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EC PULMONOLOGY AND RESPIRATORY MEDICINE

Review Article

Non-Invasive Ventilation in Chronic Heart Failure, an Important Comorbidity of COPD

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Received: April 26, 2018; **Published:** May 28, 2018

Abstract

Non-invasive ventilation (NIV) has already written history in hypercapnic respiratory failure due to chronic obstructive pulmonary disease (COPD) exacerbations and saved many lives. COPD cardiac comorbidities are the most encountered everywhere in the world, rising new questions about NIV use and limitations. Chronic heart failure, with millions of sufferers, poor survival rates and worse prognostic than in some frequent neoplastic diseases, has reduced functional capacity, with limited performance of daily life activities and health-related quality of life. Cardiac pump insufficiency is corelated with cardiovascular, respiratory and metabolic limitations. Heart failure has typical symptoms and signs, generally easy to recognise, but there are many underlining causes that need to be correctly diagnosed and treated, and also some overlapped features. There is an increased demand for new drugs and adjunct therapies. Non-invasive ventilation can improve cardiac function in both acute and long-term application through hemodynamic, ventilatory and peripheral muscle effects. Initiation of NIV may acutely increase cardiac output, while hemodynamic consequences of long-term NIV depend on the underlying cardiac conditions. Multiple variables can modulate this influence, such as NIV mode, pressure level and breathing frequencies. Ventilatory settings and the patient characteristics are of crucial importance in heart failure, a clinical condition where attentive care and repeated check-ups are strongly requested.

Keywords: *COPD; Chronic Heart Failure; Non-Invasive Ventilation; CPAP; BiPAP; Acute Respiratory Failure; Health Related Quality of Life*

Abbreviations

ARF: Acute Respiratory Failure; ASV: Adaptive Servo-Ventilation; BiPAP: Bi-Level Positive Airway Pressure; BP: Blood Pressure; CI: Cardiac Index; CHF: Congestive Heart Failure; CO2: Carbon Dioxide; CPAP: Continuous Positive Airway Pressure; CPE: Cardiogenic Pulmonary Oedema; COPD: Chronic Obstructive Pulmonary Disease; EF: Ejection Fraction; EI: Exercise Intolerance; FEV1: Forced Expiratory Volume in One Second; FVC: Forced Vital Capacity; HF: Heart Failure; HRQoL: Health-Related Quality of Life; HI-NIV: High Intensity Non-Invasive Ventilation; LI-NIV: Low Intensity Non-Invasive Ventilation; LV: Left Ventricle; LVEF: Left Ventricle Ejection Fraction; LVP_{tm}: Left Ventricular Transmural Pressure; MV: Mechanical Ventilation; 6MWT: Six-Minute Walking Test; NIV: Non-Invasive Ventilation; NTproBNP: N-Terminal Pro-Brain Natriuretic Peptide; NPPV: Non-Invasive Positive Pressure Ventilation; NYHA: New York Heart Association; OSA: Obstructive Sleep Apnoea; $PaCO_2$: Arterial Carbon Dioxide Pressure; P_{es}: Oesophageal Pressure; PS: Pressure Support

Introduction

COPD exacerbations are serious conditions requiring hospital admission, and approximately 20% of the hospitalized patients will present or develop hypercapnic respiratory failure [1]. Acute respiratory failure, leading to acute or acute-on-chronic respiratory acidosis, presents a high risk of death. According to official ERS/ATS clinical practise guidelines on NIV in acute respiratory failure, it is compulsory to initiate mechanical ventilation in order to save lives [1]. Bilevel NIV is recommended to prevent acute respiratory acidosis, to prevent endotracheal intubation and invasive mechanical ventilation in patients with mild to moderate acidosis and respiratory distress, and as an alternative to invasive ventilation in patients with severe acidosis and more severe respiratory distress [1]. Coexistence of heart failure (HF) might be challenging in terms of clinical recognition due to symptom overlapping, drug selection and NIV use.

