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Use of Noninvasive Positive Pressure Ventilation in Acute Respiratory Insufficiency after Cardiac Surgery

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Abstract:

Background: Non-invasive positive pressure ventilation (NIPPV) using bilevel positive airway pressure (BiPAP) ventilation is a safe and effective mean of improving gas exchange in many types of respiratory failure. The results of application of NIPPV to patients who had cardiac surgery and developed respiratory failure after extubation still to be investigated.

Aim of work: To compare the efficacy of NIPPV delivered through a face mask with the efficacy of conventional mechanical ventilation (CV) delivered through an endotracheal tube and investigates its hemodynamic effects in this group of patients.

Materials and Methods: NIPPV and CV were applied to twenty four patients in two groups who had open heart surgery and suffered from severe respiratory deterioration after tracheal extubation. Respiratory and invasive hemodynamic parameters were measured before starting ventilation, 1, 6, 12 hours, and before and after weaning of ventilation and incidence of ventilatory complications were recorded.

Results: Respiratory parameters improved significantly in patients in both groups after one hour but one patient was intubated in NIPPV group. There were no significant differences between the two groups as regards the hemodynamics and respiratory parameters. Respiratory complications and infection were not noticed in NIPPV group during the study.

Conclusion: NIPPV is considered an effective method of treating patients with acute respiratory insufficiency after cardiac surgery with minimal effects on respiratory and hemodynamic parameters. It reduces the respiratory complications and infection during mechanical ventilation.

Introduction:

Although mechanical ventilation with endotracheal intubation is a life saving method in cases of respiratory failure, there has been a search for methods which ensure sufficient respiration without intubation. Complications of intubation and mechanical ventilation include barotrauma, nosocomial pneumonia, sinusitis, and psychological problems[1]. Valvular surgery and coronary artery bypass graft (CABG) surgery with the use of mammary arteries are associated with alteration of lung function parameters [2].

Application of noninvasive positive pressure ventilation (NIPPV) at different levels to inspiration and expiration using face or nose masks has reduced the necessity of endotracheal intubation [3]. It is a safe and effective mean of improving gas exchange in patients with many types of acute respiratory failure [4]. In patients with acute exacerbations of chronic obstructive pulmonary disease (COPD) and hypercapnic respiratory failure, adding noninvasive ventilation to standard therapy decreased the need for endotracheal intubation and reduced mortality [5]. Similarly, noninvasive continuous positive airway pressure was effective in patients with cardiogenic pulmonary edema, particularly those with hypercapnia [6, 7]. In various forms of acute hypoxemic respiratory failure (pneumonia, congestive heart failure, and chest-wall impairment), this therapy slightly decreased the rate of tracheal intubation and improved survival [8]. While NIPPV is frequently used in the treatment of patients with acute respiratory failure, little is known about its

effect on pulmonary gases parameters and hemodynamics in patients with acute respiratory insufficiency after cardiac surgery.

Aim Of Work

This study was undertaken to compare the efficacy of noninvasive ventilation delivered through a face mask with the efficacy of conventional mechanical ventilation delivered through an endotracheal tube and investigate its respiratory and hemodynamic effects in this group of patients.

Materials And Methods

After Ethical Board approval and a written informed consent from the patients or their relatives, twenty four patients who had open heart surgery and developed acute respiratory failure after extubation during intensive care period were randomly assigned to receive either conventional mechanical ventilation with endotracheal intubation (CV) or noninvasive positive pressure ventilation (NIPPV) through a face mask. The criteria for eligibility were acute respiratory distress that had deteriorated despite aggressive medical management, including severe dyspnea at rest; a respiratory rate > 35 breaths/ min; a ratio of the partial pressure of arterial oxygen to the fraction of inspired oxygen (PaO_2:FiO_2) < 200 while the patient was breathing oxygen through a face mask; and active contraction of the accessory muscles of respiration

