

Effect of Manual Hyperinflation on Arterial Oxygenation in Paediatric Patients with Upper Lobe Collapse after Cardiac Surgery

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ABSTRACT

Lung hyperinflation is a technique used by physiotherapists to mobilize and remove excess bronchial secretions, reinflate areas of pulmonary collapse and improve oxygenation. To assess the efficacy of manual hyperinflation in improving arterial oxygenation (PaO_2) of paediatric patients with upper lobe lung collapse after cardiac surgery. 18 paediatric patients who had undergone heart surgery and having upper lobe collapse in the post-op ventilation period underwent Manual Hyperinflation (MH). Parameters included arterial oxygen tension (PaO_2) value in ABG analysis, clinical findings such as collapsed upper lung lobe in chest radiograph and air entry in auscultation were collected before and 30 min post MH session and documented. The patients were treated with manual hyperinflation delivered using a pediatric AMBU bag with pressure of about 40 cm H_2O . Four sets of eight bag compressions with inflation rate of 10 breaths per minute were delivered during each manual hyperinflation. The result showed that there was a significant improvement in arterial oxygenation (PaO_2) by administering manual hyperinflation therapy for the upper lobe collapse in post-op ventilated paediatric patients. In this study, it is evident that manual hyperinflation is an effective technique in management of Lung collapse (upper lobe) in post-op pediatric patients. This clearly demonstrates that further research in this area is warranted.

Key words: Manual hyperinflation, lung collapse, paediatric cardiac surgery, arterial oxygenation.

Kalp Cerrahisi Sonrası Üst Lob Kollapsı Gelişen Çocuk Hastalarda Manuel Hiperinflasyonun Arteriyel Oksijenasyona Etkisi

ÖZET

Akciğer hiperinflasyonu aşırı bronşial sekresyonları çıkarmak ve mobilize etmek, kollaps olan akciğer alanların tekrar açılması için fizyoterapistler tarafından kullanılan bir tekniktir. Kalp cerrahisi sonrası üst lob akciğer kollapsı olan pediatrik hastaların arteriyel oksijenasyonunu (PaO_2) iyileştirmede manuel hiperinflasyon etkinliğini değerlendirmek amaçlanmıştır. Kalp cerrahisi geçiren ve üst lob kollapsı olan 18 hastaya Manuel hiperinflasyon (MH) uygulandı. Arter kan gazı analizinde arteriyel oksijen basıncı (PaO_2) değeri, akciğer grafisindeki üst lob kollaps bulguları ve oskültasyon bulguları gibi klinik bulgular MH 30 dk öncesi ve sonrası toplanmış ve belgelenmiştir. Hastalara pediatrik AMBU vasıtasıyla yaklaşık 40 cm H_2O basınç ile manuel hiperinflasyon uygulandı. Manuel inflasyon dört defa dakikada 10 kez uygulandı. Sonuçlar gösterdiği manuel inflasyon ile arteriyel oksijenizasyonda (PaO_2) anlamlı düzelme olduğunu göstermiştir. Bu çalışmada, manuel hiperinflasyon post-op pediatrik hastalarda akciğer kollapsı (üst lob) tedavisinde etkili bir teknik olduğu açıktır. Bu alanda daha fazla araştırma yapılmasına ihtiyaç vardır.

Anahtar Kelimeler: Manuel hiperinflasyon, akciğer kollapsı, pediatrik kalp cerrahisi, arteriyel oksijenasyon

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Received: 14.01.2014, Accepted: 12.03.2015

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INTRODUCTION

Pulmonary dysfunction is a common complication of cardiac surgery (1). The mechanical properties of the lung alters which lead to reduced pulmonary compliance (2), vital capacity and functional residual capacity (3,4) in the initial ICU stay after surgery. Pediatric patients after cardiac surgery will be managed with Mechanical Ventilation (MV) and the retention of Pulmonary secretion is common (5) with these Mechanical ventilation, which may increase the weaning time from ventilation, lengthen the ICU stay and mortality of them. Many medical practitioners consider chest physiotherapy an integral part of ICU care in mechanically ventilated patients. It may include airway clearance techniques such as manual and mechanical percussion and vibration, postural drainage, facilitated coughing and suctioning via the endotracheal tube. Chest physiotherapy is used in the intensive care unit (ICU) to minimize pulmonary secretion retention, prevent pulmonary complication (6) to maximize oxygenation, and to re-expand atelectatic lung segments (7).

