International Journal of Innovative Research and Advanced Studies (IJIRAS)
Volume 6 Issue 12, December 2019

ISSN: 2394-4404

Response Of Post Operative Atelectasis To Continuous Positive Airway Pressure: A Case Report

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Abstract:

Introduction: Post operative pulmonary complications (PPCs) such as atelectasis have posed as a major threat to successful surgical procedures, giving the rising need to understand the underlying causes and subsequent management of these complications. Although findings from literatures are inconclusive, continuous positive airway pressure which is a non invasive ventilation technique has been recorded to be effective in the management of post-operative atelectasis.

Case presentation: Miss C. is a one year old infant diagnosed of ventricular septal defect (VSA) and patent ductus arteriosus (PDA) which gave need for an open heart surgery. Prior to the diagnosis, she presented with difficulty in breathing since birth, cough and catarrh which has lasted for three months before the day of presentation. Atelectasis of the left lung was noticed on radiological examination 5 days post surgery and two days after intubation accompanied with fine crepitations on ausculation and hypoxaemia.

Management and Outcomes: Continuous positive airway pressure was introduced upon the development of atelectasis and a remarkable expansion of the lungs was noticed on radiological examination after 24 hours accompanied with absence of crepitations and hypoxaemia.

Discussion: Findings from this study showed that CPAP is efficient in the management of atelectasis as it showed a remarkable lung expansion after 24 hours of CPAP therapy. Other studies have also recorded the effectiveness of CPAP in the management of post operative pulmonary complications such atelectasis. CPAP increases the rate of radiological resolution of atelectasis followed by subsequent reduction of hypoxaemia when compared with other chest physiotherapy interventions such as percussion, vibration and nerbulization; although literatures does not allow firm conclusions to be drawn on the mechanism of this effect.

Conclusion: This study showed that CPAP increases the rate of atelectasis resolution when compared to other treatment procedures such as percussion, vibration and nerbulization. However, further emphasis should be laid on the use of CPAP and other non invasive ventilation approaches for preventive rather than treatment in the management of post operative pulmonary complications.

I. INTRODUCTION

Post-operative pulmonary complications (PPCs) which is defined as a second, unexpected disease that appears up to 30 days after surgery, changing the patient's status and making therapeutic intervention necessary ; have posed as a major threat to successful surgical procedures, giving the rising need to understand the underlying causes and subsequent management of these complications (Restrepo & Braverman, 2014). PPCs occurs after 25% to 50% of major surgical procedures (Quaseem et.al, 2006) and is the second most common cause of morbidity after cardiovascular event as it has been recorded that one in four deaths occurring in week of surgery is associated with pulmonary complications. The incidence of post operative is wide and varied, ranging from 2% to 40%. Specifically, it is about 1-2% in minor surgeries, 5-10% in patients undergoing non-thoracic surgery and 22% in high risk patients (Kelkar, 2015). Studies have

demonstrated a strong relationship between PPCs and preoperative risk factors such as length and type of surgery, advanced age (>60), presence of a previous lung disease or other comorbidities, obesity, malnutrition, reduced capacity for exercise, prolonged preoperative hospital stay, respiratory status of the patient and the type anaesthesia given to the patient (Silva, Gazzana & Knorst 2010; Jaber, Chanques & Jung, 2010; Filardo, Faresin & Fernandes, 2002). Since some of these factors such as age and type of surgery are non modifiable, efforts should be focused on devising the most efficient and safe management procedures and strategies.

Specifically, atelectasis amongst other medical conditions such as pneumonia, bronchitis, bronchospasm, pulmonary embolism and acute lung injury has been recorded to be the main cause of PPCs (Kelkar, 2015) especially after upper abdominal surgery. The development of atelectasis can be attributed to various factors such as the effect of general anaesthetics, pain, postoperative diaphragmatic dysfunction, pleural opening, recumbent position, increased intra-abdominal pressures and neuromuscular blocker induced muscle paralysis (Wilcox, Baile & Hards, 1988; Burgess, Cooper & Marino, 1978; Vargas, Cukier & Terra-Filho, 1993). Its high incidence (54-92%) has constituted a major concern after cardiac surgery because it contributes to the deterioration of oxygenation and pulmonary function (Vargas, Cukier & Terra-Filho, 1993). Hamilton (1961) described atelectasis as a condition in which there is collapse of one or more definite anatomical units of the lung. This is to say that it can occur in a lobule, segment, lobe or the entire lung itself. Development of atelectasis is also associated with development of lung injury, decreased lung compliance, impairment of oxygenation and increased pulmonary vascular resistance. These adverse effects from the perioperative period persist into the postoperative period and can reduce the rate of patient recovery (Duggan & Kavanagh, 2005).