A Servo 900 C (Siemens Elema, Sweden) ventilator was used for patients assigned to the CV group and intubated with cuffed endotracheal tubes (internal diameter, 7 to 8 mm). The initial ventilator setting was in the assisted control mode, with a delivered tidal volume of 10 ml/kg of body weight and a respiratory rate of 12-16 breaths/min, a positive end-expiratory pressure of 5 cm H_2O, and FiO_2 of 0.8. Positive end-expiratory pressure was increased in increments of 2 to 3 cm H_2O up to 10 cm H_2O, until the FiO_2 requirement was 0.6 or less. Intravenous midazolam (0.05 mg/kg) or propofol (1 mg/kg) was given for sedation at the time of intubation; none of the patients received a muscle relaxant. The head of the bed was kept elevated at an angle of 45 degrees to minimize the risk of aspiration. When spontaneous breathing reappeared, the ventilator settings were changed to intermittent mandatory ventilation (rate, 4 - 7 breaths/min) with pressure support (10 cm H_2O), adjusted to achieve a spontaneous tidal volume of 8 - 10 ml/kg, a respiratory rate < 25 breaths/ min, and the disappearance of accessory muscle activity. All patients were weaned from the ventilator by reducing the level of pressure support by 4 cm H_2O twice and then decreasing the ventilatory rate by 2 breaths /min at two-hour intervals, as tolerated. Patients who tolerated an intermittent mandatory ventilation rate of 4 breath /min, a pressure-support level of 5 cm H_2O, and an FiO_2 of 0.5 or less had a two-hour T-piece trial. These patients then underwent extubation if they maintained a respiratory rate < 25 breaths/ min $PaCO_2$< 45 mmHg and a PaO_2 > 85 mm Hg.

The following requirements were considered to give the patients NIPPV support; intact coughing reflex, spontaneous respiration, minimal tracheal secretion, hemodynamic stability, no agitation or a decrease in consciousness level and adaptation of the patient to non-invasive ventilation. NIPPV was applied through spontaneous patient-triggered mode (S), spontaneous/timed mode (S/T) or timed-triggered mode (T) using (Respirnocs Inc, Murrysville, PA BiPAP S/T-D30 Model 552037) ventilatory support system. Inspiratory positive airway pressure (IPAP) was between 12-16 cmH_2O, where as expiratory positive airway pressure (EPAP) was 4-7 cm H_2O according to the patients' tolerance and to achieve an exhaled tidal volume of 8 to 10 ml/kg and a respiratory rate < 25 breaths/min.

The ventilator is connected with conventional tubing to a clear full-face mask with an inflatable soft-cushion seal manufactured in flexible non traumatic silicone rubber and is perfectly fitted to the face of the patient with low risk of air leaks. Moreover, utilizing a disposable foam spacer it is possible to reduce the pressure on the bridge of the patient's nose and to

reduce dead space (Contour Mask, Respironics Inc., Murrysville, PA Spectrum disposable 1003156 INTL). The mask was secured with head straps to avoid an excessively tight fit, and the head of the bed was kept elevated at a 45-degree angle. The patients were not sedated. Subsequently, each patient was evaluated and noninvasive ventilation was reduced progressively and consequently their inspiratory and expiratory pressure support was decreased in accordance with the degree of clinical improvement and was discontinued if the patient maintained PaO_2:FiO_2 ratio >200, a respiratory rate < 25 breaths/min, $PaCO_2$<45 mmHg, PaO_2 greater than 85 mmHg with FiO_2 of 0.5, and PEEP≤5cmH_2O without ventilatory support during the weaning period.

During the respiratory deterioration period, blood gas changes were recorded via arterial blood gas sampling for arterial pH, $PaCO_2$, PaO_2 and SaO_2 obtained through a 20-gauge plastic cannula placed in the radial artery and mixed venous sampling through 7F, pulmonary artery catheter (Edwards Swan-Ganz Baxter Healthcare Corp, Irvine, CA). The hemodynamic parameters (heart rate, mean arterial blood pressure, cardiac index, central venous pressure, and pulmonary artery pressure) were recorded.

Ventilator settings were adjusted on the basis of continuous oximetry and measurements of arterial blood gases. During the first 24 hours, ventilation was continuously maintained until oxygenation and clinical status improved. Arterial blood gas values and hemodynamic parameters were determined at baseline, one, six, twelve hours intervals during mechanical ventilation, before and after discontinuation of ventilatory support.

The patients assigned to receive NIPPV, the criteria for switching them to endotracheal intubation and CV were the failure to maintain a PaO_2 above 65 mm Hg with FiO_2 > 0.6; the development of conditions necessitating endotracheal intubation to protect the airway (coma or seizure disorder) or to manage copious tracheal secretions, hemodynamic instability, an increase in heart beating more than 20%, a change in blood pressure more than 20%, a decrease in cardiac output greater than 30% or significant electrocardiographic changes, or an inability of the patient to tolerate the face mask because of discomfort.

Patients with any of the following were excluded from the study: a requirement of emergency intubation for cardiopulmonary resuscitation, respiratory arrest, severe hemodynamic instability, encephalopathy or presence of organ failure (e.g., the simultaneous presence of renal and cardiovascular failure).

Patients were monitored for the development of infection, pneumonia, sepsis and acute lung injury.