High negative pressure and deep-suctioning causes right upper lobe (RUL) collapse in intubated, ventilated children on a paediatric cardiac intensive care unit, this lobar collapse not only prolongs the child's stay in intensive care, but can be associated with further morbidity which may have a serious implication (8). Chest Physiotherapy techniques, such as mobilization, manual hyperinflation (MH), percussion, and vibrations, are used in patients on mechanical ventilation (MV). It has been shown that the use of respiratory physiotherapy techniques can reduce pulmonary secretion retention (5,9) as well as improving dynamic compliance (10) and static compliance (11,12). Manual Hyperinflation (MH) also known as "bagging", "bag squeezing" is usually administered by physiotherapists in patients with Mechanical ventilation (11). MH is usually administered for post-operative intubated, ventilated paediatric cardiac surgery patients with lobar collapse as a part of re-expansion of lung and airway management (13,14). MH not only mobilizes the retained airway secretions in intubated and mechanically ventilated patients, but also prevents atelectasis of lungs (15,16). After disconnecting the patient from ventilator the lungs are inflated by the resuscitation bag (AMBU) so that the collapsed lobe expands. MH consists of a series commonly involves a slow, deep inspiration, inspiratory pause and fast unobstructed expiration (17). The deep inspiration expands the collapsed lung and the higher expiratory than inspiratory flow helps the airway secretions to come

out (18,19). Previous studies shows the benefits of MH are mobilization of airway secretions, prevention of sputum plugging (11,16), improved alveolar recruitment (15) but the evidence supporting its efficacy is lacking.

Research evidences shows that the advantages of chest physical therapy over therapeutic bronchoscopy is removal of retained secretions, the arterial oxygenation and partial pressure of arterial oxygen / fraction of inspired oxygen concentration ratios improves and resolves the atelectasis without the negative hemodynamic, a side effects of therapeutic bronchoscopy. Chest physiotherapy especially MH is most effective in hypoxaemia, treatment of unilobar densities and produced dramatic improvement in atelectasis of acute onset. Physical therapists trained in the ICU can safely perform chest physical therapy for the majority of patients who are critically ill (20,21).

Although MH plays an important role in the multidisciplinary approach to patients in most ICUs, there is very limited or no evidence that MH is beneficial for the expansion of collapsed lobe in post cardiac surgery paediatric patients with reference to arterial oxygenation and radiograph. There is only one study done to find the benefits of MH in the adult cardiac surgery patients concluded that MH partly prevents reduction of FRC in patients after cardiac surgery in the first post-operative days and also the incidence of signs of atelectasis on post-operative chest radiographs is significant lower in patients who receive MH (22). As there is a lack of evidence to support the use of MH in clinical practice, we aimed to investigate whether MH helps in expansion of the collapsed lung lobe in children who had cardiac surgery.

MATERIALS AND METHODS

A convenience sampling approach was adopted for this study and 18 pediatric in-patients (10 males) who had cardiac surgery and having upper lobe collapse (Right side-17 and Left side-1) in the post-op period requiring mechanical ventilation, were recruited to the study. Subjects with abnormal positioning of the endotracheal tube, acute respiratory distress syndrome, acute pulmonary edema, unstable blood pressure, untreated tension pneumothorax, and those with peak inspiratory pressures higher than 40 cmH₂O or requiring high respiratory support (FiO₂>0.7 and PEEP>10 cmH₂O) were excluded. After getting the informed consent signed by the parents, the chest radiograph, arterial blood gas analysis was done

before and 30 minutes after administering manual hyperinflation. The pre and the post values were documented for statistical analysis. Subjects were positioned in half-lying/sitting with the head of the bed slightly elevated (23) and undisturbed for 15 minutes prior to data collection. Two experienced physiotherapists for MH and an CVTS ICU nurse for ET suctioning were involved in this study. One physiotherapist squeezes the manual ventilation bag slowly to inflate the lungs. A second trained physiotherapist is necessary to provide shaking or vibration in an appropriate sequence with lung inflation. The two therapists providing the treatment were positioned to have greater freedom of movement and improved observation of the patients' response to treatment. MH was administered with a Silicone Resuscitator (AMBU) bag connected with 100% oxygen, flowing at the rate 15 l/min. Four sets of eight bag compressions with inflation rate of 10 breaths per minute were delivered during each manual hyperinflation. AMBU bag is compressed with a peak airway pressure of 40 cmH₂O controlled by the pressure manometer in the breathing circuit to maximize lung volume, followed by a two second inspiratory pause and then a quick release of the bag to enhance the expiratory flow rate (24). A positive end expiratory pressure (PEEP) valve was included in the circuit if the patient was treated with PEEP during mechanical ventilation. After this MH, tracheal suctioning was done to remove the mobilized secretions. Normal saline (1 ml) was instilled in tracheal tube before hyperinflation to assist with loosening, thick secretions and the duration of suctioning was

