Manual hyperinflation in airway clearance in pediatric patients: a systematic review

Hiperinsuflação manual para desobstrução das vias aéreas em pediatria: revisão sistemática

ABSTRACT

Objective: To perform an assessment of the available literature on manual hyperinflation as a respiratory physical therapy technique used in pediatric patients, with the main outcome of achieving airway clearance.

Methods: We reviewed articles included in the Lilacs (Latin American and Caribbean Literature on Health Sciences/Literatura Latino Americana e do Caribe em Ciências da Saúde), Cochrane Library, Medline (via Virtual Health Library and PubMed), SciELO (Scientific Electronic Library), and PEDro (Physiotherapy Evidence Database) databases from 2002 to 2013 using the following search terms: “physiotherapy (techniques)”, “respiratory therapy”, “intensive care”, and “airway clearance”. The selected studies were classified according to the level of evidence and grades of recommendation (method of the Oxford Centre for Evidence-Based Medicine) by two examiners, while a third examiner repeated the search and analysis and checked the classification of the articles.

Results: Three articles were included for analysis, comprising 250 children (aged 0 to 16 years). The main diagnoses were acute respiratory failure, recovery following heart congenital disease and upper abdominal surgery, bone marrow transplantation, asthma, tracheal reconstruction, brain injury, airway injury, and heterogeneous lung diseases. The studies were classified as having a level of evidence 2C and grade of recommendation C.

Conclusions: Manual hyperinflation appeared useful for airway clearance in the investigated population, although the evidence available in the literature remains insufficient. Therefore, controlled randomized studies are needed to establish the safety and efficacy of manual hyperinflation in pediatric patients. However, manual hyperinflation must be performed by trained physical therapists only.

Keywords: Physical therapy modalities; Insufflation; Airway obstruction; Intensive care units, pediatric

INTRODUCTION

Manual hyperinflation (MHI) is frequently used by physical therapists in patients requiring intensive care because it induces passive lung inflation, which potentiates the lung elastic recoil forces and thus increases the peak expiratory flow (PEF). These effects also favor the mobilization of secretions accumulated in the airways.\(^1\)\(^2\)

Hyperinflation may be performed manually using a self-inflatable bag (SIB) or through a mechanical ventilator. In the case of MHI, squeezing the SIB...
increases its internal pressure, which then blocks the air inlet valve and forces open the patient outlet. Conversely, as the bag re-inflates, the internal pressure decreases, and the air inlet opens, allowing for entrance of the air needed for the following inflation.\(^{(3)}\)

In spite of the beneficial effects of MHI, such as secretion removal and reopening of collapsed airways, various complications may occur, including barotrauma, volutrauma, and hemodynamic instability. However, those complications have previously been reported exclusively in adults.\(^{(2,4-6)}\)

Due to the small number of studies that investigated the use of MHI in the pediatric setting, the aim of the present study was to perform a systematic review of the use of MHI for airway clearance (AC) in children\(^{(7-9)}\) and to classify the levels of evidence and grades of recommendations of the located studies.

**METHODS**

All of the articles that met the inclusion criteria and were published from 2002 to January 2013 were collected and analyzed in a critical and synthetic manner. The search sources included the following electronic databases: Lilacs (Latin American and Caribbean Literature on Health Sciences/Literatura Latino Americana e do Caribe em Ciências da Saúde), Cochrane Library, Medline (via Virtual Health Library and PubMed), SciELO (Scientific Electronic Library), and PEDro (Physiotherapy Evidence Database). The search terms included “physiotherapy (techniques)”, “respiratory therapy”, “intensive care”, and “airway clearance”. The PICO (population, interventions, comparisons, outcomes) method was used for the literature search.\(^{(10)}\)

Letters to the editor, case reports, historical studies, editorials, comments, poster and oral presentations, literature reviews, and studies using artificial models were excluded. Controlled (randomized or quasi-randomized) studies, including clinical trials and non-experimental assays, and observational (cohort, case-control, and cross-sectional) studies were included, provided they were published in English, French, Spanish, or Portuguese.

