Noninvasive Positive Pressure Ventilation for Treatment of Acute Respiratory Failure in Immunocompromised Patient

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Introduction

The rate of patient admissions with immunosuppression to the intensive care unit (ICU) is increasing because transplantation of human organs and tissues is becoming a more common component of health care (WHO, 2003). In the past, patients with respiratory failure were treated with endotracheal intubation and conventional mechanical ventilation. Motivation for implementing noninvasive positive pressure ventilation (NIPPV) for this type of patient is stronger, in view of the poor prognosis when invasive mechanical ventilation is required.

Over the last 20 years we have witnessed a rise in the use of NIPPV in the treatment of acute respiratory failure (ARF). Meduri and colleagues were among the first to describe the use of mask ventilation to avoid endotracheal intubation (Meduri, Conoscenti, Menashe, & Nair, 1989). The literature on NIPPV has progressed from case series to randomized controlled trials covering different patient populations, interventions, and many possible options to prevent treatment failure.

This capstone project will help clinicians gain cognitive knowledge regarding the topic and help them provide optimum care for selected immunosuppressed patients with ARF. Clinicians will be able to deliver appropriate interventions that promote health and wellness for the client.

Case Presentation

Ms. C.C. is a 38-year-old female who was brought to the medical intensive care unit (MICU) from the emergency department (ED) with progressively worsening dyspnea. Her history included focal segmental glomerulosclerosis (FSGS) complicated by end-stage renal disease (ESRD), two renal transplants (1991, 2011), a recent antibody-mediated rejection of a second kidney, hypertension (HTN), hyperlipidemia (HL), and pneumonia four months prior to admission.

She was being administered immunosuppressive medications (prednisone and tacrolimus), metoprolol, nifedipine for her HTN, simvastatin for HL, and aranesp for anemia which is an erythropoiesis stimulating hormone associated with chronic renal failure and dialysis.

One week before her emergency department (ED) admission, Ms. C.C. noted shortness of breath, which was gradually getting worse. Over time she developed fatigue, worsening bilateral lower extremities edema, orthopnea, and a productive cough with a yellow, frothy sputum. When the patient arrived at the ED, her saturation was in the low 70's. This improved to 91% when 2 liters of nasal cannula (NC) were applied. Physical examination showed a body temperature of 36.8°C, respiratory rate (RR)of 26 breaths per minute (breaths/min), heart rate (HR) 102 beats per minute (bpm), and blood pressure of 149/77 mmHg. Arterial blood gas (ABG) analysis revealed pH 7.37, $PaCO_2$ 36mmHg, PaO_2 56mmHg, and SaO_2 93%. The laboratory results revealed a white blood cell (WBC) count of 14.2K/uL, creatinine (Cr) level of 4.6 mg/dL (baseline Cr 4.5 $\pm$ 0.5 mg/dL). Plain film chest x-ray (CXR) revealed bibasilar opacities and a right middle lobe lung infiltrate.

On the following day, the patient reported a marked increase in breathlessness with a RR of 30 breaths/min. Ms. CC refused to be stuck for an ABG test. As an alternative, a venous blood gas (VBG) was collected from the left internal jugular hemodialysis catheter. VBG is an alternative method of estimating systemic carbon dioxide and pH that does not require arterial blood sampling. The inability of a VBG to measure oxygenation is the major drawback when compared with an ABG. This is why there are no venous to arterial conversions for the central venous, mixed venous, or peripheral venous PvO_2 or SvO_2. Central venous pH is usually 0.03 to 0.05 pH units lower than the arterial pH and the PCO_2 is usually 4 to 5 mmHg higher, with little or no increase in serum HCO_3 (Malinoski et al., 2005).

Before application of NIPPV, the patient's VBG demonstrated pH 7.23, PCO_2 41mmHg, and HCO_3 17.2mm/L (Table 1).

Table 1

Venous blood gas measurements	**Normal range**	**Patient's value**
pH	7.33-7.43	7.23
pCO2 (partial pressure of carbon dioxide)	40-50 mmHg	41
pO2 (partial pressure of oxygen)	30-50 mmHg	39
HCO3-(bicarbonate)	22-29 mm/L	17.2
Base Excess	No range found	Minus 10
SO2 (oxygen saturation)	60-80%	73.1%

***Source:* Patient's EMR**

The patient was placed on a bi-level positive airway pressure (BiPAP) ventilation machine and transferred to the medical intensive care unit.

