Vanessa Cristina Waetge Pires de Godoy[1], Nathalia Mendonça Zanetti[1], Cíntia Johnston[2]

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

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

1. Service of Physical Therapy, Hospital São Paulo - HSP - São Paulo (SP), Brazil.
2. Department of Pediatrics, Escola Paulista de Medicina, Universidade Federal de São Paulo - UNIFESP - São Paulo (SP), Brazil.

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

Conflicts of interest: None.

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Corresponding author:
Cíntia Johnston
Rua Botucatu, 598 - Vila Clementino
Zip code: 04023-900 - São Paulo (SP), Brazil
E-mail: cintiajohnston@terra.com.br

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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

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.[7]	Randomized crossover clinical study Grade of recommendation: B Level of evidence: 2B	83 children under pressure (N=61) or volume-preset (N=22) MV Analysis of the Cp, Rp, and TV of patients submitted to tracheal aspiration only and patients submitted to respiratory physical therapy and tracheal aspiration Main outcome: secretion mobilization	PEF PIP TV ETV Cp Rp Blood gases	No significant difference in the TV, Cp, and blood gases between the groups Reduction of Cp in patients submitted to pressure-preset ventilation, and a reduction of Rp in those submitted to volume-preset ventilation only	The study did not analyze the respiratory physical therapy techniques separately A significant difference was not found between aspiration and AC techniques
Gregson et al.[8]	Observation of therapeutic results Grade of recommendation: B Level of evidence: 2C	Children aged 0 to 16 years, under MV, and hemodynamically stable needing respiratory physical therapy including MHI. A device that measured the force applied as well as the children's respiratory parameters was used Main outcome: secretion mobilization	PEF PIP TV	55 children (average age 1.6±0.02 to 13.7 years) MHI + MVB increased PEF from 19L min-1 to 40L min-1 compared to basic MV PIP increased from 22 to 35 cm H2O 95% increase of TV	There was an increase in the inspired volume, and PIP increased the pulmonary elastic recoil, favoring secretion mobilization, especially when combined with VB
Gregson et al.[9]	Prospective observational study Grade of recommendation: B Level of evidence: 2C	105 children under MV Comparison of MHI with and without chest compression vibrations Main outcome: airway secretion mobilization	PEF PEF/PIF ratio	PEF exhibited an average increase of 4% per 10% increase in TV, 5% increase per 10% increase of PIP, and an additional 3% increase per 10N of force applied PEF/PIF exhibited an average increase of 4% per 10N of force applied	The use of MHI and VB resulted in expiratory flow deviations likely to promote the central secretion movement toward the peripheral areas, thus facilitating its removal

AC - airway clearance; MHI - manual hyperinflation; MV - mechanical ventilation; PEF - peek expiratory flow; PEF/PIF - peak expiratory to inspiratory flow ratio; TV - tidal volume; PIP - peak inflation pressure; VB - manual vibration; ETV - expired tidal volume; Cp - pulmonary compliance; Rp - pulmonary resistance.

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.[8] 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 - PaO_2/FiO_2).[12] The results of another study[13] 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[14] 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.[15,16] 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).[17] 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[18] 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

(heart rate; respiratory rate; oxygen saturation - SpO_2; and systolic, diastolic, and mean arterial pressure). These authors concluded that MHI did not cause hemodynamic instability in that patient sample.

However, a pilot study[5] conducted with adults subjected to MV for different reasons, who were hemodynamically stable for at least 2 h before MHI, reported a reduction in cardiac output (from 10 to 15.8%) alone or in association with a reduction in the mean arterial pressure, without any changes in the heart rate. This reduction in cardiac output may be explained by a decrease in the ventricular preload due to impaired venous return caused by high TV and the application of PEEP.

In another prospective study,[19] the diastolic arterial pressure and systemic vascular resistance exhibited significant increases following MHI, while the heart rate, pulmonary artery pressure, and mean and systolic arterial pressures did not exhibit significant changes. The use of protective strategies during MV in pediatric patients, including the application of low TV (6 to 8mL/kg) may account for the lack of hemodynamic changes observed in another study[18].

Another study[7] did not distinguish among various techniques for AC, including MHI, and rather clustered them together as respiratory physical therapy. The results demonstrated significant improvements in TV, respiratory system compliance, and pulmonary resistance in some participants when respiratory physical therapy was compared to intratracheal aspiration.

