Non-invasive positive pressure ventilation in acute respiratory failure

An alternative modality to invasive ventilation at a general hospital

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ABSTRACT

Objectives: Non-invasive positive pressure ventilation (NPPV) is a relatively new modality of managing acute respiratory failure (ARF). It has not been applied before in our area. The aim of this study is to verify the use of NPPV on patients with ARF at a general hospital level.

Methods: All patients admitted at the Al-Amiri Hospital, Kuwait (a secondary medical center) between 1999 and 2001 with ARF and met the inclusion criteria were included in the study. The non-invasive mode of nasal ventilation was used as the respiratory support.

Results: A total of 21 patients were included in the final analysis. The major cause of ARF type 2 was chronic obstructive pulmonary disease (COPD) in 71%. The overall success rate of NPPV trials was 71.4%. In the successful trials of ARF type 2, the arterial blood gas parameters of $PaCo_2$ ($p<0.005$), pH ($p=0.023$), and PaO_2 ($p<0.001$) showed improvement from the first hour of intervention. Analysis of variance with repeated measurement for the arterial blood gas variables showed statistical significance of changes in favor of NPPV during initial close monitoring with $p<0.001$. The percentage of successful trials at the general wards was 82% versus 67% for the intensive care unit cases (ICU). Surprisingly, failure of trials related mainly to the clinical status of the patients.

Conclusion: Non-invasive positive pressure ventilation is an effective ventilatory support in ARF in a proper clinical setting. It may be used safely in the general hospital outside the ICU.

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A decade ago, the classical management of acute respiratory failure is the invasive ventilatory support with endotracheal intubation (ETI) at an intensive care unit (ICU) facility. Recently, non-invasive positive pressure ventilation (NPPV) has been adopted using different patient interface such as nasal or full-face mask for selected groups of patients in acute respiratory failure (ARF).[1] The idea had emerged from the practice of using NPPV for chronic respiratory failure, thereby trying to avoid the complications related to ventilatory support utilizing ETI. Different group of investigators utilized different modalities of non-invasive respiratory support with either machines intended for invasive ventilation or those built specially for non-invasive modality.[1-9] They

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Table 1 - Clinical features of the study group.

Patients features	Range and number	Successful cases (N=15)		Failure cases(N=6)	
		n	(%)	n	(%)
Gender					
Male to female ratio	3:2				
Age (years), mean±SD	59.4 ± (16.6)				
Co- morbid illness					
DM	8	5	(33)	3	(50)
LVF	3	2	(13)	1	(16)
Corpulmonale	2	2	(13)	0	(0)
CCF	7	4	(26)	3	(50)
Hypothyroidism	2	2	(13)	0	(0)
Hypertension	11	8	(53)	3	(50)
*Others	6				
Radiological findings					
Normal	4	4	(26)		(0)
Labor pneumonia	6	4	(26)	2	(33)
Bronchopneumonia	3	3	(20)		(0)
Post TB fibrosis	1	1	(6)		(0)
Bronchoiectasis	2	1	(6)	1	(16)
Pulmonary congestion	4	2	(13)	2	(33)
Interstitial infiltrate	1	0	(0)	1	(16)

*Others - bronchopneumonia, septicemia, myocardial infarction, asthma, cerebrovascular accident, chronic renal failure, advanced carcinoma all were among failure group,
DM - diabetes mellitus, LVF - left ventricular failure, CCF - congestive heart failure, TB - tuberculosis

Table 2 - Microbiological isolate from culture specimen.

Microbiological isolate	N of cases	Successful cases (N=15)		Failure cases (N=6)	
		n	(%)	n	(%)
Hemophilus influenzea	5	3	(20)	2	(33)
Streptococcus pneumonae	1	1	(6)	0	(0)
Actinomycosis	1	1	(6)	0	(0)
Staphylococcus aureus	2	2	(13)	0	(0)
Klebsiella	2	1	(6)	1	(16)
Mixed growth	5	3	(20)	2	(33)
Negative culture	5	4	(26)	1	(16)

reported different rates of success. The British Thoracic Society (BTS) and the international consensus conferences on intensive care medicine had published preliminary guidelines for utilizing NPPV in the setting of a general hospital.[10-11] These guidelines is aimed to identify patients who are suitable for NPPV, setting standards of care for those in ARF receiving NPPV, helping to guide the selection among different ventilatory modes and patient interface. Yet, this modality were not adopted routinely all over the world especially in a general hospital practice. The aim of this manuscript is to report a study conducted on our patients utilizing this modality of ventilator support to determine rate of success, factors affecting the final outcome and to verify its feasibility both in ICU and less dependent care facility, such as, high dependency units and general wards.