Physical exam on arrival in MICU was notable for the high RR 35 breaths/min, and increased work of breathing. Her vital signs were: temperature 36.5C, blood pressure 118/63, heart rate 98 beats/min, SpO_2 93%. Her weight was 93 kg, height 155 cm.

In addition to the earlier mentioned past medical history, Ms. C.C. had pancreatitis in her 20's, peritoneal dialysis (PD), hemodialysis (HD), polyomavirus hominis, better known as BK virus (BKV), which is the most frequent pathogenic agent of polyomavirus nephropathy (BKVN) in kidney transplant patients (Harza et al., 2014), plasmapheresis, deep venous thrombosis (DVT), seborrheic keratosis, gastroesophageal reflux disease (GERD), anemia, two renal transplant surgeries, and reduction mammoplasty. Her family history includes arthritis, coronary artery disease (mother); diabetes type 2 (father, mother, and sister); hypertension (father and mother); stroke (sister, when 45-years-old). She is allergic to the following medications: escitalopram, muromonab-CD3, and vancomycin. Patient stated that she never smoked, or used alcohol, or street drugs. Ms. C.C. lives alone on social security disability benefits.

Neurologically: the patient was awake and alert, although tired and unable to complete full sentences. For that reason we couldn't obtain a full review of systems. Pulmonary: she was having shortness of breath, increased work of breathing, and orthopnea. The patient noticed that these symptoms improved after non-invasive positive pressure ventilation (NIPPV) was applied. Auscultation of her heart and lungs showed normal heart sounds without pathological murmurs. Decreased breath sounds in lung bases with bilateral crackles were heard more on the right side than on the left. Abdomen exam was negative. Good urine output and peripheral + 2 pitting edema in lower extremities from toes to the knees. Repeated CXR demonstrated findings consistent with acute respiratory distress syndrome (ARDS) or pulmonary edema picture.

Our initial treatment plan for C.C. included continuing empirical antibiotic therapy for community-acquired pneumonia which was started in the ED (Ceftriaxone, Azithromycin). Based on hospital policy, infectious disease guidelines, and the patient's clinical presentation, antibiotics were changed based on the algorithm for ICU patients with a high risk for pseudomonas infection. Patient received linezolid, cefepime, and doxycycline on admission to MICU which were adjusted later in her hospital stay.

In the ED, the patient received a first dose of 40mg Lasix intravenously (IV) for diuresis. We decided to continue her on Lasix 80-120 mg IV BID with Diuril 500mg IV daily to augment diuresis. Despite that, urine output was low and HD needed to be performed daily to relieve fluid overload and acidosis. In the treatment of ARDS, the patient was net 2-3 L negative fluid balance every day. At the end of her stay in the MICU, the patient was dialyzed with a net total removal of 12 L.

Considering Ms. C.C.'s respiratory failure, we placed her on a BiPAP face mask ventilation machine with the following settings: fraction of inspired oxygen (FiO2) 40%, inspiratory positive airway pressure (IPAP) 10cm H_2O, and expiratory positive airway pressure (EPAP) 5cm H_2O. Patient was borderline hypoxic with oxygen saturations in the low 90's. Later that day, Ms. C.C. was enrolled in the research study and placed on NIPPV by helmet. The purpose of this study is to evaluate the efficacy of helmet ventilation when compared with face-mask ventilation in patients with acute hypoxemic respiratory failure. The study includes assessments of oxygenation and/or ventilation, the need for intubation, and rates of ICU complications.

Ms. C.C.'s saturations where in the high 80's when NIPPV via helmet was applied. Initially, the ventilatory parameters were set as follows: FiO_2, 70%; positive end-expiratory pressure (PEEP) 7cm H_2O; pressure support 5cm H_2O. In the first few hours of helmet NIPPV, we observed a de-synchronization between the patient and the ventilator. We proceeded to increase pressure support and modified PEEP to better support the patient's inspiratory effort and oxygenation. With these settings, the respiratory parameters stabilized, and de-synchronization between patient and ventilator decreased.

