

ADVANCED HIGH-FREQUENCY CHEST WALL OSCILLATION DEVICES FOR OPTIMAL AIRWAY CLEARANCE: A COMPREHENSIVE STUDY ON THERAPEUTIC EFFICACY AND TECHNOLOGICAL INNOVATIONS

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BACKGROUND:

High-frequency chest wall oscillation (HFCWO) devices are used to improve airway clearance in a variety of respiratory conditions. This study comprehensively assessed recent systematic reviews of HFCWO devices to determine their clinical application in patients with pulmonary conditions. It also aimed to (1) summarize the evidence on efficacy and safety, (2) identify trends in scientific publications and patents, and (3) list regulatory requirements across geographic regions.

INTRODUCCION:

Effective management of bronchial secretions and maintaining airway patency can be challenging in patients with respiratory and neuromuscular conditions or in the postoperative period after thoracic or abdominal surgeries. In addition to postural drainage, manual chest wall physiotherapy (CWPT), and Positive Expiratory Pressure (PEP) systems, mechanical devices have been increasingly utilized to facilitate secretion mobilization and elimination. Such devices work by delivering high-frequency vibrations to the chest wall and include High-Frequency Chest Wall Oscillation (HFCWO), High-Frequency Chest Wall Compression (HFCWC), or High-Frequency Chest Compression (HFCC) systems. They induce percussive forces on the external chest wall, thereby ameliorating secretion mobility and potentially achieving airway clearance within the bronchial tree. HFCWO devices deliver high-frequency oscillations of high-pressure air to the patient's chest. HFCWC devices use a piston to deliver high-pressure air to the patient's chest. HFCC devices use a piston to deliver high-frequency compressions directly to the patient's chest. Empirical evidence highlighted the efficacy of airway clearance devices in a variety of medical conditions. Patients with bronchiectasis reported improvement in dyspnea, cough, and quality of life after using HFCWO devices (NICOLINI; GRECCHI; BANFI, 2022). In patients with chronic obstructive pulmonary disease (COPD) exacerbations, HFCWO had a favorable impact on blood gas parameters, inflammatory markers, and cortisol regulation (CHENG et al., 2022), increased sputum expectoration and decreased the hospitalization duration (HUANG et al., 2022). In burn patients and smoke inhalation,



HFCWO may enhance pulmonary function and could be included in the comprehensive pulmonary rehabilitation protocols (ALLAM; BADAWEY, 2021). Among patients with cystic fibrosis (CF), investigations have highlighted the comparable efficacy of both mobile and nonmobile HFCWO devices in terms of sputum clearance and resultant alterations of airway geometry (LEEMANS et al., 2020). In patients with severe craniocerebral injury, HFCWO therapy is associated with improved oxygenation levels, better lung compliance, and increased pulmonary surfactant protein (SP) concentrations within the airways (GE et al., 2023). HFCWO therapy has exhibited safety, tolerability, and enhanced compliance among pediatric patients with cerebral palsy and neuromuscular disorders (YUAN et al., 2010). Additionally, in mechanically ventilated patients with excessive secretions, HFCWO has emerged as a valuable additional therapy to improve lung aeration (LONGHINI et al., 2020). Recent systematic reviews and meta-analyses have been conducted to offer a more precise estimate of the effectiveness of HFCO devices. The aim of this study is to comprehensively assess these studies and determine the clinical application of HFCWO devices in patients with pulmonary conditions. The study is structured with three specific objectives: (1) To comprehensively summarize the existing systematic reviews and meta-analyses of studies evaluating HFCWO devices in the treatment of respiratory diseases with a focus on their efficacy and safety; (2) To identify trends in scientific publications and patents on HFCWO devices; (3) To list and summarize the regulatory requirements for HFCWO devices across geographic regions.

KEY WORDS:

HFCWO, CWPT, chest, wall, physiotherapy

METHODS:

This study was a bibliographic and bibliometric investigation into the current landscape of HFCWO devices and their therapeutic applications. The research on scientific and gray literature was undertaken using human-AI interactive thought-based prompt engineering approaches, including Chain-of-Thought Prompting (CoT) and Tree of Thoughts (ToT). Scientific evidence was synthesized through an umbrella review of systematic reviews.

RESULTS:

The evidence for the use of HFCWO devices is mixed. Some studies have shown that HFCWO devices can be effective in reducing hospitalizations and improving symptoms in patients with respiratory diseases. The analysis of the selected patents reveals a clear trend of innovation in the field of HFCWO devices, with China emerging as a leader with 90 patent deposits, followed by the United States with 57, Brazil and Canada with 6 each. The regulations for HFCWO devices vary in different geographical regions. In the United States, HFCWO devices are classified as Class II medical devices by the FDA and must be subject to premarket notification (510(k)) before being marketed. However, in other major regions, such as Europe, Canada, Australia, and Asia, the specific regulations for HFCWO devices are unclear.

CONCLUSIONS:

Accumulating research suggests that HFCWO devices are safe and effective for the treatment of respiratory diseases, but more evidence is needed. There is an increasing trend in scientific interest and innovation on HFCWO devices. The regulatory processes for HFCWO devices are similar worldwide, with nuances of reference to those, well defined, practiced in the USA, by UL and FDA and a tendency towards standardization, however, each country may have particularities.

REFERENCES:

ALLAM, N. M.; BADAWEY, M. M. Does High-Frequency Chest Wall Oscillation Have an Impact on Improving Pulmonary Function in Patients With Smoke Inhalation Injury? *Journal of Burn Care & Research*, v. 42, n. 2, p. 300–304, 4 Mar. 2021.

CHENG, G. et al. Effects of High-Frequency Chest Wall Oscillation Expectoration System on Pulmonary Rehabilitation and Cortisol Function in Patients with Severe AECOPD. *Disease markers*, v. 2022, p. 3380048, 22 Jul. 2022.

GE, J. et al. High-frequency chest wall oscillation multiple times daily can better reduce the loss of pulmonary surfactant and improve lung compliance in mechanically ventilated patients. *Heart & lung : the journal of critical care*, v. 61, p. 114–119, 27 May 2023.

HUANG, H.-P. et al. Effects of High-Frequency Chest Wall Oscillation on Acute Exacerbation of Chronic Obstructive Pulmonary Disease: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *International Journal of Chronic Obstructive Pulmonary Disease*, v. 17, p. 2857–2869, 10 Nov. 2022.

LEEMANS, G. et al. The effectiveness of a mobile high-frequency chest wall oscillation (HFCWO) device for airway clearance. *Pediatric Pulmonology*, v. 55, n. 8, p. 1984–1992, Aug. 2020.

NICOLINI, A.; GRECCHI, B.; BANFI, P. Effectiveness of two high-frequency chest wall oscillation techniques in patients with bronchiectasis: a randomized controlled preliminary study. *Panminerva Medica*, v. 64, n. 2, p. 235–243, Jun. 2022.

YUAN, N. et al. Safety, tolerability, and efficacy of high-frequency chest wall oscillation in pediatric patients with cerebral palsy and neuromuscular diseases: an exploratory randomized controlled trial. *Journal of Child Neurology*, v. 25, n. 7, p. 815–821, Jul. 2010.

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