Methods. This study was conducted in Al-Amiri Hospital in Kuwait (secondary medical center) with 410-bed, with established respiratory unit, ICU, and high dependency unit (HDU) between 1999 and 2001. All patients admitted with acute hypercapnic respiratory failure who met the inclusion criteria and whose clinical condition did not require intubation were included. The inclusion criteria were 1) Patient in acute hypercapnic respiratory failure not responding to maximal standard therapy including oxygen with pH ≤7.3, $PaCO_2$ >6 kPa and PaO_2 <8 kPa. 2) Patients who were compliant with NPPV. 3) Patients who had acute hypoxic respiratory failure with PaO_2<8 kPa, normal or low $PaCO_2$ not responding to maximal specific standard medical treatment including oxygen entrainment. Patients should be able to clear their respiratory secretions, protect their airways and should be hemodynamically stable. Those excluded were patients who were non compliant or who refused this modality from the beginning, those who did not meet the inclusion criteria or in whom NPPV was contraindicated. Among the contraindications to apply NPPV were patients who were too drowsy to communicate or were unconscious, those who were hemodynamically unstable or were revived from cardiac or respiratory arrest, those with gastro-intestinal bleeding or severe hemoptysis, or those with facial deformity or recent facial surgery. Patients were kept on NPPV using mainly bi-level positive airways pressure with either nasal or full-face mask unless otherwise indicated, when continuous positive airway pressure (CPAP) was used initially. They were kept on NPPV continuously for 1-4 hours, then as tolerated on the subsequent 48-72 hours or even earlier if their respiratory parameters return to normal or to their baseline before admission. Relevant radiological, biochemical, microbiological and hematological investigations were carried out on admission.

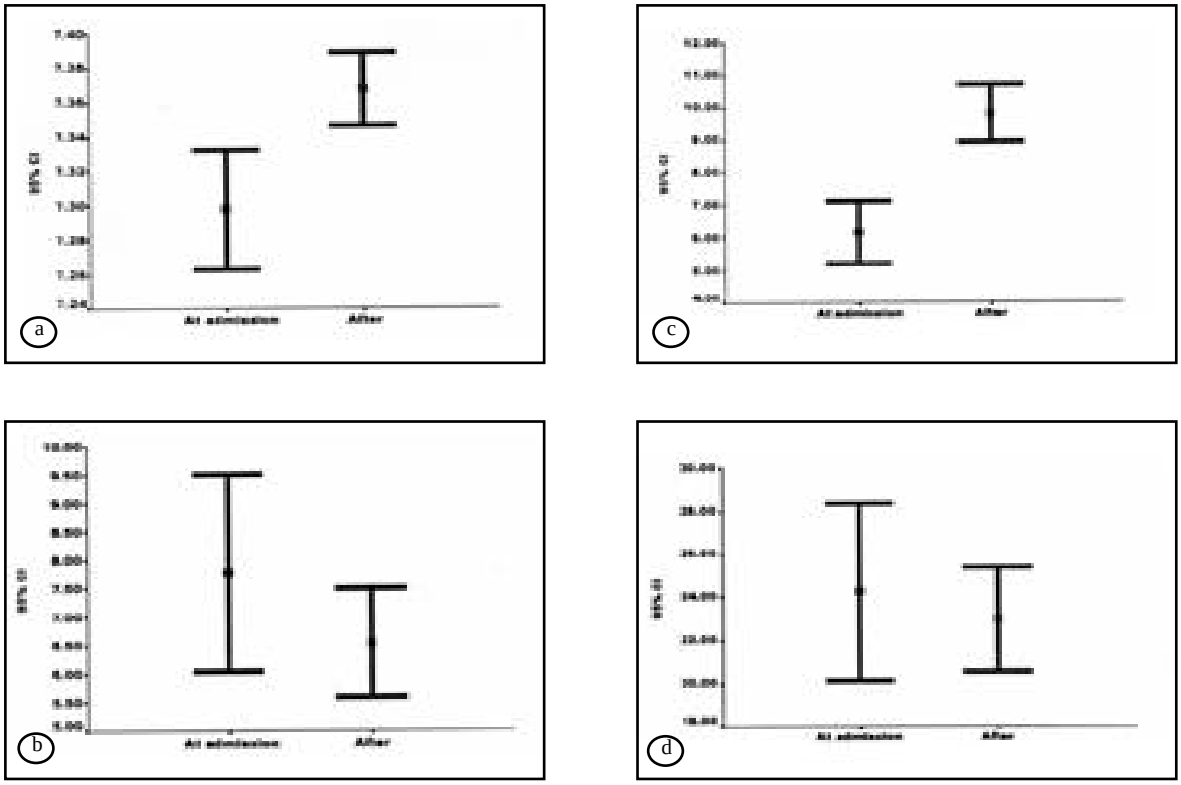

Figure 1 - Arterial blood gas parameters on admission and after supportive ventilation **a)** arterial pH values at admission and after supportive ventilation **b)** arterial PaCo2 values at admission and after supportive ventilation **c)** arterial PaO2 values at admission and after supportive ventilation and **d)** arterial HCO_3 values at admission and after supportive ventilation.

