reduction of 3.3 points in sensitivity of dyspnea by the BORG scale; above all, there was an average increase in vital capacity of 1.5L (43%) and in the distance walked by these individuals in the 6-minute walk test (50.4m), increasing the time off Non-Invasive Ventilation (NIV) between 2 .5 to 6 hours in dependent patients, as in the study by Rieg et al.[9], who observed an improvement in peripheral oxygen saturation (SpO_2) with a median greater than or equal to 88% compared to spontaneous ventilation, which maintained the saturation lower than 70% in the profiles of obese and chronic obstructive patients.

The presence of risk factors for atelectasis and pulmonary hypoinflation, such as being overweight or induction of intraoperative general anesthesia, are reasons that indicate prophylactic intervention, to allow the patient, through the teaching-learning effect, to understand and also perform the procedure. EzPAP® in a coordinated and synchronized way with the increase in inspiratory flow and PEP offered by the device. Thus, in the postoperative period of thoracic and abdominal surgeries, greater acceptance and adherence to lung expansion therapy are expected.

The effectiveness of a prophylactic and preventive protocol was evaluated in patients who underwent blunt chest trauma and who have risk factors for lung injuries such as pulmonary contusion or rib fractures. The prophylactic protocol used resources such as MetaNeb or EzPAP®, resulting in a decrease in hospital stay (1.5 days) and a 12% reduction in the need for unplanned ICU admission[9].

Oliveira et al.[22] and Verweel et al.[23] emphasize that the increase in expiratory positive pressure accelerates the rate of absorption of the pleural effusion, and reduces the formation of fibrosis between the pleurae, due to infectious pleural effusions such as in tuberculosis or empyema. Certainly, reports of improvement in lung compliance and reduction in pleural fibrosis allow us to understand that the positive expiratory pressure system favors clinical situations of pulmonary restriction, ventilatory failure, and hypoxemia.

The EzPAP® device increases expiratory positive airway pressure during expiration and decreases during inspiration, offering a conservative and minimally invasive therapeutic option to stimulate reabsorption of pleural fluid by the lymphatic system and to treat hypoinflated and atelectasized lungs.

There was a gap in the literature concerning patients with restrictive lung disorders such as pleural effusion, given that the physiological mechanisms regarding the action of positive pressure in these patients are not fully understood.

Few studies have compared positive end-expiratory pressure (PEEP) devices, which did not allow a more robust analysis and discussion of the effects of positive pressure on different devices, but the indication

and advantages of EzPAP® are strong, justified by the Coanda effect, a mechanism that increases the inspiratory flow to the patient by up to four times.

Is noticed some limitations of the analyzed studies, are: the investigation of the respiratory muscle strength, thoracic cirtometry, and pulmonary function, must compose the mandatory evaluation to follow the outcomes of the use of EzPAP®. The inclusion of this evaluation in future studies will allow a better understanding and discussion of the initial and final results of the therapy.

The biggest limitation of the study was the gap in the effect of EzPAP® regarding its specific use in Pleural Effusion. It highlights the need for experimental and observational studies to profile patients with pleural effusion.

The studies did not establish age as an outcome variable, nor did they compare the pulmonary repercussions in each age group, given that the pulmonary function of elderly patients is susceptible to the effects of aging, such as a reduction in vital capacity from 25% to 40%[24]. Also, little consideration was given to comorbidities that affect respiratory performance. It is noteworthy that these limitations do not compromise the individualized indication and eligibility of the therapy, since the advantages mentioned are greater than the disadvantages.

Conclusion

Lung expansion therapy using the EzPAP® proves to be suitable for what it proposes. The advantages found were: reversal of atelectasis and pulmonary hypoinflation, correction of hypoxemia, and reduction of the sensation of dyspnea. No reports of disadvantages that expose the patient to risk or serious damage were identified since the device is indicated for conscious and oriented patients capable of controlling their respiratory mechanics. Therefore, EzPAP® is safely indicated for lung expansion.

Conflict of interest

The authors declare that there is no potential conflict of interest.

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