Heart failure is a life-threatening disease and it should be considered a global health priority. Approximately 1 - 2% of population in developed countries is diagnosed with heart failure, namely 26 million of people worldwide, and the prevalence increases with age [2]. Prognostic is poor, and the survival rates are worse than in bowel, breast and prostate cancer. Heart has difficulties in pumping blood leading to functional limitation, with important cardiovascular, respiratory and metabolic alterations. HF patients have reduced functional capacity, with limited performance of daily life activities and health-related quality of life (HRQoL) [3]. According to European Society of Cardiology [2], HF is a clinical syndrome characterized by typical symptoms (e.g. breathlessness, ankle swelling and fatigue), that may be accompanied by signs (e.g. elevated jugular venous pressure, basal pulmonary crackles and peripheral oedema) produced by a structural and/or functional cardiac abnormality, resulting in a reduced cardiac output and/or elevated intracardiac pressures at rest or during stress. For therapeutic reasons, identification of the cardiac underlying cause of HF is of major importance. Myocardial abnormality is the most frequent, but not the only possible problem; HF might be generated also by valves, pericardium, endocardium, heart rhythm and conduction abnormalities, sometimes more than one at a time [2].

The main symptoms in HF are dyspnoea and fatigue during exercise and/or daily life activities, which limit exercise tolerance; progressively will appear dyspnoea at rest. Exertional dyspnoea or exercise intolerance (EI) is correlated with abnormal respiratory function and involves several mechanisms: chronotropic failure, reduced myocardial β-adrenoceptor density and sensitivity, diastolic dysfunction, declining ventricular function consecutive to myocardial and vascular remodelling with reduced cardiac output, impaired tissue oxygen extraction, abnormalities in skeletal muscle structure and metabolism, reduced skeletal muscle blood flow during exercise, and hyperventilation caused by elevated physiologic dead-space in the oedematous lung [4,5].

There are supposed to be multiple mechanisms of expiratory flow limitation in CHF: airway dysfunction either because of previous smoking history, advanced age, obesity, or due to bronchial oedema and increased reactivity [6]. Approximately 80% of CHF patients present a restrictive spirometric pattern, mainly attributed to extravascular volume expansion and fluid accumulation in interstitial compartments of the lungs, increased heart volume and reduced lung compliance. Accumulation of interstitial fluid will lead to flooded alveoli and impaired alveolar gas exchange, with dyspnoea and muscle weakness [4]. Excessive ventilatory requirements, inspiratory muscle fatigue, exacerbated muscle ergoreflex, accentuated sympathetic activity, will lead to increase in central motor command to the respiratory muscles, with enhanced perceived exertion and fatigue, comparable to changes found in skeletal muscles [5].

A decreased level of activity will lead to reduced physical fitness, with further worsening of symptoms, limited daily life activities, and progressive reduction of functional capacity [5]. Six minutes walking test (6MWT) is the simplest, low cost method of evaluating functional capacity. 6MWT can reproduce daily life activities, evaluate exercise tolerance, assess the degree of functional limitation, and enable prognostic stratification [5]. Detection of co-morbidities is of great importance, as they may trouble diagnosis (e.g. chronic obstructive pulmonary disease COPD or obstructive sleep apnoea OSA), treatment, aggravate symptoms and affect HRQoL.

Types of non-invasive ventilation used in heart failure

Non-invasive ventilation (NIV) is used nowadays in many settings, starting from its proven effectiveness in some common clinical conditions in critical care as cardiogenic pulmonary oedema (CPE), COPD exacerbations, ventilatory support for patients with ventilatory

pump failure, and to prevent extubation failure. NIV means delivery of non-invasive intermittent positive pressure ventilation or application of continuous positive airway pressure through a nasal or face mask. The best known NIV therapies used in HF are continuous positive airway pressure (CPAP), where a constant pressure is administered during inspiration and expiration, and bi-level positive airway pressure (BiPAP), with application of both positive inspiratory and expiratory pressures [5].