Arterial blood gas (ABG) determination was carried out before starting NPPV and then at half an hour, one hour, 4 hours and 24 hours after starting NPPV. Success was defined as improvement in ABG parameters of pH, $PaCo_2$, PaO_2, at first 4 hours, that was maintained for 24 hours with stabilization of patient's general condition. Failure was defined as non-successful trial over the first 12 hours, or deterioration of patient's clinical condition whichever comes first. Those in need of ETI during the trial were identified and were excluded from the final analysis.

Statistical methods. The statistical package for social sciences (SPSS) Windows version 11.0 was used for data analysis. The descriptive statistics percentage and mean were used to describe the findings. The comparison between ABG parameters on admission and after one hour for both successful and failure groups was carried out using paired t-test and analysis of variance (ANOVA) was used for repeated measurement in each group separately. A value of $p<0.05$ was taken as significant.

Results. Among all the ARF cases, only 21 patients who met the inclusion criteria completed the study. **Table 1 and 2** summarizes the clinical data of the included patients. The patients age were 17-82 years with male to female ratio of 3:2. Among them 62% were smokers. The major cause of hypercapnic ARF was COPD (71%), followed by overlap syndrome of COPD and obstructive sleep apnea. The main admission site was the general ward in 52% of the cases whereas 43% of them were managed at the ICU. Arterial blood gas parameters on admission were in the range of 3.8-12.6 kPa for $PaCo_2$, 3.69-7.99 kPa for PaO_2 and 7.1-7.45 for pH. Non-invasive positive pressure ventilation attained a success rate of 71.4% and was highest among the COPD cases (73.3%). Among the successful group, the mean $PaCO_2$ was 8.2 kPa versus 12.2 kPa in the failure group, whereas the mean PaO_2 was 6 kPa versus 6.26 kPa and PH 7.27 versus 7.25 for both groups. **Figure 1a, 1b, 1c & 1d** summarizes the values of ABG parameters on admission and after supportive ventilation.

In the successful trials of hypercapnic ARF, the ABG parameters of $PaCO_2$ ($p<0.005$), pH ($p=0.023$) and PaO_2 ($p<0.001$) showed a statistically significant improvement in the first one hour of intervention. Analysis of variance with repeated measurement for ABG variables showed again statistical significance of changes in favor of NPPV during initial close monitoring with $p<0.001$. With regards to symptoms, those patients with associated symptoms of apnea and snoring were more common in the successful group than among the failures (66% versus 0%) whereas drowsiness (83% versus 66%) and excess respiratory secretion (100% versus 86%) were more common among the failure. Other admission symptoms related to failure were chest pain (50% versus 33%) and wheezes (100% versus 60%). In the study group, a total of 11 patients managed in the general medical wards, 9 of the them had successful trials (82%). Whereas, among those who were managed at a higher care level as ICU, 6 out of 9 cases had successful trials (67%) and a single case was managed at HDU had a failed trial. Serious co-morbid conditions were more common among the failure group. Congestive heart failure was found among 50% of the failure cases versus 26% in the success group and relatively diabetes mellitus (50% versus 33%). Chronic renal failure and advanced carcinoma on the other hand, both were 16% among the failure group but none in the successful cases. Radiological abnormalities as consolidation and pulmonary congestion were more common in the failure group 100% versus 73% among the successful cases. Microbiological screen with blood and sputum cultures was of high yield in both groups being more prominent among the failure ones. Both groups had positive cultures (83% among the failures versus 73% for the successful cases) with almost similar pathogens isolated such as *haemophilus influenzae* or as mixed growth of more than one pathogen.