During the two days following, the pressure support values were, respectively, 10cm H_2O, and PEEP values were min. 7 and max. 18 cm H_2O. The high PEEP settings where applied when the patient had pronounced accessory muscle use with labored breathing, RR in the high 30’s and 40’s breaths/min and saturations in the low 90’s. In addition to NIPPV, nebulizer treatments of albuterol-ipratropium and hypertonic sodium chloride were administered to improve air movement and reduce inspiration and expiratory wheezes.

On the third day, the MICU service was able to wean down the PEEP from 18 to 5cm H_2O, and FiO_2 from 80% to 40%. The helmet was removed, and the patient was placed on a non-rebreather face mask (NRB FM). Ms. C.C. tolerated it well, without any increased work in breathing or evidence of excessive desaturation levels. Her VBG improved: pH 7.4, PCO_2 45 mmHg (Table 2).

Table 2

Venous blood gas measurements	**Normal range**	**Patient's value**
pH	7.33-7.43	7.40
pCO2 (partial pressure of carbon dioxide)	40-50 mmHg	45
pO2 (partial pressure of oxygen)	30-50 mmHg	36
HCO3-(bicarbonate)	22-29 mm/L	27.9
Base Excess	No range found	Minus 2.8
SO2 (oxygen saturation)	60-80%	78%

***Source:* Patient's EMR**

Of note, when the patient was transferred to the regular floor, she was stable on 4L NC while awake and on BiPAP during the night. Her urine output didn't improve after a trial diuresis with 120 mg IV Lasix; she will need HD for now. Her antibiotic course was continued in order to cover for possible staphylococcal pneumonia. To prevent allograft rejection, the immunosuppressive agent, tacrolimus (Prograf), was restarted. Unfortunately, due to a life-threatening infection, adequate levels of immunosuppression to dampen the immune response were not maintained and the patient is at high risk for rejection and loss of the renal allograft.

Intervention Goals and Outcomes

The first intervention for Ms. C.C. in MICU included the use of NIPPV to reduce the work of breathing, while improving oxygenation, respiratory rate, and gas exchange without the use of an endotracheal tube (ETT). The second intervention was to keep a negative fluid balance in order to reduce pulmonary edema. The third intervention was a pharmacological approach to treat a life threatening infection. The last intervention included keeping the patient safe by maintaining a structured environment and support.

The primary rationale for the use of NIPPV was to decrease the work of breathing and improve respiratory mechanics. In acute pulmonary edema the main beneficial effect of NIPPV is improvement of gas exchange and the reduction of preload and afterload, which improved the cardiac performance. Ms. C.C. was a good candidate for NIPPV because she was awake, breathing spontaneously, and could protect her airway. Although the face mask is the most common interface used to deliver NIPPV, it may also be responsible for a certain proportion of NIPPV failures. Complications contributing to mask intolerance for Ms. C.C. were increased respiratory rate, pulse oximeter desaturation, and the loss of seal integrity when higher PEEP pressures were required. NIPPV via a nasal- or full-face mask typically begins to show air leaks when the required pressure exceeds 15-20cm H_2O. In an attempt to improve patient tolerance while delivering higher pressures, a transparent helmet was applied.

The ‘helmet’ is a hood made of clear, latex-free plastic that covers the patient’s entire head. It has a sealed connection and a soft collar that adheres to the neck. The collar ring is secured by two armpit braces and has two ports, one for inspiratory and another for the expiratory flow of gases to a mechanical ventilator (Figure 1). It is supposed to limit the pressure on the skin, preventing necrosis, air leaks, and discomfort. The helmet allowed Ms. C.C. to speak, to cough, and to have full view of her surroundings. She was able to maintain it continuously for a longer period of time than would have been possible with a face mask.

Figure 1. Helmet for non-invasive ventilation. (Nava & Hill, 2009)

Evaluation of the clinical response to the initiation of NIPPV is critical to the successful implementation of this therapy. Based on clinical research studies' reviews, patients who are ventilated by helmet are expected to experience an improvement in oxygen saturation, serum pH, reduced respiratory rate, and heart rate (Esquinas et al., 2013). However, the helmet has a larger internal volume which might facilitate carbon dioxide (CO_2) rebreathing. In a cohort study, Antonelli and et al. observed that patients in the helmet group had a lower decrease in $PaCO_2$ when compared to the face mask group (Antonelli et al., 2004).