The role of physiotherapy in the management of post pulmonary complications cannot be overemphasized. This is supported by evidence which shows that chest physiotherapy is common in treatment and prevention of postoperative pulmonary complications such as atelectasis (Stiller & Munday, 1992). The frequency and duration of the treatment given is dependent on the individual requirements, preference of the therapist and institutional practice. Chest physiotherapy includes a wide range of treatment techniques which includes some form of breathing exercise and coughing which would improve ventilation distribution; postural drainage, vibrations or percussions to the chest wall aimed at reducing atelectasis by enhancing the clearance of excessive or retained pulmonary secretions from the airways; incentive spirometry, intermittent positive pressure breathing (IPPB) and continuous positive airway pressure (CPAP) (Stiller & Munday, 1992).

Continuous positive airway pressure (CPAP) is a type of therapy that uses a high pressure gas source to deliver constant pressure to the airways throughout both inspiration and expiration (Weksler & Ovadia, 1991) with oxygen added in appropriate amounts. It is a form of non- invasive venitalation technique that has been proven useful in the management of post operation pulmonary complications such as atelectasis. CPAP used a variety of masks, which are placed over the nose, mouth or over the full face (Pelosi & Jaber 2010). Its aim is to improve the oxygenation of patients while preventing common postoperative complications in vulnerable people.

This report describes a case of post-operative atelectasis in an infant diagnosed with ventricular septal defect and patent ductus arteriosus. It also reviews the pathophysiology of atelectasis and the physiotherapy strategies used in its management.

II. LITERATURE REVIEW

This chapter would consider the conceptual framework of variables of interest which are atelectasis and continuous positive airway pressure.

The term atelectasis describes a state of collapsed and non-aerated region of the lung parenchyma, which is otherwise normal. This pathological condition is usually associated with several pulmonary and chest disorders and represents a manifestation of the underlying disease, not a disease *per se*. The developing lung is particularly predisposed to atelectasis once airway obstruction develops. In early childhood the airways are smaller and more collapsable, the chest wall is more compliant, and the collateral ventilation through intraalveolar and bronchiole-alveolar pores is not completely developed.

Atelectasis is influenced by pulmonary surfactant deficiency, such as in hyaline membrane disease (HMD) of prematurity and by surfactant dysfunction, in neardrowning, and in the acute respiratory distress syndrome (ARDS). Surfactant can directly modify alveolar tension with the changes of lung volumes, preventing collapse of small alveoli at low lung volumes and facilitating collapse at high lung volumes. The surfactant components (phospholipids, lipids, four surfactant-associated proteins, and calcium) may explain the properties of surfactant which are required for the normal function of peripheral gas exchange apparatus (Robertson, 1994).

III. PATHOPHYSIOLOGY

Air trapping and hyperinflation are produced by partial airway obstruction, atelectasis by complete obstruction. The gases trapped by complete occlusion are absorbed by the blood perfusing that region of the lung. The rate of gas absorption depends on the gas solubility. For these reasons atelectases are more common in HMD (hyaline membrane disease) and in the postoperative period, when high concentrations of oxygen are administered to the patient. If alveoli are collapsed a greater effort is required to reinflate them than when they are filled with air; an even greater effort is required to expand lung tissue which has been collapsed for days rather than for hours. Atelectasis produces alveolar hypoxia and pulmonary vasoconstriction to prevent ventilation-perfusion mismatching and to minimize arterial hypoxia. The vascular response is less effective when a large part of the lung is collapsed; if the blood cannot be diverted, it flows through the atelectatic non-ventilated region and produces intrapulmonary shunting (Redding, 1984; Hazinski, 1998).