Data were given as mean ± standard deviation SD or numbers. Students "t" test, Chi-square or Fisher's exact test and analysis of variance were used as appropriate. A $p<0.05$ was considered statistically significant. All statistical analyses were done using the SPSS version 12 software.

Results:

Twenty four patients were enrolled in the study and randomized into two groups, 12 patients in each one. There were no differences among the groups with regard to age, sex, body weight, height, type of surgery, duration of surgery. One patient in the noninvasive ventilation group required endotracheal intubation due to failure to maintain PaO_2 above 65 mmHg two hours after the start of ventilation due to aspiration and acute respiratory failure. None of the patients required emergency intubation. The patients in the noninvasive-ventilation group had a shorter duration of mechanical ventilation (2.0±1.4 vs. 5.2±2.8 days) and a shorter stay in the intensive care unit (5.1±2.9 vs. 11.4±3.1 days) than those in the conventional-ventilation group. The patients in NIPPV group did not show ICU-acquired infection, pneumonia or sepsis as shown in table -1.

Table - 1: Patients' Characteristics (mean±SD):

Parameters	Group NIPPV (n=12)	Group CV (n=12)
Age (yr)	56±9	57±8
Sex (Male/Female)	9/3	10/2
Body weight (kg)	81±8	83±9
Height (cm)	168±11	171±8
EF (%)	41±9	40±10
Hypertension (y/n)	10/2	9/3
DM (y/n)	8/4	7/5
Dyslipidemic (y/n)	7/5	9/3
COPD (y/n)	2/10	4/8
Surgery (number of patients) :		
CABG	7	8
Valvular	4	2
Combined	1	2
Duration of operation (min)	227±51	224±46
ICU stay (days)	5.1±2.9*	11.4±3.1
Duration of mechanical ventilation(days)	2.0±1.4*	5.2±2.8
Complications:		
Pneumonia	_	2
Sepsis	_	1
Death	_	1

*P<0.05(significant difference between the two groups). CABG= coronary artery bypass grafting,

COPD= chronic obstructive pulmonary disease, EF=ejection fraction, DM=diabetes mellitus.

The conventional-ventilation group had shown two cases of pneumonia related to the endotracheal intubation and a case of sepsis and one patient died of cardiogenic shock due to a new myocardial infarction. The other patients were successfully discharged from the hospital without further complications.

Blood Gas Changes

The two studied groups had similar baseline respiratory, blood gases and hemodynamic parameters. The patients in the two groups had a similar initial significant change in arterial blood gases parameters, PaO_2:FiO_2 and SvO_2 within the first hour of mechanical ventilation (P<0.01). The changes in blood gases parameters were similar in the two groups. There was a sustained improvement in blood gas parameters over studied time intervals in both ventilation groups, but there were no statistically significant changes in pulmonary parameters, oxygenation or CO_2 elimination (table-2).

Table - 2: Blood gas parameters in both groups (mean±SD):

Variable	Group	baseline	1h	6h	12h	Before weaning	After weaning
pHa	NIPPV	7.29±0.4	7.33±0.3*	7.36±0.2	7.38±0.4	7.43±0.3	7.45±0.3
	CV	7.28±0.3	7.36±0.4*	7.38±0.3	7.41±0.3	7.44±0.3	7.43±0.2
P_aO_2 mmHg	NIPPV	58±5	83±6*	86±4	92±6	97±4	97±5
	CV	56±5	86±4*	93±4	95±6	98±6	97±5
P_aCO_2 mmHg	NIPPV	56±5	49±6*	46±7	44±6	40±6	40±5
	CV	57±5	47±7*	44±7	40±6	39±5	39±6
P_aO_2:FiO_2	NIPPV	122±26	182±29*	189±23	198±22	242±31	238±21
	CV	119±20	186±27*	196±27	204±24	246±25	239±28
SaO_2%	NIPPV	78±7	92±5*	96±5	97±7	98±7	97±8
	CV	76±7	93±8*	95±6	97±5	99±8	98±7
SvO_2%	NIPPV	59±3	68±4*	71±2	71±3	73±2	73±3
	CV	58±3	69±4*	72±3	73±2	74±4	73±3

*P<0.05(significant difference between the two groups). pHa=arterial pH, PaO_2=arterial oxygen tension, $PaCO_2$= arterial carbon dioxide tension, PaO2:FiO2=arterial oxygen tension : inspired oxygen fraction, SaO_2 %=arterial oxygen saturation, SvO_2%=mixed venous oxygen saturation.