Ms. C.C. was monitored closely in MICU. We observed that the patient's HR dropped from 90's-100's to high 80's in the first hours after applying the helmet. Her saturation improved and her RR decreased over time. Her blood gases improved as well. Patient's ABG while she is on BiPAP face mask is shown in Table 3.

Table 3

Arterial blood gas measurements	**Normal range**	**Patient's value**
pH	7.35-7.45	7.23
pCO2 (partial pressure of carbon dioxide)	34-46 mmHg	37
pO2 (partial pressure of oxygen)	80-100 mmHg	43
HCO3-(bicarbonate)	22-29 mm/L	15.5
Base Excess	No range found	Minus 11
SO2 (oxygen saturation)	90-98%	82.4%
Source: **Patient's EMR**		

After 14 hours on NIPPV by helmet patient's VBG is shown in Table 4.

Table 4

Venous blood gas measurements	**Normal range**	**Patient's value**
pH	7.33-7.43	7.29
pCO2 (partial pressure of carbon dioxide)	40-50 mmHg	49
pO2 (partial pressure of oxygen)	30-50 mmHg	35
HCO3-(bicarbonate)	22-29 mm/L	23.6
Base Excess	No range found	Minus 3
SO2 (oxygen saturation)	60-80%	63.9%
Source: **Patient's EMR**		

Patient's VBG after 40 hours of use of NIPPV is shown in Table 5.

Table 5

Venous blood gas measurements	**Normal range**	**Patient's value**
pH	7.33-7.43	7.40
pCO2 (partial pressure of carbon dioxide)	40-50 mmHg	45
pO2 (partial pressure of oxygen)	30-50 mmHg	36
HCO3-(bicarbonate)	22-29 mm/L	27.9
Base Excess	No range found	Minus 2.8
SO2 (oxygen saturation)	60-80%	78%

Source: **Patient's EMR**

The most critical time for the patient was the second day on NIPPV. Ms. C.C. was on the highest settings of FiO_2 (80%) and PEEP (18 cm H_2O) for 14 hours. Thankfully, the patient was weaned from NIPPV after 24 hours and remained stable on NRB-FM.

With worsening renal failure, Ms. C.C. developed metabolic acidosis and pulmonary edema from fluid overload. A positive fluid balance, caused by a third spacing, is associated with impaired organ function and worse outcomes for ARDS patients (Sakr, 2005). Conversely, achieving negative fluid balance improves survival and lung function (Wiedemann et al., 2006). The resolution of pulmonary edema is essential for lung recovery, because it reduces an air space inflammation process and improves restoration of a functioning alveolar-capillary membrane (Craig et al., 2010).

Our second intervention for Ms. C.C. was fluid removal with aggressive diuresis using Lasix and daily hemodialysis. By achieving net zero or negative fluid balance we expected to see improvements in the patient's lung function and a shorter duration of mechanical ventilation (Roch, Guervilly, & Papazian, 2011). The patient's clinical condition has dramatically improved after becoming net negative 6 L after her second hemodialysis, in addition to the broad spectrum antimicrobial therapy and helmet NIPPV. While in the MICU, the patient was dialyzed with a total removal of 12 L in five days.

Pneumonia is an infectious disease and its survival is associated with correct antibiotic therapy and many other supportive measures not discussed in this paper. Antibiotic therapy was given to Ms. C.C. on an empirical basis for community-acquired pneumonia in the ED and the patient was briefly started on ceftriaxone and azithromycin. She was followed by the infectious disease team during this hospitalization daily. The antibiotic therapy select was based on her history of vancomycin allergy and out of concern for QT prolongation. The patient in MICU received linezolid, cefepime, and doxycycline. This was changed to azithromycin for broad coverage after subsequent electrocardiograms (EKG's) demonstrated normal QT intervals. One dose of Voriconazole was given for suspected fungal infection. Later that day, it was stopped due to the patient’s clinical improvement prior to becoming therapeutic on antifungal therapy. In addition, we stopped azithromycin due to negative culture results and to prevent QT interval prolongation. We continued the linezolid and cefepime course to cover for possible *Staphylococcus aureus* pneumonia, given CXR findings concerning cavitary lesions. In general, antibiotic changes were made based on the patient’s clinical presentation, diagnostic test results, hospital protocols and infection disease team recommendations.

