Prevention of postoperative atelectasis in the post-cardiac surgical patient with poor left ventricular function: a study of the efficacy of bi-level positive airway pressure

Abstract

Background and aims: To determine the efficacy of Bi-level positive airway pressure (BiPAP) in prevention of postoperative atelectasis in patients with Off Pump Coronary Artery Bypass Grafting (OPCAB) with low left ventricular ejection fraction ≤35% and effect on various hemodynamic & oxygenation parameter.

Subjects and methods: This Prospective, randomized, case-controlled, pilot study included forty patients, who underwent elective (OPCAB) and were randomized into two groups i.e. group-B (BiPAP) and group-C (Control). All patients received same regimen of medication. Group-B was kept on BiPAP immediately following extubation, while, group-C received conventional physiotherapy only. All hemodynamic and oxygenation parameter were recorded and chest radiographs were done to find out incidence of atelectasis. Patients were followed up to their discharge.

Results: In group B, cardiac output was reduced after application of BiPAP at 0 & 12hrs but later on it normalized. There was no other significant effect on other hemodynamic parameters. As far as the oxygenation is concerned PaO2 remained high throughout first 48hrs and the difference inPaO2 was significant at 12hrs (PaO2 mmHg - group B-146±37, group C-121±18) (p=0.05) and at 48hrs (PaO2 mmHg-group B-146±41, group C- 110±9) (p=0.05). Arterial blood oxygen saturation was better maintained in group-B. There was significant difference in the occurrence of atelectasis in group-B and group-C (10% v/s 60%) (p=0.003). Although the effects on ICU stay, hospital stay and mortality was same.

Conclusion: In patients, undergoing elective cardiac surgery with low Ejection Fraction intensive use of BiPAP can be considered as effective means of avoiding the deleterious consequences of cardiac surgery on postoperative pulmonary complications originating form atelectasis.

Keywords: atelectasis, off pump coronary artery bypass grafting, bi-level positive, airway pressure, left ventricular ejection fraction

Introduction

Cardiac surgery frequently results in post operative pulmonary restriction syndrome. This syndrome is multi-factorial including post operative pain, absorption atelectasis, effect of anesthetic/sedative drugs and phrenic nerve dysfunction.1 These all combined together lead to high incidence of postoperative pulmonary complications, which includes retention of tracheo-bronchial secretions, atelectasis and pneumonia.2 These complications produces secondary hypoxemia, prolonged ventilator use and ventilator associated pneumonia with subsequent increased Intensive care unit (ICU) and hospital stays as well as increased morbidity and mortality.3 Conventional chest physiotherapy, incentive spirometry (IS) and intermittent positive pressure breathing (IPPB), used in an attempt to improve post operative pulmonary functions, may have a beneficial effect in post operative pulmonary impairment.4,5 Continuous positive airway pressure (CPAP) can restore functional residual capacity (FRC) to pre-operative value,6 Improve oxygenation7 and decrease work of breathing.8 Although CPAP is better than IS and IPPB, but its effects are not sustained.9 Bilevel positive airway pressure (BiPAP) is another non-invasive mode which has been used to treat many diseases like acute exacerbation of chronic bronchitis (AECB),10 obstructive sleep apnea (OSA)11 and cardiogenic pulmonary oedema.12 Pressure support ventilation (PSV) in BiPAP allows recruitment of zones of alveolar collapse and PEEP prevents alveolar collapse at end expiration thereby improving oxygenation and decreasing postoperative atelectasis. Patient with low left ventricular ejection fraction (LVEF) tend to go into pulmonary congestion and edema once the positive pressure ventilation is weaned off in post CABG period. We hypothesized that post-extubation application of BIPAP may reduce the incidence of atelectasis and improve oxygenation indices in these groups of patients. Hence, we performed a randomized prospective, placebo-controlled study to see the effectiveness of prophylactic use of BIPAP in prevention of postoperative atelectasis in post cardiac surgical patients.
Methods

Present study was conducted at tertiary care cardiac facility and included forty consecutive patients undergoing elective off pump coronary artery bypass graft surgery (OPCAB) with low LVEF £35 % (measured by ECHO) after approval of institutional ethics committee and written informed consent from all patients. Baseline demographic profile (age, sex, weight) and smoking history and history of pulmonary disease were recorded for all patients.