ISSN: 2394-4404

IV. CAUSES OF ATELECTASIS

Atelectasis may occur mainly in three ways:

- ✓ airway obstruction;
- ✓ compression of parenchyma by extrathoracic, intrathoracic, chest wall processes
- ✓ increased surface tension in alveoli and bronchioli due to surfactant deficiency or dysfunction.

V. PRESENTATION OF ATELECTASIS

The signs and symptoms of atelectasis are often non-specific: the disease, which leads to the obstruction, may cause fever, cough, tachypnoea, wheezing, ronchi, and chest pain. Furthermore, in the case of infections such as bronchiolitis, bronchitis, pneumonia and tuberculosis and with tumours, asthma and CF, the presence of atelectasis does not change the clinical picture unless the obstructed area is large. Suggestive signs of atelectasis are localized reduced breath sounds or a constant wheeze. There may also be reduced chest wall expansion. If the obstruction involves a main bronchus, wheeze can be heard and cyanosis and asphyxia may be present, with mediastinal and cardiac displacement and elevation of the diaphragm. Aspiration of a foreign body in a previously well child is an acute respiratory emergency. If a large bronchus is present immediate intervention is mandatory. If the foreign body is lodged in a smaller airway there may be a symptom-free period, followed by infection in the area of atelectasis causing fever, malaise and cough.

A full medical history and specific clinical characteristics may help to identify the aetiology of the atelectasis. The patient with bronchopulmonary dysplasia exhibits a neonatal history of HMD and mechanical ventilation (Kennedy, 1999); the patient with CF may present with failure to and steatorrhea, but persistent wheezing may give a clue to the presence of atelectasis (Ruzal-Shapiro, 1998). Frequent vomiting or cough during and immediately after feeding, especially in young babies, suggests recurrent aspiration or gastroesophageal reflux. In asthma the presence of bronchial inflammation producing cellular debris and mucus plugs may cause airway obstruction, which is particularly frequent in the right middle lobe, leading to the so-called “right middle lobe syndrome”; this characterizes most cases of persistent atelectasis in childhood (De Boeck , Willems, Van Gysel, Corbeel & Eeckels, 1995). The right middle lobe bronchus is longer than other bronchi, starting at the bronchus intermedius after a sharp angle, leading to retention of intrabronchial secretions.The occurrence of migrating or rotating atelectasis may be an early manifestation of neuromuscular diseases such as Werdnig–Hoffman disease (Leistikow, Jones, Josephson & de Sierra, 1999). Another rare cause of intrabronchial obstruction with ensuing persistent atelectasis, often accompanied by pneumonitis resistant to therapy (with wheeze, and haemoptysis), is a bronchial carcinoid tumour (Wang, Wilkins & Bode, 1993).

VI. DIAGNOSIS OF ATELECTASIS

Once the diagnosis of atelectasis is suspected, chest radiographs using both the anterior-posterior and lateral projections are mandatory to document the presence, extent, and distribution of the atelectasis. Radiographically, there can be problems differentiating atelectasis from simple lobar consolidation (Swischhuk & John, 1995). With consolidations the alveoli are full of exudates and there is no significant loss of lung volume. However, as the pneumonia clears, atelectasis may develop because of mucus plugs or surfactant dysfunction. A more marked loss of volume in one lobe and compensatory emphysema in an accompanying lobe indicates the presence of atelectasis.

The difficulty in diagnosis is best exemplified by atelectasis of the right middle lobe. In this case, the loss of volume is so small it may appear as a dense band, suggesting pleural thickening rather than an atelectatic lobe (Swischhuk & John, 1995). In atelectasis associated with greater loss of volume, other radiographic findings may be useful. With loss of volume, the mediastinum shifts towards the involved lung: with volume gain, such as a pleural effusion or a large unilateral chest mass, it moves away from the involved lung. The presence of a unilateral elevated diaphragm may also suggest atelectasis, whereas it is unaffected in lobar pneumonia. With a pleural effusion the diaphragm may be displaced downwards and flattened on the side of the effusion. Ultrasonography may be useful in determining whether the opacity represents fluid or collapsed lung (Swischhuk & John, 1995). Differentiating atelectasis from lobar consolidation is a common dilemma in the assessment of respiratory infections in children. Viral infections commonly cause lower respiratory tract infections in childhood, whilst bronchial asthma causes atelectasis secondary to mucous plugging; in some patients radiographic differentiation of atelectasis and pneumonia is very difficult, and in such cases a clinical history is helpful. Coryza, nasal congestion and mild fever generally accompany viral infections; in asthma the consolidation is almost always due to atelectasis, since bacterial pneumonia seldom precipitate an acute asthma attack. If confusion remains, chest radiographic follow-up may be useful to demonstrate rapid resolution, which is more rapid with atelectasis. Peripheral atelectasis may be mistaken for a tumour mass, in which case a CT scan is helpful. Atelectasis may occur in any lobe or segment of the lung, but the right and left lower lobes are the most frequently involved. The right middle lobe is vulnerable fromenlargement of the hilar lymph nodes and is also the most commonly affected in asthma.