One investigator performed the initial selection of the articles related to the investigated subject and written in the indicated languages in the databases. A second selection was independently performed by another investigator based on the inclusion and exclusion criteria and the analysis of each article’s eligibility. The studies that met the inclusion criteria were selected. Any disagreements were resolved by a third examiner. The full text of the selected articles was obtained.

The included studies were classified according to the levels of evidence of the scientific publications and their corresponding grades of recommendation, according to the classification of the Oxford Centre for Evidence-Based Medicine.\(^{(11)}\)

**RESULTS**

A total of 218 articles were located, but 215 of these were excluded because they did not address the topic investigated in the present study. Therefore, 3 articles were included in the systematic review, the outcomes and results of which are described in table 1 together with the additional comments.

One report was a prospective observational study\(^{(9)}\) that included 105 children submitted to mechanical ventilation (MV), whose average age was 1.3 years (range of 1 week to 15.9 years), as well as 59 children who were younger than 2 years old. The influence of chest compression–vibrations performed by 19 physical therapists, combined with MHI for AC on the inspiratory and expiratory flow, was analyzed. The results showed that the increase in PEF was correlated with the increases in inflation volume and pressure, as well as with the force that was applied. In addition, the increase in the inspiratory to expiratory flow ratio (PEF/PIF) was determined according to the force applied during compression-vibration, which varied from 15 to 179 Newtons (N) (46N on average).

Another one of the included studies\(^{(8)}\) consisted of 55 children (aged 0 to 16 years) who were subjected to MV, hemodynamically stable, and required respiratory physical therapy including MHI. For that purpose, the physical therapists performed the chest maneuvers using a device that measured the average force applied as well as the children’s respiratory parameters during the interventions. The results showed that increase in the inspired volume and peak inspiratory pressure increased the lung elastic recoil, which favors the mobilization of secretions, especially when MHI is combined with manual vibration (VB).

The third study was a randomized clinical trial\(^{(7)}\) in which 83 children (with an average age ranging from 9 months±3 days to 19 months and a weight of 7kg) submitted to MV (pressure- or volume-preset ventilation) also received respiratory physical therapy or intratracheal aspiration alone. The children were evaluated 30 min after the interventions about lung physiological parameters and gas exchange to compare the two interventions (respiratory physical therapy versus intratracheal aspiration). The children submitted to pressure ventilation exhibited
a reduction in pulmonary compliance 30 min after intratracheal aspiration, and the children submitted to volume ventilation exhibited a reduction in the pulmonary resistance 15 and 30 min after physical therapy. Analysis of the individual responses showed significant increases in tidal volume (TV) following physical therapy, together with changes in blood gas variables suggestive of mild metabolic acidosis.

**DISCUSSION**

One of the main causes of atelectasis in pediatric patients is the accumulation of secretions in the airways. In this condition, MHI may promote the recruitment of previously collapsed airways because it is able to stimulate the central motion of secretions and facilitate their removal, which reduces the incidence of atelectasis. In one study conducted with children diagnosed with atelectasis and subjected to MV, MHI induced an increase in spontaneous TV and improvements in chest radiographic signs and the oxygenation index (partial pressure of oxygen in arterial blood/fraction of inspired oxygen - PaO₂/FiO₂). The results of another study corroborated these findings and suggested that MHI may reduce the areas with lung collapse in pediatric patients subjected to general anesthesia.

Regarding the mechanism of action of MH, one study showed that the PEF must be approximately 0.4L/sec (24.6L/min) for that technique to be effective in AC. Following the use of various SIB models (for adults), the results showed that this device may not be effective in the removal of secretions depending on the level of positive end-expiratory pressure (PEEP) used, in addition to the presence of significant differences in the PEF and TV promoted by the various models of SIB used. Moreover, these differences may represent a negative factor in the case of children, as high TV and pressures are predisposing factors for lung injury (barotrauma, volutrauma, and biotrauma). None of the studies included in the present systematic review analyzed the SIB models used.

In regard to the possibility of MHI causing hemodynamic instability, one prospective descriptive study that assessed children and adolescents (aged 1 month to 13 years) who were diagnosed with acute respiratory failure and subjected to MV for ≥12 h before MHI did not find significant differences in the average values of the investigated variables.