Hemodynamic Parameters

This study examined the changes in basic circulatory parameters with the initiation of NIPPV and CV. Invasive measurements of HR, MAP, CVP, MPAP, PCWP, CI, PVR, and SVR showed similar baseline parameters. There were no significant differences in any of the hemodynamic parameters measured at different time intervals of the study between both groups. Cardiac index increased significantly from 2.5 to 3.1 l/min/m^2 in NIPPV group ($p < 0.01$) after an hour from the start of ventilation.

Table - 3: Hemodynamic values in both groups (mean±SD):

Parameter	Group	Baseline	1hr	6hrs	12hrs	Before weaning	After weaning
HR beat/min	NIPPV	105±7	100±6	94±8	91±7	87±6	88±6
	CV	104±9	107±9	103±8	101±9	99±7	96±7
MBP mmHg	NIPPV	99±7	96±7	91±6	91±5	89±6	88±5
	CV	106±10	105±9	104±11	102±9	100±8	98±8
CVP mmHg	NIPPV	7±2	6±3	7±2	7±1	8±2	8±2
	CV	10±3	10±2	9±2	10±2	8±3	9±2
MPAP mmHg	NIPPV	20±5	19±4	18±5	18±4	17±5	18±5
	CV	21±5	20±6	19±5	19±4	19±5	19±4
PCWP mmHg	NIPPV	12±2	13±2	13±1	14±2	12±3	12±2
	CV	13±4	13±3	12±3	12±4	14±4	13±4
CI l/min/m^2	NIPPV	2.5±0.2	3.1±0.2*	3.0±0.1	3.1±0.2	3.2±0.3	3.2±0.2
	CV	2.7±0.3	2.8±0.2	2.9±0.3	3.0±0.3	3.2±0.2	3.2±0.2
SVR dyn.s.cm^{-5}	NIPPV	1721±221	1687±193	1611±151	1553±131	1472±137	1421±150
	CV	1783±204	1737±225	1712±196	1669±212	1610±188	1568±231
PVR dyn.s.cm^{-5}	NIPPV	139±21	131±27	125±31	123±28	120±32	121±24
	CV	147±29	145±24	144±30	138±21	139±27	131±30

*P<0.01(significant difference between the two groups). HR=Heart Rate (beat/min), MBP=mean blood pressure (mmHg), CVP=Central venous pressure (mmHg), MPAP=mean pulmonary artery pressure (mmHg), PCWP=Pulmonary capillary wedge pressure (mmHg), CI=Cardiac index (L/min/m^2), SVR=Systemic vascular resistance (dyn.s.cm^{-5}), PVR=Pulmonary vascular resistance (dyn.s.cm^{-5}).

Discussion:

Understanding the clinical indications for and limitations of NIPPV allows successful use of this method of mechanical ventilation during postoperative period following cardiac surgery. It is such an unusual complication that patients who have had open heart surgery may suffer from respiratory failure in ICU after extubation. In many of those patients there are different risk factors such as COPD and excessive weight, and most commonly respiratory outcome depending on cardiac complications [9, 10].

The primary treatment of acute respiratory failure has been mechanical ventilation support using endotracheal intubation for many decades. NIPPV is an alternative treatment which may be easily applied to patients, where respiratory failure developed after open heart surgery and not required immediate intubation and it may eliminate the need of reintubation in suitable patient groups [11].

Patients developing acute ventilatory failure in the absence of other organ dysfunction, without central nervous system disorders, and with no need for immediate endotracheal intubation (e.g.,respiratory arrest or inability to protect the airway) constitute the group of patients for whom beneficial results can be expected. Patients developing hypercapnic ventilatory failure stand to benefit most clearly from NIPPV [12].

The serious complications as pneumonia or sinusitis related to the endotracheal tube and events leading to death are shown more in patients of conventional-ventilation group than in the noninvasive-ventilation group. Avoiding intubation was associated with a lower incidence of septic complications [11].

Noninvasive mechanical ventilation may be an option for short-term ventilatory support in patients with hypercapnic ventilatory failure who are not responding adequately to pharmacologic intervention and are not in need of immediate intubation and mechanical ventilation [6].

Its advantages include improved patient comfort, reduced need for sedation, provides flexibility in the beginning and termination of mechanical ventilation, maintenance of airway defense, speech, and swallowing mechanisms, ability to comm.-unicate, lessens the need for invasive monitorization and enables early patients mobilization and avoidance of the compli-cat-ons associated with an endotracheal tube[7].

Furthermore, substantial reductions in the length of intensive care and total hospital stay were observed by Brochard et al[12].