Table 1. Demographic data and characteristics of the study populations

Age, yr	1.6±0.6
Male, n	10
Female, n	8
Type of surgery	
ASD, n	8
VSD, n	7
ALCAPA, n	2
BT shunt, n	1
Side of the lung	
Right, n	17
Left, n	1
OT and ICU parameters	
Durations	
Surgery, min	235±62
Intubation, hrs	120 (62-180)
ICU stay, hrs	48.2 (36.8-76.6)
Total hospital stay, days	7.8 (6.2-9.4)
Core temperature in ICU	5.4±0.6

Table 2. Mean arterial oxygenation (PaO₂)

	PaO ₂ Value	
	Pre-test Before MH	Post-test 30 min after MH
Mean	56.78	82.89
SD	10.81	5.17
n	18	18
't' value	14.1243	

limited to 15 seconds. The suctioning session involved instillation of one ml of normal saline in the tracheal tube, followed by suctioning, once per minute, for four minutes. The catheter was inserted fully to the carina and then withdrawn one cm prior to the application of negative pressure. Intermittent negative pressure was applied unless the secretions were very viscous requiring continuous suction for aspiration. Inspired oxygen concentration (FiO₂) was maintained at 100% for all patients only during the manual hyperinflation and suction procedures and returned back to the preset value in their ventilator after intervention. Heart rate, blood pressure, ECG and SpO₂ were monitored during all procedures. Parameters obtained included chest radiograph and arterial oxygen tension (PaO₂). The pre and the post (30 min after MH) radiograph and Arterial oxygen tension (PaO₂) values are collected, tabulated and analyzed statistically.

Primary endpoint

The primary endpoint was the change of arterial oxygen tension before and 30 minutes after the manual hyperinflation. This is done by the arterial blood gas (ABG) analysis. All measurements were performed by the same investigator and analyzer for standardization of the data.

Secondary endpoints

Chest radiographs (AP view) were obtained in a half-lying / sitting position, both pre and 30 minutes after the administration of Manual hyperinflation. Each radiograph was evaluated for the presence of atelectasis, pulmonary infiltrate, extra-vascular lung fluid, pleural fluid, and pneumothorax. Auscultation of the upper lobe for air entry.

Other data collected:

These included the number of MH maneuvers per patient; demographics (age, gender, side of the lung, type of surgery), duration of surgery, intubation, core temperature of ICU and length of stay in ICU and hospital (Table 1).

Statistical Analysis

Data were presented as mean with standard deviation (SD). Descriptive statistics were used to summarize patient characteristics. Data were analyzed using SPSS for Windows version 10.0 and a paired t-test for the pre and post value of arterial oxygenation with $p < 0.0001$ showed the t value 14.1243 with 17 degree of freedom and 1.849 as the standard error of difference. By conventional criteria, this difference is considered to be extremely statistically significant (Table 2).

RESULTS

The result showed that there was a significant improvement in the arterial oxygenation (PaO_2) by administering manual hyperinflation therapy for the upper lobe collapse in post-op ventilated paediatric patients. All 18 subjects showed a significant improvement in the radiological (Figure 1 and 2) and auscultatory findings, demonstrated improvement in the clinical picture with regard to the chest radiograph and improved air entry on auscultation.

DISCUSSION

The results of this research study can be summarized as follows: (1) Arterial oxygenation (PaO_2) improved significantly by MH in paediatric patients after cardiac surgery (2) MH helped in expansion of the collapsed lung lobes (3) MH is an treatment option for improving the pulmonary function in paediatric patients after cardiac surgery. The primary purpose of using manual hyperinflation is to improve airway clearance effectively and efficiently in intubated patients. Though few studies done in the past (10,14) examined the effect of percussion on intubated patients and shown improvement (10) or no significant

pulmonary function changes (14) the uncontrolled studies have reported that percussion is ineffective (14) We, in this current study used manual hyperinflation. Although MH is widely used in order to remove pulmonary secretions and treat atelectasis, (25) there is no evidence to support its routine use in clinical. This lack of evidence is due, in part, to the scarcity of studies (6,26,27) examining the clinical relevance and efficacy of MH and to the maneuver itself.