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**Table 1 - Use of manual hyperinflation for airway clearance in pediatric patients**

| Author               | Study design/level of evidence | Sample                                                                 | Variables considered for the analysis of outcome AC | Results following MHI | Comments                                                                 |
|----------------------|--------------------------------|------------------------------------------------------------------------|-----------------------------------------------------|------------------------|-------------------------------------------------------------------------|
| Main et al.(13)       | Randomized crossover clinical study | 83 children under pressure (N=61) or volume-preset (N=22) MV            | PEF, PP, TV                                        | No significant difference in the TV, Cò, and blood gases between the groups | The study did not analyze the respiratory physical therapy techniques separately | A significant difference was not found between aspiration and AC techniques |
| et al.               | Grade of recommendation: B     | Analysis of the Cò, Rp, and TV of patients subjected to tracheal aspiration only and patients submitted to respiratory physical therapy and tracheal aspiration | PEF, PP, TV                                        | Reduction of Cò in patients submitted to pressure-preset ventilation, and a reduction of Rp in those submitted to volume-preset ventilation only |                                                                 |
|                     | Level of evidence: 2B          | Main outcome: secretion mobilization                                   |                                                     |                        |                                                                 |

**Variables and Acronyms**

- AC - airway clearance; MHI - manual hyperinflation; MV - mechanical ventilation; PEF - peak expiratory flow; PEF/PIF - peak expiratory to inspiratory flow ratio; TV - tidal volume; PP - peak inflation pressure; VB - manual vibration; ETV - expired tidal volume; Cò - pulmonary compliance; Rp - pulmonary resistance.
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Following the analysis of three studies conducted in children and the comparison of these results to those of studies in adults, MHI seems to contribute to the mobilization of secretions as a respiratory physical therapy for AC (level of evidence 2C). However, the analyzed studies exhibited some limitations, such as the absence of homogeneous samples and the lack of detailed descriptions of the method used in the application of MHI (especially in the case of the single published randomized controlled study). In addition, these studies failed to report on the short-, medium-, and long-term hemodynamic effects of MHI. The outcome variables were different in the three analyzed studies (blood gases, pulmonary function, and short-term clinical response), and the study populations and participant ages also differed between reports. Moreover, the investigated diseases were different, which made the analysis of the main outcome difficult.

CONCLUSIONS

Manual hyperinflation appeared useful for AC in the investigated population, although the evidence available in the literature remains insufficient. Therefore, randomized controlled studies are needed to establish the safety and efficacy of manual hyperinflation in pediatric patients. However, manual hyperinflation should be performed by trained physical therapists only.

RESUMO

Objetivo: Avaliar, na literatura, a aplicação da hiperinsuflação manual como técnica de fisioterapia respiratória em pediatria, considerando a desobstrução das vias aéreas como desfecho principal.

Métodos: Revisão realizada nas bases eletrônicas Lilacs, Biblioteca Cochrane, Medline (via Biblioteca Virtual em Saúde e Pubmed), SciELO e PEDro (período de 2002 a 2013), utilizando os descritores: “physiotherapy (techniques)”; “respiratory therapy”; “intensive care” e “airway clearance”. Os estudos foram selecionados e classificados por nível de evidência e recomendação (método Oxford Centre for Evidence-Based Medicine) por dois avaliadores, e um terceiro avaliador refez a pesquisa e conferiu a classificação dos artigos.

Resultados: Foram incluídos 3 estudos, que somaram 250 crianças (de zero a 16 anos). Os principais diagnósticos encontrados foram: insuficiência respiratória aguda, pós-operatório de cardiopatias congênitas e abdominais alta, transplant de medula óssea, asma, reconstrução traqueal, lesão cerebral, lesão de vias aéreas e doenças pulmonares heterogêneas. Os estudos foram classificados em nível de evidência 2C e grau de recomendação C.

Conclusões: A hiperinsuflação manual parece ser útil para a desobstrução das vias aéreas nessa população, embora as evidências da literatura sejam ainda insuficientes. Assim, são necessários estudos controlados e randomizados para determinar a segurança e a eficácia da hiperinsuflação manual em pediatria. A mesma deve ser realizada somente por fisioterapeutas treinados.

Descritores: Modalidades de fisioterapia; Insuflação; Obstrução das vias respiratórias; Unidades de terapia intensiva pediátrica
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