However, there may be some problems limiting the treatment such as patient adaptation, need for patient cooperation, the lack of direct airway access, skin, facial ache and ulcers caused by mask pressure, sense of drying in the nose, eye irritation (conjunctivitis), claustrophobia, sleep disorders and mask leakage. Gastric distension seems to be uncommon with NIPPV when mask pressure is limited to 20 to 25 cm H_2O. Therefore routine nasogastric suctioning is not recommended [13].

Two randomized, prospective trials comparing NIPPV with standard therapy showed a significant decrease in the need for mechanical ventilation and a trend toward decreased mortality [12, 14].

Other subsets of patients who seem to clearly benefit from NIPPV are those developing ventilatory failure in the postoperative period and those with acute cardiogenic pulmonary edema. In patients with hypoxemic respiratory failure, results are more conflicting. One randomized prospective trial in a group of patients with various causes of respiratory failure did not reveal any benefit of noninvasive ventilation except in the subgroup with acute hypercapnia [15].

The results obtained during this study concerning shortening ICU stay with noninvasive ventilation, changes in respiratory and hemodynamic parameters were comparable with a study of 12 healthy volunteers where no significant differences in any of the hemodynamic parameters measured after the placement of NIPPV. Similar results for most hemodynamic parameters were found with the exception of significant but small increases in the

cardiac index, stroke volume and oxygen saturation [16, 17].

NIPPV was more effective at unloading the respiratory muscles than CPAP in acute cardiogenic pulmonary edema. In addition, NIPPV and 10 cm H_2O CPAP produced a reduction in right and left ventricular preload without a change in cardiac index, which suggests an improvement in cardiac performance [18].

Conclusion:

NIPPV is considered an effective safe method of treating patients with acute respiratory insufficiency after cardiac surgery with minimal effects on respiratory and hemodynamic parameters. It reduces respiratory complications and infection during mechanical ventilation, and reduces hospital stay. It is shown to be an alternative treatment which may be easily applied to patients and it may eliminate the need of reintubation in suitable patient groups.

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استعمال التهوية الرئوية الصناعية إيجابية الضغط غير النافذة في حالات القصور الرئوى بعد عمليات القلب

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خلفية البحث: يعد إستخدام التهوية الرئوية غير النافذة بالتهوية الإيجابية ثنائية المستوى وسيلة أمنة ومؤثرة فى تحسين عملية تبادل الغازات فى حالات الفشل الرئوى المختلفة، و لكن آثرها فى حالات القصور الرئوى بعد عمليات القلب و بعد إزالة الأنبوب الحنجري لم تظهر بعد و لا زالت قيد البحث و الفحص.
الهدف من البحث: مقارنة كفاءة التهوية الرئوية غير النافذة ايجابية الضغط من خلال القناع الوجهى وكفاءة التهوية الرئوية الميكانيكية التقليدية من خلال الأنبوب الحنجرى وبحث تأثيرهما على القياسات الرئوية ووظائف الدورة الدموية فى المرضى بعد عمليات جراحة القلب.
الطرق والوسائل البحثية: تم استخدام هذين النوعين من التهوية الرئوية الميكانيكية على عدد 24 مريض مقسمين الى مجموعتين ممن اجرى لهم عمليات فى القلب وعانوا من قصور رئوى فى الفترة مابعد العملية وبعد ازالة الانبوب الحنجرى. وتم قياس الوظائف الرئوية ووظائف الدورة الدموية قبل بدء التهوية الميكانيكية وعند ساعة وست واثنى عشر ساعة وقبل وبعد الفطام منها. وتم تسجيل معدل حدوث المضاعفات الناتجة عن التهوية الرئوية الميكانيكية فى المجموعتين.
نتائج البحث: تحسنت القياسات الرئوية فى كلا المجموعتين بدرجة ملحوظة بعد مرور ساعة من بدء التهوية الرئوية الصناعية ولكن مريضا واحدا لم يسجب للتهوية الرئوية الايجابية ثنائية المستوى وتم وضع انبوب حنجرى له. ولم يكن هناك فرق ملحوظ بين المجموعتين بالنسبة للقياسات الرئوية ووظائف الدورة الدموية. وكانت المضاعفات الرئوية والالتهابات أقل حدوثا فى مجموعة التهوية الرئوية الايجابية ثنائية المستوى غير النافذة.
الاستنتاج والتوصيه: تعد التهوية الرئوية غير النافذة ايجابية الضغط احدى الوسائل المؤثرة فى علاج مرضى القصور الرئوى مابعد عمليات جراحة القلب وبأقل تأثير على القياسات الرئوية ووظائف الدورة الدموية. كما أنها تحسن معدل البقاء وتقلل من مضاعفات التهوية الرئوية الميكانيكية.