In recurrent aspiration syndrome (usually caused by milk aspiration in infants), the most frequently affected lobes are the posterior areas of the upper and lower lobes, because the infants lie supine for much of the day. In toddlers or older children, who spend more time vertical, the lower lobes the lingula and the right middle lobe are more frequently affected (Roberston, 1994).

ISSN: 2394-4404

VII. TREATMENT OF ATELECTASIS

The treatment of atelectasis varies depending on the cause, the duration and the severity. Respiratory infections are common causes of atelectasis in childhood, but are generally transient (except TB) with resolution within 3 months following antimicrobial therapy (Hazinski 1998). If the atelectasis does not resolve, bronchodilator inhalation and physiotherapy are performed (Hazinski, 1998). Aerosol therapy by inhalation of jet-nebulized saline increases sputum volume and clearance compared with physiotherapy alone. (Conway, Fleming, Perring & Holgate, 1992). The use of inhaled β2-agonists in patients with CF and bronchiectasis should be reserved for those who have demonstrated a clinical or lung function response to bronchodilator (Eber, Oberwaldner & Zach, 1988). Chest physiotherapy is commonly used in paediatric respiratory diseases: the benefit is thought to be due to mobilization of secretions by huffing and coughing from the smaller to the more central airways. Patients with chronic pulmonary diseases, such as CF and ciliary dyskinesia, usually improve with antibiotics and regular home chest physiotherapy.

If atelectasis occurs in the intensive care unit, in the postoperative period or during mechanical ventilation, postural drainage and chest percussion, together with bronchodilator therapy, may help. When atelectasis persists, bronchoscopy should be used to investigate and remove the cause of the obstruction. Resistant atelectases have been successfully treated by positive pressure ventilation using a flexible bronchoscope inserted into a subsegmental bronchus with a small balloon cuff at the distal end of the scope (Krell & Prakash, 1994). The use of nebulized recombinant human Dnase I (rhDNase), which hydrolyses bacterial and cellular DNA present in sputum plugs, has been described in the management of a mechanically ventilated child with asthma (Greally, 1995). It has also been used in patients with cystic fibrosis (Harms, Matouk & Tournier, 1998). The diagnosis and early management of atelectasis in children is important so as to optimize resolution and prevent permanent atelectasis with the possibility of irretrievable lung damage.

VIII. DESCRIPTION OF THE INTERVENTION (CONTINUOUS POSITIVE AIRWAY PRESSURE [CPAP])

Continuous positive airway pressure is a form of Non Invasive Ventilation (NIV). Its mechanism of action involves using a high pressure gas source to deliver constant positive pressure to the airways throughout both inspiration and expiration (Weksler, 1991). CPAP can be delivered in various ways including nasal, oronasal, and facial masks or with a helmet that covers the entire head (Pelosi, 2010). With CPAP therapy, pressures of 7 to 10cm H2O appear well tolerated with few adverse effects. It is often instituted intermittently for instance 60-90 minutes at two-to-three hourly intervals. However, pressures greater than 20cm H2O are generally avoided following abdominal surgery to reduce the presence of air in the digestive tract (Pelosi, 2010). Although that CPAP has been recorded to prevent post operative complications such as atelectasis, contradictions to its use have also been identified. These include inability to fit a mask, uncooperative patients, medical instability and inability to protect the airway (Nava, 2009). Poor compliance with CPAP has been noticed especially in patients undergoing long term treatment as 46% to 83% of patients have been recorded to be non-adherent to treatment (Weaver, 2008). Reasons for the non compliance include noise from machine, discomfort by the mask, claustrophobia, skin trauma and nasal congestion.