Patients were randomized into 2 groups:

i. Group B - BiPAP (n=20)

ii. Group C (Control) - Non BiPAP (n=20)

A comprehensive preoperative work up of all patients, once they had been comprehensively optimized on medication was done in the form of baseline hemodynamic parameter, arterial blood gases (ABG), Chest x-ray (CXR)-PA view and corresponding lateral view (if required), liver function Test (LFT), renal function test (RFT) and complete blood count (CBC). Surgical and anesthetic techniques were same for both groups. Extubation was performed when the patient met the standard criteria for the same. Patients assigned into group-B were started on BiPAP immediately following extubation for a period of 12hours. On the other hand, group C patients wereadministered oxygen by venturi mask (FiO2=0.6). Both groups received conventional (routine) chest physiotherapy. Post operatively the patient’s temperature, arterial blood gases (ABG), hemodynamic parameters [e.g. heart rate (HR), blood pressure (BP), cardiac output (CO), cardiac index (CI), systemic vascular resistance (SVR), pulmonary vascular resistance (PVR), pulmonary artery pressure (PAP), respiratory parameters [e.g. respiratory rate (RR) and arterial saturation of hemoglobin (SpO2)] were recorded at baseline (0hours) and every 4 hourly. CXR, CBC and RFT were done every 24-hour. A radiologist who was blinded to the groups reported CXR. Radiological atelectasis score was defined according to Richter et al.13 0- Clear lung field, 1-Plate atelectasis or slight infiltration, 2-Partial atelectasis, 3-Lobar atelectasis and 4-Bilateral lobar atelectasis. We also noted in-hospital mortality, ICU stay, total hospital stay, development of atelectasis and pneumonia during hospital stay.

Pneumonia was defined, if any of the three of the following criteria were present

i. New and persistent radiological infiltrate consistent with pneumonia

ii. Fever >38°C.

iii. Leukocytosis >11000/ml or <4000/ml

iv. Purulent sputum

v. Microorganism isolated from at least one of the following samples

a. Broncho alveolar lavage (BAL)

b. End tracheal tube aspirate

c. Sputum

Patients in both groups had the same regimen of chest physiotherapy and IS. Postoperatively pain relief was managed by intravenous Tramadol hydrochloride 50-100mg thrice daily and prn (maximum dose of 300mg/day) to remove bias of different modes of pain relief. All patients were kept on prophylactic antibiotic (injection Cefazoline 1g intravenous. preoperatively and thereafter every 8hourly till the chest tube removal) as per hospital protocol. Patients in both groups were also continued on ionotropic support, diuretic, vasodilators, anticoagulants, anti adrenergic etc as required. Any respiratory co morbidity e.g. chronic obstructive pulmonary disease (COPD), pneumonia etc. were also noted. The requirements of additional antibiotics in the postoperative period for respiratory or other infections in addition to the antibiotic given routinely were noted, as was reintubation/ tracheotomy.

BiPAP Protocol

All patients were thoroughly evaluated by a pulmonary physician preoperatively, who was unaware about treatment protocol in both groups. BiPAP machine, (Respironics Inc, Murrysville PA) is a pressure-limited ventilator, that cycles between adjustable inspiratory and expiratory pressure using either flow triggered or time triggered cycling modes. BiPAP was applied in all patients with a backup respiratory rate of 12-14 breath per minute with an initial IPAP setting of 8cm H2O and initial EPAP setting of 4cm H2O to maintain positive pressure gradient of 4cm H2O between inspiratory and expiratory phase. Supplemental O2 (8-10l/min) via the BiPAP machine was given in order to maintain the SaO2 above 94%. A soft cushioned nasal or facemask (depending on patient’s comfort) was used to provide BiPAP. Chinstrap was also used to avoid mouth leak in case of nasal mask or if the patient was a mouth breather. Patients with distension of the stomach had an or gastric tube placed to decompress the stomach. Nasal mask were switched to or nasal mask if there was significant air leakage through the mouth despite chinstrap or if the patient was not able to tolerate nasal mask.