NIV complements physical training, the main resource of cardiac rehabilitation for patients with limited functional capacity. CPAP may improve cardiac and respiratory performances in HF patients by increasing functional residual capacity, opening collapsed and under ventilated alveoli, thus decreasing right-to-left intrapulmonary shunt, improving oxygenation and lung compliance, with clear benefits in functional capacity [3,4]. CPAP has shown to decrease mortality, length of stay, hospital costs and prevent readmissions in HF [7].

An important issue to study furtherly is the ideal positive pressure to promote increased exercise tolerance. There are some authors advocating a CPAP value of 10 cm H_2O, because it promotes alveolar recruitment and effective gas exchange. A lower value, namely 6 cm H_2O or the best tolerated value by the patient, would produce a significant improvement in cardiac output. Lower pressure levels seem to promote favourable effects on exercise tolerance, have a beneficial effect in the distance travelled during 6MWT, and avoid discomfort that often leads to a lack of adherence to treatment [5].

The use of bilevel NIV as an adjunct strategy to physical exercises in hospitalized patients with decompensated HF has showed that intervention was effective in increasing exercise tolerance compared to sham ventilation with CPAP [8]; patients were assessed through an exercise test with constant load with bilevel NIV. Early exercise with cycle ergometer was implemented in critically ill patients, resulting an improvement in exercise capacity and muscle strength at hospital discharge. It seems that the use of BiPAP augments the effects of training programme as intensity and duration of exercise by unloading respiratory muscles, relieving cardiac stress and improving cardiac function [8].

Inspiratory pressure support (PS) unloads ventilatory muscles, with reduced exertional leg discomfort and increased exercise endurance in patients with stable advanced CHF [6]. The addition of pressure support (5 cm H_2O) predictably reduces the transmural pressure gradient and increase LV afterload, with improved peripheral blood flow to the legs, increased nutrient supply to the exercising muscles, and enhanced clearance of carbon dioxide (CO_2) and waste metabolites, with consecutive improvement in acid-basic status [6].

Adaptive servo-ventilation (ASV) failed to improve left ventricular ejection fraction (LVEF) in HF cases with OSA, though New York Heart Association (NYHA) class and activities of daily living improved significantly in the ASV group. However, all-cause mortality and cardiovascular mortality were higher in the ASV group. The device producer currently advises that ASV is contraindicated in patients with symptomatic chronic HF (NYHA ≥ II, with LVEF ≤ 45%), and predominant moderate to severe OSA [9].

Effects of NIV in heart failure

CPAP can improve cardiac function in patients with congestive heart failure (CHF) through hemodynamic, ventilatory and peripheral muscle effects [5,8].

Hemodynamic effects of NIV in HF

The main effect is increasing in intrathoracic pressure, with decreasing the large variations in pleural pressure [5], thereby reducing cardiac preload by impeding cardiac filling, and afterload, by reducing left ventricular transmural pressure (LVP_{tm}) [10]. CPAP also decreases the peripheral vascular resistance and contributes to reducing the left ventricle (LV) post-load [5]. The use of NIV increases LVEF by improving the contractile performance of the heart and reduces myocardial oxygen consumption associated with production of carbon dioxide [4,5], decreases mitral regurgitation fraction and cardiac sympathetic nervous activity [4]. All these effects may decrease the resting heart rate (HR) and systolic blood pressure, although perfusion of peripheral tissue is high, due to a greater cardiocirculatory efficiency [5,10]. Thus, CPAP administered via a face or nasal mask can acutely improve cardiac output in patients with poorly compensated CHF [10] and promotes improvement in the autonomic modulation of HR in patients with chronic HF [5].