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).[7] 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 inclusos 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, transplante 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

REFERENCES

1. Dias CM, Siqueira TM, Faccio TR, Gontijo LC, Salge JA, Volpe MS. Efetividade e segurança da técnica de higiene brônquica: hiperinsuflação manual com compressão torácica. Rev Bras Ter Intensiva. 2011;23(2):190-8.
2. Santos LJ, Blattner CN, Micol CA, Pinto FA, Renon A, Pletsch R. Efeitos da manobra de hiperinsuflação manual associada à pressão positiva expiratória final em pacientes submetidos à cirurgia de revascularização miocárdica. Rev Bras Ter Intensiva. 2010;22(1):40-6.
3. Oliveira PM. Fatores que influenciam a técnica de hiperinsuflação manual com balão autoinflável neonatal e pediátrico [dissertação]. Campinas: Faculdade de Ciências Médicas, Universidade Estadual de Campinas; 2011.
4. Lemes DA, Guimarães FS. O uso da hiperinsuflação como recurso fisioterapêutico em unidade de terapia intensiva. Rev Bras Ter Intensiva. 2007;19(2):221-5.
5. Singer M, Vermaat J, Hall G, Latter G, Patel M. Hemodynamic effects of manual hyperinflation in critically mechanically ventilated patients. Chest. 1994;106(4):1182-7.
6. Denehy L. The use of manual hyperinflation in airway clearance. Eur Respir J. 1999;14(4):958-65. Review.
7. Main E, Castle R, Newham D, Stocks J. Respiratory physiotherapy vs. suction: the effects on respiratory function in ventilated infants and children. Intensive Care Med. 2004;30(6):1144-51.
8. Gregson RK, Stocks J, Petley GW, Shannon H, Warner JO, Jagannathan R, et al. Simultaneous measurement of force and respiratory profiles during chest physiotherapy in ventilated children. Physiol Meas. 2007;28(9):1017-28.
9. Gregson RK, Shannon H, Stocks J, Cole TJ, Peters MJ, Main E. The unique contribution of manual chest compression-vibrations to airflow during physiotherapy in sedated, fully ventilated children. Pediatr Crit Care Med. 2012;13(2):e97-e102.
10. Santos CM, Pimenta CA, Nobre MR. A estratégia PICO para a construção da pergunta de pesquisa e busca de evidências. Rev Latinoam Enferm. 2007;15(3):508-11.
11. Phillips B, Ball C, Sackett D, Badenoch D, Straus S, Haynes B, et al. Oxford Centre for Evidence-Based Medicine - Levels of evidence (March 2009). Grades of recommendation. Available from: http://www.cebm.net/?O=1025
12. Maa SH, Hung TJ, Hsu KH, Hsieh YI, Wang KY, Wang CH, et al. Manual hyperinflation improves alveolar recruitment in difficult-to-wean patients. Chest. 2005;128(4):2714-21.
13. Tusman G, Böhm SH, Tempra A, Melkun F, García E, Turchetto E, et al. Effects of recruitment maneuver on atelectasis in anesthetized children. Anesthesiology. 2003;98(1):14-22.
14. Maxwell L, Ellis E. Secretion clearance by manual hyperinflation: Possible mechanisms. Physiother Theory Pract. 1998;14(4):189-97.
15. Savian C, Chan P, Paratz J. The effect of positive end-expiratory pressure level on peak expiratory flow during manual hyperinflation. Anesth Analg. 2005;100(4):1112-6.
16. Jones AM, Thomas PJ, Paratz JD. Comparison of flow rates produced by two frequently used manual hyperinflation circuits: a benchtop study. Heart Lung. 2009;38(6):513-6.
17. Jauncey-Cooke JI, Bogossian F, East CE. Lung protective ventilation strategies in paediatrics - A review. Aust Crit Care. 2010;23(2):81-8. Review.
18. Cunha MT, Videira NL, Cristianni R, Martins SR, Corte L. Impacto hemodinâmico e respiratório da técnica da hiperinsuflação manual em crianças sob ventilação mecânica. Pediatria (São Paulo). 2008;30(1):15-21.
19. Paratz J, Lipman J, McAuliffe M. Effect of manual hyperinflation on hemodynamics, gas exchange, and respiratory mechanics in ventilated patients. J Intensive Care Med. 2002;17(6):317-24.