This is the first study assessing the effect of MH in arterial oxygenation of the upper lung lobe collapsed paediatric patients after cardiac surgery. The findings from this study are in line with the previous studies suggesting that MH is beneficial for patients after surgery. A randomized controlled trial done before concluded improvement of PaO_2 , static compliance and reduced the duration of mechanical ventilator, in patients after myocardial revascularization (9). One more randomized controlled trial confirmed MH improved oxygenation after surgery (12). Plugging of airway secretions may lead to airway obstructions, thereby causing gas resorption distal to the obstructions, leads to lobar collapse in mechanically ventilated patients. Clearance of airway secretion by MH have been demonstrated before. Higher expiratory than inspiratory flows produced by MH clears the airway secretions in intubated and mechanically ventilated patients. Our data suggest that MH could contribute to the recovery of collapsed lung areas after cardiac surgery in paediatric patients. MH does this by administering increased tidal volumes, inspiratory pause which creates transpulmonary pressures to overcome alveolar collapses (28). Studies done in the past showed that airway pressures of 40 cmH₂O maintained for eight to nine seconds is needed to reopening the collapsed lung tissue completely (29). As MH is not capable of providing such pressures for lon-

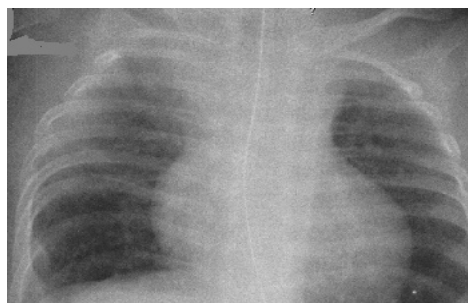


Figure 1. Pre MH therapy

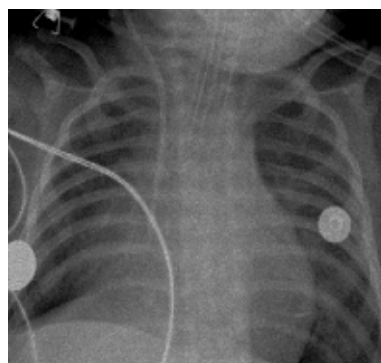


Figure 2. Post MH therapy

ger than a few second, a short-lasting natural occurring maneuvers, such as coughing and sighs, also result in re-recruiting of lung tissue. Hypoxemia reported up to 60% of patients with hypoxic periods within the first two days after tracheal extubation (30,31). Though the reasons for atelectasis after cardiac surgery are multiple, which includes the higher levels of intra-operative FiO_2 , type of surgery, obesity and post-operative pain. Absorption atelectasis during mechanical ventilation is most likely to occur when levels of FiO_2 are high (31). Indeed, higher levels of FiO_2 during mechanical ventilation because of general anesthesia during surgery are associated with atelectasis formation (32,33). It is stated that MH cause short-term hyperinflation of lung and many times the safety of application of MH was questioned. Researchers (34-36) studied the adverse effect of MH and suggested if MH is performed in a controlled conditions by trained physiotherapists has minimal side effects.

Though our study has some limitations, such as the small sample size but the statistical analysis shows an extreme significance in improving the arterial oxygenation. Second limitation is not having a control group to assess the superiority of the treatment. Third was impossible to conduct a blind study.

To conclude from this study, it is evident that manual hyperinflation along with conventional physiotherapy is an effective technique in management of Lung collapse (upper lobe) in post-op paediatric cardiac surgery patients. MH improved the arterial oxygenation in these patients which was statistically significant and the disappearance of the collapsed upper lobe post MH in chest x-ray proved the study clinically. As this is short term study conducted with a small single group of patients, further studies evaluating the effectiveness of MH cardiac surgery paediatric patients in comparison with various other chest physiotherapy technique, medical management, ventilator management and suctioning technique can provide additional evidence.

Ethical Approval

This study was approved by the ethical and research committee of the Amrita Institute of Medical Sciences and Research Centre, Kochi.

Conflict of Interest

There is no funding agency / research support / conflict of interest for this study.

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