In a study conducted by Naughton., *et al.* [10] have been used some parameters to assess the effects of CPAP in CHF. Intrathoracic pressure was estimated from oesophageal pressure (P_{es}), while systolic left ventricular transmural pressure (LVP_{tm}), a determinant of LV afterload, was assessed by subtracting P_{es} during systole from systolic blood pressure; cardiac index (CI) was assessed by cardiac echocardiography. The study showed that the amplitude of inspiratory P_{es} swings in CHF patients was greater than in healthy subjects. The more negative P_{es} in CHF patients, the greater influence over systolic LVP_{tm} comparing to healthy subjects. Moreover, unlike in healthy subjects, increasing levels of CPAP in CHF cases were associated with progressive decrease in P_{es} amplitude, peak inspiratory and systolic LVP_{tm}, without any change in CI. Thereby, CPAP unloads LV and inspiratory muscles of CHF patients without compromising CI [10].

Changes in P_{es} provide a reasonable estimate of changes in intrathoracic and systolic pericardial pressures; P_{es} amplitude provides a good index of the degree of inspiratory muscle force generation and energy expenditure per breath. Reductions in P_{es} amplitude and P_{es} amplitude x respiratory rate indicate that CPAP succeeded to unload inspiratory muscles, thus reducing their energy demand [10]. In CHF patients, CPAP has reduced P_{es} amplitude x respiratory rate, and another index, LVP_{tm} x heart rate, that shows myocardial systolic force generation and oxygen consumption over time. Thus, by reducing myocardial and inspiratory muscle energy demand, CPAP allowed redistribution of blood flow to other organs, to better match their energy requirements. Reduction in heart rate in the group with CHF could potentially improve subendocardial perfusion and allow for better LV diastolic filling. Therefore, CPAP can improve cardiorespiratory efficiency in patients with CHF, even in the absence of any increase in CI [10].

Negative intrathoracic pressure contributes to LV afterload by increasing LVP_{tm}. In HF, heart is very sensitive to changes in afterload, with more influence over hemodynamic induced by marked negative intrathoracic pressures. CPAP generated consistent dose-related reductions in peak inspiratory and systolic LVP_{tm} in CHF patients by increase in peak and systolic P_{es}. These effects of CPAP in CHF patients were observed in addition to afterload reduction by pharmacological agents. Reductions in LVP_{tm} secondary to CPAP resulted mainly from increase in P_{es} rather than decrease in systolic blood pressure [10].

Normally, there is a beat-by-beat variation in heart rate derived from fluctuations in parasympathetic and sympathetic nervous system input to the sinoatrial node. In congestive HF there is an impairment of modulation of heart rate arising from alterations in both harmonic (parasympathetic and sympathetic nervous system) and nonharmonic components of total spectral power [11]. Reduced heart rate variability in congestive HF would be attributed to diminished parasympathetic input, decreased beta-adrenoreceptor in responsiveness to neurally released or circulating norepinephrine and augmented non-oscillatory cardiac adrenergic drive [11]. Low heart rate variability in both time and frequency domain has been associated with increased mortality and a greater risk of sudden death. Short-term application of nasal CPAP (10 cm of H_2O) may improve the altered neural control of heart rate and cardiac function in CHF through increasing time and frequency domain indexes of parasympathetic activity, and the nonharmonic components of the heart rate variability signal [11]. CPAP use in CHF with elevated pulmonary capillary wedge pressure generates a reduction in preload and afterload, an increase in stroke volume and cardiac output, and a significant reduction in heart rate [11].

Recent studies have suggested partial reversal of LV diastolic dysfunction after CPAP therapy through improved myocardial oxygenation, diminished LV pressure overload and sympathetic activation [12]. In patients with severe obstructive sleep apnoea (OSA), 3-month of CPAP therapy, at least 4 h per night, ≥ 6 nights per week, improved LV diastolic function, arterial stiffness and ventricular-vascular coupling. The pulse wave velocity, 24-h mean diastolic blood pressure (BP), night-time diastolic BP, arterial elastance index and ventricular-vascular coupling decreased significantly in the CPAP treated patients [12]. OSA contributes to the development of LV diastolic dysfunction and consecutively HF, even in patients with preserved ejection fraction; LV systolic and diastolic stiffness are recognized as key contributors to the pathophysiology of HF with preserved EF [12].