The last intervention was to maintain a structured and safe environment for Ms. C.C. Non-invasive ventilation implemented as an alternative to intubation was provided in ICU. The presence of trained personnel familiar with successful strategies when initiating NIPPV via helmet facilitated the patient’s tolerance to treatment. ICU staff with greater experience in this technique where prepared to intubate promptly if the goals of the intervention were not met (i.e., haemodynamic stability, adequate oxygenation, good cooperation). Research studies showed delaying intubation of these patients' runs the risk of unanticipated respiratory or cardiac arrest with attendant morbidity and mortality.

Current Research

There are a few research studies investigating the mortality rates of immunocompromised patients with respiratory failure who require mechanical ventilation.

Over a 19-month period, Hilbert et al. studied the use of NIPPV in 52 immunosuppressed patients, ages 34 and older. They demonstrated an association between the use of noninvasive ventilation and a reduction in ETT placement, or other serious complications, and an increased chance of survival during the hospital stay. Serious complications and events leading to death included: severe sepsis or septic shock, cardiogenic shock, renal failure, hepatic failure, ventilator-associated pneumonia, sinusitis, and gastrointestinal bleeding. In this randomized study, they found that only 12 of the 26 patients in the NIPPV group (46 percent) required invasive mechanical ventilation, as compared with 20 of the 26 patients (77 percent) who received standard treatment without use of NIPPV (P=0.03). In addition, noninvasive ventilation resulted in a significantly lower rate of serious complications and a reduced mortality rate in the hospital (13 vs. 21 patients; P=0.02) (Hilbert, Gruson, & Vargas, 2001).

The study by Hilbert et al. included only seven patients who had organ transplantation in the past. Most of the patients in the study had hematologic cancers with neutropenia who would generally be expected to have a low rate of survival (Hilbert, Gruson, & Vargas, 2001).

In further research, a randomized trial by Antonelli et al. found significant differences in the rate of intubation in patients on NIPPV who underwent solid organ transplantation and who were treated for acute respiratory failure (20 percent, as compared with 70 percent in the control group)(Antonelli, Conti, & Bufi, 2000). The ICU mortality rate was lower for patients who received NIPPV, while the rates of death in the hospital did not differ significantly in the two groups (Antonelli, Conti, & Bufi, 2000). These findings, combined with those of Hilbert et al., suggested consideration of NIPPV as a ventilatory mode for select immunocompromised patients with respiratory failure.

Neither of these studies focused on patients diagnosed with ARDS. In the following prospective survey, completed by Antonelli et al., the research team agreed that the mortality rate for patients on NIPPV was lower among the 147 ARDS patients. They also identified that patients on noninvasive ventilation with ARDS failed to improve gas exchange (around 50%) (Antonelli et al., 2007). However, patients who achieved a PaO_2/FiO_2 of 175 or higher within one hour of NIPPV use had a lower risk of intubation (59% vs. 39%) (Antonelli et al., 2007). In the same study, a high mortality rate (54%) was observed in patients who were intubated after failing NIPPV (Antonelli et al., 2007). Possible contributors to the high mortality rate for these patients were sepsis, septic shock and the progression of multiple organ failure. This raises the concern that postponing intubation by 12-72 hours could have contributed to their mortality. Unfortunately, it is not possible to conclude whether the lower mortality rate (19%) among patients who succeeded with NIPPV is due to the positive effect of noninvasive ventilation or because they were less sick (Antonelli et al.,2007). Overall, the risk-benefit ratio of NIPPV is still not defined in ARDS and current evidence does not support the routine use of NIPPV in these patients (Antonelli et al.,2007).