Discussion. In this study, we showed that NPPV is an effective modality of ventilator support in ARF used in proper clinical settings, even in places not familiar with its practice. It can be an alternative to ETI and mechanical ventilation in selected groups of patients especially those with chronic lung disorders who are liable by the nature of their diseases, to develop complicated courses in the ICU. It could spare them the risk of infections and prolonged stay at hospital. They can maintain contact with their surroundings, resulting in early mobilization, better nutrition and high morale especially in those with COPD who are more prone to depressive mood at exacerbation. It is well known that COPD patients can have a prolonged course at ICU once intubated and mechanically ventilated. As such, NPPV is a good alternative to keep them away from more invasive intervention.[1,4,5,8,12] Our data were consistent with those earlier studies that COPD patients once correctly selected can attain successful trials.

The mechanism of action of NPPV in COPD cases was under analysis by several investigators. Conway et al[13] speculated that positive pressure increase recruitment of alveoli, improving ventilation/perfusion (V/Q) mismatch, correcting the hypoxemia and so improving the mental status, cardiac and renal function and tissue perfusion. Carrey et al[14] supported these findings and suggested that a small but consistent reduction in both end-tidal and arterial $PaCo_2$ observed in their group of patients as a whole (a heterogeneous group of acute and chronic respiratory failure of both obstructive and restrictive lung disease) indicate that an increase in alveolar ventilation occurs during NPPV coupled with reduction in muscle energy expenditure as a result of either an increase in over all minute ventilation or alternatively improvement in V/Q relationship. A further explanation for the improvement in those successful studies is that NPPV may decrease the diaphragmatic work in patients with COPD as demonstrated by other investigators as Kramer et al, Carrey et al, Brochard et al and Appendini et al.[5,14-16] Hence, short periods of NPPV may be sufficient to break the vicious cycle of acidosis due to ineffective ventilation and muscle fatigue while other therapeutic modalities have an effect on the precipitating cause.[6]

Furthermore, NPPV has been shown to be helpful in hypoxemic respiratory failure patients who did not respond to specific therapy including entrained oxygen. Those patients were cases of pneumonia, interstitial lung disease, congestive cardiac failure and pulmonary embolism. Also, included were asthmatics in acute exacerbation who needed mainly continuous positive airway pressure (CPAP) support. It has been shown that CPAP can be helpful in such hypoxic respiratory failure.[10,11] Continuous positive airway pressure can decrease the work of breathing as it increases alveolar recruitment, functional residual capacity and by so decreasing the anatomical shunt.[12,17] It is fairly practical and rather safe to utilize it outside the ICU setting, such as at an intermediate care level or even a general ward, provided there is a trained personnel as a respiratory therapist or nurse around all the time and a motivated physician monitoring the patients progress and intervene when necessary. We had a higher success rate at the general ward than a higher care level. It could also be argued that those at ICU were more critical cases and had advanced disease. In our study, the successful trials of ARF, showed early improvement in ABG parameters after the first one hour of treatment initiation. It has been shown that one of the predictors of successful trials is early

improvement in arterial blood pH[7,18,19] and early rise in PaO_2 after the first one hour of starting NPPV.[5,7] Contrary to other studies,[7,18] our data showed that failure was not related to degree of hypoxia or acidosis at presentation, as both of them were comparable between the successful and failure groups. It could be that our sample is smaller than the other investigators and as such a marked difference could not be detected.

In this analysis, we tried to study factors that may contribute to failure of trials. Among the factors that were examined and proved to accompany failure of trials were unfavorable symptomatology of excess respiratory secretions and drowsiness.[2,18] Patients who are unable to clear their airways or maintain clear sensorium will be less able to comply or respond to NPPV. Newer machines are provided with back up rate and better humidifier that may overcome these 2 problems. Still, it cannot help much in clearing the secretions. It is important to keep a close monitoring on patients prone to accumulate secretions and to avoid in particular full-face mask in such situation especially for a confused patient. Severe co-morbid disease can adversely influence the likelihood of NPPV trials success as it could worsen the already existed physiological disturbances in ARF.[7] It has been shown before that among COPD patients who were admitted to ICU, those with increased mortality are with higher urea concentration and lower systolic blood pressure at admission than those who survived.[20] The British Thoracic Society Standards of Care Committee stated that from data collected, NPPV can be more successful in patients with less severe physiological derangement at baseline and in whom there were rapid improvement in pH and respiratory rate with NPPV.[11] Other factors that had been examined and found to contribute to failure of trials are patients of hypercapnic ARF who got radiological proof of pneumonia or pulmonary congestion as reported by Ambrosino et al.[18]

We believe that NPPV is an effective technique of managing ARF in a proper clinical settings. It can be used safely outside ICU facility. Patients could be saved from ETI and mechanical ventilation and their related complications. We think a larger study can be carried out to promote its use in most general hospitals providing practical local guidelines can be adopted to fit each hospital settings and its available facilities.

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