Respiratory effects of NIV in HF

NIV improves parameters of pulmonary function by increasing pulmonary compliance, improving gas exchange, ventilation/perfusion ratio and oxygenation, reducing pulmonary oedema [4], ventilatory work and airflow limitation by decreasing airway resistance in

patients with HF [3,5]. All these effects will enable exercise to be performed more effectively, with reduced fatigue. CPAP progressively increased FVC and FEV1 in HF patients [3,4], probably due to increase in functional residual capacity and opening of collapsed alveoli [3].

Peripheral muscle effects of NIV in HF

NIV with inspiratory pressure support reduces discomfort in lower limbs and increases exercise resistance. It seems that pressure support may improve exercise time through improve in peripheral perfusion and muscle oxygenation by enhancing cardiac output and/or by altering regional vascular distribution [5]. Smaller quantities of lactate after 6MWT have also been attributed to the use of CPAP in HF patients; NIV seems to attenuate the metaboreflex [3]. NIV may reduce respiratory work and increase physical performance in HF patients through increasing microcirculation in peripheral muscles and enhancing local blood flow, and possibly by improving oxygenation through increasing transpulmonary pressure and facilitating alveolar ventilation [5].

CPAP use before 6MWT allows an increase in peak HR and distance travelled due to an improved chronotropic reserve, one of the mechanisms responsible for increased exercise capacity, along with increase in pulmonary function [5]. As result of an improved performance of cardiovascular and respiratory systems, these patients show a lower cardiac work when performing 6MWT and reduced dyspnoea post-test as assessed by the Borg scale [3,5].

NIV may act as a co-adjuvant therapy in the attempt to improve patients' physical capacity and decrease dyspnoea during exercise. As an adjunct strategy [8], NIV reduces respiratory work, improves blood oxygenation and lung compliance, with better cardiac and respiratory responses during exercise [13]. There is a direct benefit from regular physical training in HF patients by promoting a gradual improvement in exercise tolerance, increasing oxygen consumption and oxidative capacity of the skeletal muscles; blood flow to the respiratory muscles tends to rise significantly during exercise training due to redistribution of blood flow from the locomotor muscles [5].

In acute heart failure, lungs have more water, a reduced volume and compliance, and an increased airway resistance. CPAP, through positive end-expiratory pressure, may improve oxygenation by increasing end-expiratory volume, with recruitment of alveoli and redistribution of fluid, but cannot decrease lung water. By improving lung compliance and reducing the non-elastic power, CPAP reduces the work of breathing and decreases the arterial carbon dioxide tension; there is probably a reduction in threshold work (the work required to initiate a breath) too [14]. Cardiac performances may be improved through a reduction in LV afterload due to an increase in intrathoracic pressure [6,14]. In contrast to mechanical ventilation (MV), CPAP maintains respiratory efforts and minimizes the consequent reduction in venous return [14].

Cardiogenic pulmonary oedema is suggested by dyspnoea of sudden onset, typical findings on a chest radiography, and widespread rales, without a history of pulmonary aspiration of infection. It was proven since 1991 that CPAP delivered by face mask in patients with severe CPE can result in rapid improvement in respiratory rate, respiratory acidaemia and oxygenation, and reduce the need for intubation and MV [1,14]. NIV is associated with reduction in hospital mortality, it is not associated with increased myocardial infarction, and both modes, CPAP and BiPAP are recommended in patients with acute respiratory failure (ARF) due to CPE by the experts [1]. Decision to institute MV is based on the trend of arterial-blood gas values and the clinical status of the patients. MV is required by deteriorating clinical condition along with a rise in arterial carbon dioxide tension to more than 55 mmHg, or a fall in arterial oxygen tension to less than 70 mmHg during inspiration of 100 percent oxygen [14].