Monitoring of clinical and hemodynamic parameters along with patient’s comfort were done and if, the patient required more inspiratory assistance, pressure was increased by 2cm H2O increments every 3-5min until SpO2 (>94%) and PaO2 (>60mmHg) were optimized. On the other hand if patient felt that the pressure was too high, the aspiratory pressure was lowered in 2cmH2O decrements every 3-5min until comfort was obtained. Similarly for hypoxemic patients, EPAP was raised in increments of 2cmH2O with IPAP at fixed interval above EPAP (i.e. PS was maintained at 4-5cmH2O). For hypoxic patients IPAP was raised in increments of 2cmH2O with EPAP raised in a ratio to IPAP of approximately 1:2.5. After every ventilator setting change, ABG was done to monitor the blood gases. Successful BIPAP management was defined as

i. Increased PaO2, increased SpO2 or decreased PaCO2

ii. Improvement in pulse and respiratory rate and avoidance of endotracheal reintubation (ET)

Statistical Analysis

The Chi-square or Fisher exact tests were applied for comparison of categorical data as appropriate. Results were expressed as mean±SD. Mean value of group B and C were compared by using student t-test. A p-value of less than 0.05 was considered significant. All analysis were done by using SPSS statistical software (version 10.0; SPSS Inc. Chicago, IL).

Results

There was no significant difference in demographic profile (age, gender, weight, height and smoking status (pack year), co morbidity, co-morbidities, hospitalization, and other co-morbidities). There was no significant difference in demographic profile (age, gender, weight, height and smoking status (pack year), co morbidity, co-morbidities, hospitalization, and other co-morbidities).
conditions and pulmonary function test between two groups (Table 1). Duration of surgery (248±19min v/s 252±17min, p=0.488) and postoperative total ventilator time (482±18min v/s 491±23 min, p=0.177) were statistically similar in both groups. The absolute values or proportional changes in vitals as compared to baseline e.g. HR, RR, systolic blood pressure (SP), and diastolic blood pressure (DP) were not significantly different in both groups. Table 2 pH values were similar in both groups but PaO₂ was higher and PaCO₂ was lower throughout study period in group B. CO and CI were reduced in group B after application of BiPAP (at 0hrs - 4.2±0.7) and (at 12hrs - 4.3±0.4) (p<0.05) which was statistically significant (Table 3).

All vital parameters were recorded for both groups every 4 hourly, however for calculations, data only at 0 hr, 1hr, 24hr and 48hr are taken as shown in Tables 2, Table 3. There was significantly reduced incidence of atelectasis in group B as compared to group C (10% v/s 60%) (p<0.003) while the incidence of pneumonia was twice in group C (n=1 v/s n=2) (Table 4).

Table 1 Baseline characteristics of patients in both group

<table>
<thead>
<tr>
<th></th>
<th>Group B (n=20)</th>
<th>Group C (n=20)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs) (Mean±SD)</td>
<td>54.9±6.34</td>
<td>56.1±8.08</td>
<td>0.605</td>
</tr>
<tr>
<td>Sex (M/F)</td>
<td>18/2</td>
<td>18/2</td>
<td>1</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>78±4</td>
<td>76±6</td>
<td>0.223</td>
</tr>
<tr>
<td>Smokers (n)</td>
<td>8</td>
<td>6</td>
<td>0.74</td>
</tr>
<tr>
<td><strong>History</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension (n)</td>
<td>9</td>
<td>7</td>
<td>0.747</td>
</tr>
<tr>
<td>Diabetic Mellitus (n)</td>
<td>4</td>
<td>6</td>
<td>0.715</td>
</tr>
<tr>
<td>COPD/Asthma (n)%</td>
<td>(4) 20</td>
<td>(5) 25</td>
<td>1</td>
</tr>
<tr>
<td>Previous MI / CAD (n)</td>
<td>20</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td><strong>Preoperative PFT(Mean±SD)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FVC (ml)</td>
<td>3398±736</td>
<td>3295±627</td>
<td>0.637</td>
</tr>
<tr>
<td>FEV₁ (ml)</td>
<td>2580±678</td>
<td>2523±714</td>
<td>0.798</td>
</tr>
</tbody>
</table>

COPD, chronic obstructive pulmonary disease; FVC, forced vital capacity; FEV₁, forced expiratory volume in 1 second