CPAP improves respiratory function postoperatively by increasing functional residual capacity, improving alveolar recruitment and reducing work of breathing (Nava 2009; Pelosi, 2010). Consequences of atelectasis such as pneumonia and acute respiratory failure may subsequently be prevented.

IX. CASE PRESENTATION

Miss C. is a 1 year and a month old baby who presented at University of Nigeria Teaching Hospital with complaint of difficulty in breathing since birth, cough and catarrh which has lasted for three months from the day of presentation. She was chronically ill looking with intranasal oxygen and urethral catheter insitu. SPO2 and PR were recorded to be 71% and 128bpm respectively, tachypnoeic (RR of 48cpm), and coarse crepitation in the lung zones with the right lung greater than that of the left lung. Patient was queried for congestive cardiac failure (CCF) and asynotic heart disease. However, further investigations with echocardiogram revealed the presence of Ventricular Septal Defect (VSD) and Patent Ductus Arteriosus (PDA) and were consequently booked for surgery in three weeks time. All through the period of admission before the surgery, the patient maintained a SPO2 range of 70-75%, RR of 48-54cpm and PR of 125-128bpm. The surgical procedures constituted of PDA ligation, VSD repair and aortic arch repair (which was discovered during the surgery). After surgery, the patient was intubated (SIMV mode) with FiO2 of 60% which was reduced to 45% on the second day post-surgery and was intubated three days post-surgery. Physiotherapy management commenced immediately after surgery with percussion, vibration, positioning, suctioning and 6 hourly nebulization with bronchodilator and mucolytic agents.

Nevertheless, radiological examinations revealed left-lung atelectasis with hyperinflation of the adjacent lung (see Fig 1) and fine crepitation on ausculatation and no mediastinal shift 5 days post surgery and 2 days after extubation. Her PaO2 reduced from 86mmHg to 40mmHg indicating hypoxaemia. SPO2 also reduced from a range of 95-98% to 65%-70%. To treat the left atelectasis, alongside with the other management procedures named above; we introduced the use of continuous positive airway pressure.

ISSN: 2394-4404

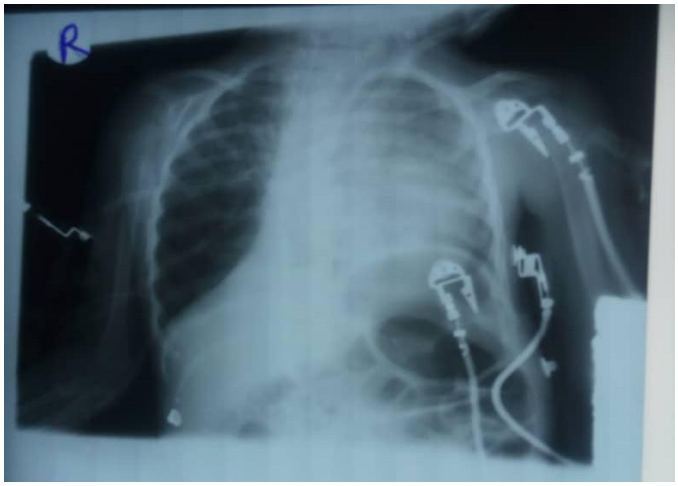

Figure 1: Radiograph showing atelectasis of the left lung

In order to ensure patient comfortabilty and compliance, we constructed an improvised CPAP device (Fig 2) by connecting an oxygen flow meter/ humidifier to urinary bag containing 5 litres of water which connects the nasal prone at the other end of the Y-tubing. The supplementary oxygen was set at 10litres and through this connection; a set amount of pressurized air is constantly delivered to the patient.

This was delivered to the patient 4 hourly with 2 hourly supplemental oxygen. The use of CPAP showed a remarkable improvement as follow up x-ray 24 hours later revealed full expansion of the left lung (Fig 3), absence of crepitations with PO2 and SPO2 at 86mmHg and 97% respectively. As a result the procedure was stepped down to 2 hourly CPAP and 4 hourly supplemental oxygen. Treatment using CPAP was terminated the next day after the step down and it was followed by removal of supplemental oxygen.