In properly chosen patients with cardiogenic shock, NIV can successfully replace invasive MV. Cardiogenic shock is a state of critical end-organ hypoperfusion due to reduced cardiac output, often resulting in multiorgan failure. NIV treated patients tended to be more congestive, higher PaO2 on admission being associated with better prognosis. Mechanically ventilated patients presented predominantly with hypoperfusion, more severe metabolic acidosis, higher lactate levels and greater need for vasoactive drugs [15]. Confusion, prior coronary artery bypass grafting, cardiogenic shock etiology, higher lactate level and lower baseline PaO_2 were independent predictors

of mortality; ventilatory strategy did not affect outcome. The group of European Respiratory Society experts [1] could not make a firm recommendation regarding the use of NIV for CPE in the pre-hospital setting due to heterogeneity of trials design, support personnel and patient selection.

NIV has some advantages when comparing to MV. It allows patients to communicate, eat, move at a certain extent, and breathe spontaneously. The risks of nosocomial infections, ventilator-associated pneumonia and injuries from intubation procedure are diminished. Administration of complete sedation with augmentation of shock-induced hypotension and loss of vasomotor tone can thus be avoided [15]. Still, persistence of tachycardia and severe acidosis during NIV treatment is associated with NIV failure and urgent need of MV. CPAP may be followed by possible side effects including nasal skin necrosis, gastric distension, pulmonary aspiration, barotrauma (if the valve of the mask becomes occluded), non-intended air-leaks and asphyxia (if the gas supply fails) [14].

Recommendations of NIV in COPD and HF

COPD is a condition with high mortality and morbidity rates worldwide; chronic hypercapnic respiratory failure is often seen in COPD end-stage, and treatment options become limited at this point [16], in part due to multiple comorbidities. Cardiovascular comorbidity is high in COPD patients due to systemic inflammation processes and to an extensive range of common risk factors, where smoking is the most prominent. Improvement in hypercapnia and hypoxemia might have a positive effect on cardiovascular comorbidity according to some studies showing a link between non-invasive positive pressure ventilation (NPPV) therapy and cardiovascular improvements [17].

Expiratory flow limitation and increased respiratory frequency may reduce expiratory time during training in patients with COPD, resulting in increased end-expiratory lung volume, a complex condition named dynamic hyperinflation. Inspiratory muscles are overloaded in COPD plus CHF, with greater elastic and resistive work of breathing. Moreover, these muscles might be functionally weakened, with increased ventilation during physical exercise in COPD patients. It was described a so-called respiratory muscle metaboreflex, starting with fatiguing contractions that would stimulate diaphragmatic thinly myelinated group III and unmyelinated group IV fibres, thereby increasing limb sympathetic outflow and vascular resistance. Muscle metaboreflex would than redirect blood flow from locomotor muscles to respiratory muscles to postpone and even to avoid the failure of the "vital pump". It was shown improved peripheral muscle delivery after respiratory muscle unloading (under stable cardiac output and arterial oxygen content) in CHF-free COPD and in COPD-free CHF. It is therefore supposed that respiratory muscle metaboreflex in potentiate in COPD patients with coexistence of CHF [18].

Effective NPPV was proven to reduce chronic hypercapnia and to improve survival in stable hypercapnic COPD patients. NIV is more effective in preventing endotracheal intubation in hypercapnic acute respiratory failure (ARF) due to COPD than in non-COPD conditions. Reductions in arterial carbon dioxide pressure (PaCO2) during NPPV were associated with decreases in pro-brain natriuretic peptide (proBNP) levels and in systemic inflammation level in COPD patients [17]. Hypercapnia may affect inflammatory processes; local and systemic inflammation are important in the pathogenesis of COPD. NPPV-induced reductions in $PaCO_2$ might have positive influence in the context through its anti-inflammatory effects. NPPV using high inspiratory positive airway pressure levels to significantly reduce $PaCO_2$ has been shown to induce a reduction in cardiac output; this finding need to be consider in cases with pre-existent cardiac diseases. Still, 3-month of NPPV was not associated with worsening in important cardiovascular biomarkers and therefore might be safely applied in COPD patients [17].