In the same study, Antonelli et al. mentioned that 30% of patients received NIPPV via helmet. More recently, a helmet has been introduced to deliver NIPPV, reducing discomfort, pressure necrosis of the skin, eye irritation and gastric distension. The helmet was well tolerated by ARDS patients and was used for an extended period in the continuous application of NIPPV. Patients tolerated this treatment for more than 72 hours, with a median duration period of 42 hours. (Antonelli et al., 2007). For patients with acute hypoxemic respiratory failure and cardio genic pulmonary edema, few studies showed NIPPV via helmet or face mask had similar gas exchange improvement, but the helmet was more comfortable and allowed longer continuous application (Antonelli et al., 2002), (Tonnelier et al., 2003). Even with some downsides such as asynchrony and the noise inside the gear, the helmet is tolerated better by most patients on NIPPV.

Theoretical Model

Peplau’s Theory of Interpersonal Relations emphasizes the importance of the nurse-patient relationship, focusing on interactions between nurses and patients rather than nurses observing or doing things for patients. This theory can be used by practitioners in ICU to guide and improve their relationships with patients as they learn to manage their pain, anxiety, fatigue and etc.

The relationship is explained as an interpersonal process which has a starting point, continues through phases and is time limited with an end point (Cody, 2011). The nursing model identifies four interpersonal relationship phases, including: orientation, identification, exploitation, and resolution. Each phase overlaps the other in relation to health problems as the nurse and patient work together to understand the meaning of the problem and work towards resolving difficulties (Cody, 2011).

The orientation phase begins when the appropriate professional clinician and patient come together and the patient starts to recognize and understand his/her problems and need for help. Seeking help is often the first step in the learning experience prior to personal-social growth (Cody, 2011). Improvement in the patient's ability to control symptoms is only possible when there are no barriers to assessing and relieving them. Patient barriers include reluctance to report the problem, concern that reporting a problem will distract the practitioner from treating the underlying disease, fear that symptoms mean worsening disease, concerns about the side effects of pharmaceutical interventions (Fletcher, Knight , & Stewart-Brown, 2001).

During the identification phase, the clinician acts as a teacher, resource, and counselor who can help the patient move on to the exploitation phase. Identification with a clinician who takes the role of a helping person, and who provides unconditional care is a way of meeting patients' needs and overwhelming problems. In this phase, patients start to recognize the areas affecting their quality of life (e.g., pain, anxiety, depression, lack of sleep, decreased cognitive function, and etc.) and work with the clinician who acts as a leader to progress towards resolution (Cody, 2011). This is the time when the identification phase starts to overlap with exploitation phase.

The exploitation phase uses professional assistance for problem solving alternatives. The patient views him/herself as a central part of the helping environment and actively pursues information from those who can help. The patient may start making minor requests, and develop and achieve new goals (Cody, 2011). This is the opportune time to implement the nursing plan, take action toward meeting goals and progress toward the final phase.

The final phase is the resolution phase and can only occur when the other phases have been met (Peplau, 1997). In this phase, the patient's needs have been met through the collaboration of patient and clinician. The practitioner encourages the patient to be independent and to move from the current situation to return to community life. The end point is the termination of the relationship between patient and clinician.

According to Peplau, nursing is a significant, therapeutic, interpersonal process that involves problem-solving. In the interpersonal relationship phases, the nurse undertakes much of the work when he/she interacts with the patient and reveals the kind of person the nurse becomes. This makes a substantial difference in what the patient will learn while receiving nursing care.

Comprehensive Treatment Plan

Therapeutic goals for patients with ARF should focus on supportive treatment and relieving symptoms. Also, because ARF is a very complex illness, it needs to be managed in a multifactorial, holistic way. In this section we will present the management of the patient’s condition as well as the actual management given to the patient during his hospital stay

In addition to ventilator measures, hemodialysis, and IV antibiotic treatment, Ms. C.C. received unfractionated heparin (5,000 units subcutaneously three times per day) to prevent venous thromboembolism. She also was on stress ulcer prophylaxis with an agent such as esomeprazole (Nexium 40 mg IV daily).

Other medications included bronchodilators (to relieve bronchospasm) and hypertonic 7% sodium chloride (to decrease the thickness of mucus in the airways). In addition to aerosol therapy, chest physiotherapy was performed to enhance the clearance of mucus from the airway. The use of deep breathing techniques helped the patient to expectorate and stimulate a cough.