Figure 3: Radiograph showing a fully expanded left lung

Figure 2: Improvised CPAP

X. DISCUSSION

The atelectasis and subsequent hypoxaemia observed in Miss C. is a common occurrence among post surgical patients especially those who underwent thoracic or upper abdominal surgery as the development of atelectasis few days after surgery is in line with previous studies (Jain, Rao & Kumar, 1991; Stock, Dows & Cooper, 1984; Vargas, Cukier, Terra-Filho 1993) which showed that atelectasis is common on days 2-5 post surgery. This can be attributed to effect of general anaesthesia, post-operative diaphragmatic dysfunction, recumbent position, pain and neuromuscular blocker inhibition induced muscle paralysis.

Non compliance of patients to the use of CPAP as a result of discomfort from the masks and noise from the machine has also been recorded in previous studies. However, this present study utilized an improvised CPAP device which was connected to the oxygen flow meter and delivered using nasal prongs. As a result, the patient was compliant with the treatment procedures as studies also showed that nasal prongs are comfortable for CPAP delivery when compared to facemasks and helmets.

Findings from this study showed that CPAP is efficient in the management of atelectasis as this study showed a remarkable lung expansion after 24 hours of CPAP therapy. Other studies (Ireland, Chapman, Matthew, Herbison & Zschsrisd, 2014; Rama-Maceiras, 2009) have also recorded the effectiveness of CPAP in the management of post operative pulmonary complications such atelectasis. CPAP increases the rate of radiological resolution of atelectasis followed by subsequent reduction of hypoxaemia when compared with other chest physiotherapy interventions such as percussion, vibration and nerbulization; although literatures does not allow firm conclusions to be drawn on the

mechanism of this effect. However, findings from Bartlett, Brennan, Gazzaniga & Hanson, 1973; Oulton, Hobbs & Hicken, 1981 are in disagreement with our present study as they both recorded that chest physiotherapy significantly decreases the incidence of clinically important post operative pulmonary complications but there is no clear indication of which treatment technique or regimen is superior.

Although age does not appear to be a key factor in atelectasis, this condition has shown to be common in children which is evident in this present study. This can be attributed to the lower RFC, greater compliance of the thoracic cage and paradoxical movements of the ribcage in response to the contraction of the diaphragm as well as having a greater closure volume (Strundberg, Tokics, Brismar, Lundquist & Hedenstierna, 1987). The chest radiographs showed that the areas of atelectasis were confined to the lower and middle lung lobe as supported studies conducted by (Poelaert, Szegedi, Blot & Vincent, 2013; Fleisher, 2010) which recorded that in patients with 90% of patients with normal lungs, develop atelectasis in the most dependent lung segment after intubation.

This current study also has an advantage of being able to clearly separate the effect of prophylactic regimen to atelectasis from the effect of the treatment of atelectasis. In as much as chest physiotherapy procedures like chest percussion, vibration and nerbulization were introduced immediately after surgery, it still didn't prevent the development of post operative atelectasis. The difference is important in our everyday clinical practice as several authors have also emphasized on the need for studies analyzing separately the preventive and therapeutic regimen (Denehy & Zerney, 2001; O'Donohue, 1985). CPAP therefore should not be used only as a therapeutic intervention but also for the prevention of post operative atelectasis .

Our study also recorded some limitations. Firstly, the improvised CPAP used did not give room for quantification of the positive pressure delivered to the patient. As a result, we were unable to record the exact pressure which was effective in the treatment of atelectasis. Also, active chest physiotherapy interventions such as deep breathing exercises and the use of incentive spirometry could not be used in the management to the patient owing to the age of the patient and her inability to follow instructions. Subsequent comparisons could not be made between those interventions and CPAP. Finally, as a single case study, findings cannot be generalized to the wider population and researcher's own subjective feeling may influence the case study.

XI. CONCLUSION

This study showed that CPAP increases the rate of atelectasis resolution when compared to other treatment procedures such as percussion, vibration and nerbulization. Patient's comfort during the use of CPAP can also be achieved with the use of nasal prongs instead of masks as there was no sign of discomfort or reduced compliance throughout the treatment duration. However, further emphasis should be laid on the use of CPAP and other non invasive ventilation approaches for preventive rather than treatment in the management of post operative pulmonary complications.

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