There are some direct effects on the cardiovascular system; 3-month of NPPV was associated with a significant reduction in proBNP levels. This finding suggests some direct positive effects of NPPV on cardiovascular hemodynamic and/or fluid homeostasis. Home NPPV decreases pulmonary artery systolic pressure in obesity hypoventilation syndrome and right ventricular overload. Consecutively, reduction in proBNP over time might be also due to direct improvements on the cardiovascular system. Moreover, it is possible that the vasodilating effect of CO_2 might be responsible for peripheral oedema in chronic hypercapnia. Reduction of proBNP with NPPV over time would reduce peripheral oedema, which might explain the correlation seen between decreases in proBNP and $PaCO_2$ in the study conducted by Dreher [17].

When comparing the cardiac and pulmonary effects of 6 weeks of low-intensity NIV (LI-NIV; respiratory rate ≤ 12 breaths/min) and 6 weeks of high-intensity NIV (HI-NIV; respiratory rate 20 - 22 breaths/min) in stable hypercapnic COPD patients, both modes have improved dyspnoea during physical activity, lung function and HRQoL [16,19]. No significant changes in blood pressure or rhythm disturbances were observed; both modes of ventilation improved FEV1 and tended to decrease respiratory muscle activity, and this effect was maintained while spontaneously breathing during the day. HI-NIV tended to be more effective in improving gas exchange and spontaneous diurnal blood gases [16,19].

In general, cardiac output and NTproBNP did not changed, although they have been some variations in individual effects depending on the pressure applied and/or the co-existence of heart failure. It was detected a trend towards reduction in work of breathing and NT-proBNP after 6 weeks of NIV. In patients with pre-existing HF, application of very high inspiratory pressures might reduce cardiac output; a worse dynamic hyperinflation during HI-NIV may increase pulmonary vascular resistance and the risk of patient-ventilator asynchrony (wasted efforts), barotrauma and cardiovascular interferences [19]. Overall, LI-NIV seems to be more beneficial or less harmful compared to HI-NIV in these patients, as it maintains negative pleural pressure during inspiration, which is transmitted to the right atrium. In HI-NVVP, there is a positive swing in plural pressure during inspiration, leading to a higher right atrial pressure, decreased venous return, and a decreased atrial preload [19].

Decreasing the patient's inspiratory time and increasing the respiratory flow with HI-NPPV has been shown to reduce the effort of the diaphragm in COPD patients, up to diaphragm atrophy due to complete rest. However, the risk appears to be minimal considering that respiratory muscles of patients with severe COPD seem to be resistant to fatigue compared with normal subjects, and patients using HI-NPPV are still breathing spontaneously most of the time, which should minimise atrophy [19].

There is no reason to prevent HI-NIV use in COPD patients due to concerns of adverse cardiac outcomes like lowering in cardiac output and oxygen transport; HI-NPPV in stable patients is more effective than LI-NPPV at acutely improving gas exchange and reducing the patient's respiratory effort [19]. Still, patients with HF comorbidity will be treated with caution and cardiac function will be checked regularly [16,19].

Conclusions

It is largely accepted nowadays that among cardiovascular risk factors there is a consistent group acting on respiratory system as well. In selected cases, it might be difficult to establish who was the first, the cardiac or the respiratory condition. As they are in a well-recognized anatomical and functional proximity, the sufferance of one system will soon or later reflect on the other one through complex mechanisms. Having a clear diagnosis, therapy and strategy for advanced stages is frequently challenging. NIV is a valuable intervention for COPD cases associated with chronic heart failure cases through hemodynamic, ventilatory and peripheral muscle effects.

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Volume 7 Issue 6 June 2018