Table 2 Vital and physiological parameters recorded in both groups

<table>
<thead>
<tr>
<th></th>
<th>Preoperative</th>
<th>0hr</th>
<th>12hr</th>
<th>24hr</th>
<th>48hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart Rate/min</td>
<td>98±16</td>
<td>100±14</td>
<td>92±16</td>
<td>96±12</td>
<td>93±14</td>
</tr>
<tr>
<td>BP (SP) mmHg</td>
<td>115±11</td>
<td>122±14</td>
<td>119±18</td>
<td>118±10</td>
<td>118±9</td>
</tr>
<tr>
<td>BP(DP) mmHg</td>
<td>57±6</td>
<td>66±10</td>
<td>60±8</td>
<td>60±7</td>
<td>61±6</td>
</tr>
<tr>
<td>PAP(SP) mmHg</td>
<td>35±10</td>
<td>32±7</td>
<td>32±9</td>
<td>27±6</td>
<td>36±8</td>
</tr>
<tr>
<td>PAP (DP) mmHg</td>
<td>15±7</td>
<td>15±3</td>
<td>14±5</td>
<td>11±4</td>
<td>14±4</td>
</tr>
<tr>
<td>CO(L/mi)</td>
<td>4.4±0.8</td>
<td>4.7±0.9</td>
<td>4.2±0.7</td>
<td>4.7±0.7</td>
<td>4.3±0.4</td>
</tr>
<tr>
<td>CI(L/mm)</td>
<td>2.6±0.5</td>
<td>2.7±0.4</td>
<td>2.4±0.4</td>
<td>2.7±0.3</td>
<td>2.4±0.3</td>
</tr>
<tr>
<td>SVR dyne sec cm-5</td>
<td>134±365</td>
<td>124±283</td>
<td>1379±639</td>
<td>1233±177</td>
<td>1282±148</td>
</tr>
<tr>
<td>PVR dyne sec cm-5</td>
<td>151±82</td>
<td>154±67</td>
<td>173±98</td>
<td>120±45</td>
<td>172±46</td>
</tr>
</tbody>
</table>

BP, blood pressure; SP, systolic pressure; DP, diastolic pressure; PAP, pulmonary artery pressure; SVR, systemic vascular resistance; PVR, pulmonary vascular resistance; *: Significant; P<0.05.
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Table 3 Vital and physiological parameters recorded in both groups-respiratory

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Preoperative</th>
<th>0 hr</th>
<th>12 hr</th>
<th>24 hr</th>
<th>48 hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory rate/ min</td>
<td>19±3</td>
<td>18±3</td>
<td>18±3</td>
<td>19±2</td>
<td>19±3</td>
</tr>
<tr>
<td>ABG</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PH</td>
<td>7.4±05</td>
<td>7.5±04</td>
<td>7.4±09</td>
<td>7.4±03</td>
<td>7.4±04</td>
</tr>
<tr>
<td>PaO₂ mmHg</td>
<td>156.4±55</td>
<td>148±40</td>
<td>150±41</td>
<td>140±41</td>
<td>146±37*</td>
</tr>
<tr>
<td>PaCO₂ mmHg</td>
<td>38.5±4.6</td>
<td>39.5±5.5</td>
<td>39.5±3.9</td>
<td>40±3.2</td>
<td>40±5</td>
</tr>
<tr>
<td>SpO₂ (%)</td>
<td>99±1.4</td>
<td>98±12</td>
<td>99.2±1.1</td>
<td>98±6.6</td>
<td>99.4±3.6</td>
</tr>
</tbody>
</table>

Table 4 Outcome measures in both groups

<table>
<thead>
<tr>
<th>Outcome Measures</th>
<th>Group B</th>
<th>Group C</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basal Atelectasis (%)</td>
<td>0.1</td>
<td>0.6</td>
<td>0.003</td>
</tr>
<tr>
<td>(2/20)</td>
<td>(12/20)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pneumonia (%)</td>
<td>0.05</td>
<td>0.1</td>
<td>1</td>
</tr>
<tr>
<td>(1/20)</td>
<td>(2/20)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICU Stay (days)</td>
<td>3.6±1.2</td>
<td>4.3±1.5</td>
<td>0.085</td>
</tr>
<tr>
<td>Hospital Stay (days)</td>
<td>8.9±3.7</td>
<td>9.5±3.1</td>
<td>0.582</td>
</tr>
<tr>
<td>Mortality (%)</td>
<td>0.05</td>
<td>0</td>
<td>0.047</td>
</tr>
<tr>
<td>(1/20)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Discussion

Postoperative pulmonary restriction syndrome i.e. occurrence of basal atelectasis with decline in lung function leading to various complications is a well-known entity after cardio thoracic or upper abdominal surgery. This restriction of pulmonary function usually persists from a few days to 2-3 weeks leading to postoperative pulmonary complications and increasing the morbidity and cost of treatment. This alteration of ventilatory function is multi factorial: phrenic nerve dysfunction/palsy, effect of anesthetic/analgesic drugs, pain, mechanical functional alteration of chest wall due to sternotomy, pleural opening, prolonged recumbent position, diaphragmatic dysfunction, associated cardiac surgery and underlying lung status. All these combined together contribute to major cause of post operative morbidity and mortality. During normal breathing, large intermittent breaths (about three time the tidal volume), which are known as sigh, occur about 10 times per hour. Post operatively such sighing is absent and the shallow rapid respiration may decrease ventilation to the dependent lung region and may contribute to the

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Pasquina et al.\(^{30}\) in a comparative study of CPAP and non invasive pressure support ventilation (NIPSV) to treat atelectasis after cardiac surgery observed an improvement in the radiological atelectasis score in 60% of the patients with NIPSV versus 40% of those receiving CPAP (p=0.02). They did not find any difference in oxygenation (\(\text{PaO}_2/\text{FiO}_2\)), pulmonary function tests or length of stay.\(^{30}\) Although their findings are similar to ours, but they analyzed the therapeutic effects of NIPSV on atelectasis after cardiac surgery while we observed the prophylactic effect of BiPAP for the development of atelectasis after cardiac surgery. As already stated BiPAP increases the FRC and keeps the alveoli open throughout both phases of respiration. There are fewer tendencies for segment or any part of segment to collapse because of alveolar interdependence, which helps to prevent an alveolus to collapse spontaneously. This tendency, which is enhanced by EPAP, tends to stabilize the alveoli because the alveolar pressure is kept above atmospheric pressure during expiration (PEEP) so the alveoli hold the adjacent alveoli open and not let them collapse. Although the development of pneumonia was twice in group C but this was statistically insignificant because of small study size and this may be a chance finding. Only one and two patients in group B and group C respectively developed pneumonia, which could not be explained solely on the basis of BiPAP. There were other confounding factors too, which may lead to bias. Mean duration of ICU stay and hospital stay was 3.6±1.2days and 8.9±3.7days in group B, while it was 4.3±1.5days and 9.5±3.1days in group C, but it was non-significant (p 0.085 and 0.582 respectively). Our findings are consistent with Jean et al. There was one death in group B due to intractable arrhythmias and none in group C. Jean et al found significant improvement in FVC, FEV, PEFR in BiPAP group (12/4) and Stock et al and Lindner et al also found improvement in FRC and FEV1 and FVC value after CPAP therapy, but in our study, we did not perform post operative PFT. In spite of use of internal mammary artery in all patients for surgical myocardial revascularization, the post operative pulmonary atelectasis was significantly lower in our BiPAP group, while, in contrast P. matte, Ferdinand et al.\(^{31}\) found a large impairment in post operative pulmonary function when the mammary arteries were used as conduit for revascularization as compared to the saphenous vein graft.

**Figure 1** Graph II Vital & Physiological Parameters (hemodynamics) in both groups.

**Figure 2** Showing Respiratory Parameters among Two Groups.

**Conclusion**

In summary for a majority of patients undergoing cardiac surgery with poor LVEF <35% use of BiPAP along with conventional physiotherapy can be considered as an effective means of avoiding the deleterious consequences of cardiac surgery on post operative pulmonary complications originating from atelectasis like ventilator associated pneumonia. This was demonstrated by significantly lower (10% vs 60%) incidence of atelectasis, lower incidence of pneumonia and higher \(\text{PaO}_2\). Large multicentre study is required to show other beneficial effects of BiPAP on other variables like ICU/hospital stay and morbidity or mortality.

**Limitations**

As this study was a small size case controlled, non blinded study (i.e. the respiratory therapist was not blinded in order to make ventilator adjustments) and the follow up of patients was short and post operative PFT were not performed so the improvement in FEV, FVC could not be compared to the functional improvement after BiPAP. We also expected to find an effect on the development of pneumonia, ICU stay, total hospital stay, mortality but because the study was small with short follow up that difference in these variables could not be studied.

Acknowledgements

None.

Conflict of interest

The author declares no conflict of interest.

References