The patient also received a stress dose of 125mg methylprednisolone to reduce airway inflammation. The use of corticosteroids for ARDS patients is controversial, however, some clinical trials showed positive results and beneficial effects of corticosteroids on ARDS pathophysiology (Peter et al., 2008).

For nutritional support, Ms. C.C. received a liquid renal diet with supplements. From research studies we know that malnutrition is present in up to 40% of ICU patients and is associated with increased mortality (Giner, Laviano, Meguid & Gleason, 1996). Meta-analysis of randomized trials showed an improved mortality rate and decreased infectious complications with early (<24 or 48 hours) enteral nutrition when compared to delayed (either enteral or parenteral) feeding (Marik & Zaloga, 2004). Regardless of all the good benefits of enteral feeding and the extensive use of nutritional support, we still can find much disagreement and differences in practice over what, when, and how to feed critically ill patients.

In addition to all the treatments, it is very important for hospital personnel to alleviate anxiety for ARF patients' and provide reassurance to them every time they are assessing the patient or providing subsequent care. Communication skills, such as asking closed questions during assessment, may be used if patients are breathless to a point where they cannot answer in full sentences. Another simple technique that can be used to control the patient's anxiety is a change in the body position because it may reduce symptoms by maximizing lung expansion. Ms. C.C. was worried and anxious as a result of dyspnea. One of the benefits of NIPPV is that the patient is able to talk and can advise the staff about the position in which he/she feels some relief.

In instances with patients suffering pain, relief should be delivered as soon as possible and future pain control optimized. Professional advice may be necessary because of the respiratory depressant effects of some analgesics. Ms. C.C. was taking hydrocodone-acetaminophen or fentanyl 12.5 mcg IV push for neck pain and sleep as needed.

Clinicians should make all reasonable attempts to minimize oxygen consumption (Smyth, 2005). This can be achieved by minimizing patient exertion. Patients should be assisted with the ordinary activities of daily living (e.g., meeting hygiene needs) and all essential tasks, such as sputum suction, drinks and nurse call light, Patients should be encouraged to participate in mobilization therapy. This therapy has been associated with shorter use of the ventilator and hospital time in the ICU for patients with ARF (Schweickert et al., 2009). Clinicians should understand that patients will require time to 'catch their breath' during and/or after exertion, so activities should be planned with this in mind. For sleep disturbances, which are extremely common in critically ill patients, we should control noise and light exposure during the night. Van Dongen et al. shows that consistently sleeping for more than nine hours or fewer than eight hours a day has a negative impact on physiological, psychological and cognitive functions (Van Dongen et al, 2003).

Eventually, we will need to start educating patients about the importance of up-to-date immunizations, hand-washing, secondhand smoke elimination, post-hospital discharge clinics and the use of available resources of the multi-dimensional health care team (e.g., physical and occupational therapy, rehabilitation nursing, home health care, subspecialty colleagues). In addition, primary care physicians should screen for mental health disturbances and treat or refer as needed.

Cost of Treatment Plan

This section presents data showing how the length of ICU and hospital stays are tightly linked to costs of care and how they can be reduced by avoiding intubation in some patients.

Each year, 1.1 million of the 4.4 million people in the United States who are admitted to the ICU are affected by ARF. In 2005, the average length of the ICU and hospital length-of-stay (LOS) was 14 days for patients with ARF. This figure represents 7% of all hospital days. Total hospital costs for the care of intubated adults was $27 billion or 12% of all hospital costs in the United States (Wunsch et al., 2010). Zilberberg et al. (2008) calculated an increase of hospital bed usage between the years 2000 and 2020. They believe bed usage will increase from 3.6 million to 5.5 million for ICU mechanical ventilated patients, and the expected annual hospital costs may go over $64 billion (Zilberberg & Shorr, 2008).

Although mechanically ventilated patients represent a small fraction of hospitalizations, they are responsible for a disproportionate percentage of hospital days and costs (Wunsch et al., 2010). Daily hospital fixed costs include staff salaries, utility payments, equipment costs and other overhead expenses. In the ICU, fixed costs are higher as a result of greater nurse and other personnel staffing balanced with more advanced patient support. The ICU also uses more monitoring equipment than other less acute hospital patient care units. In addition to fixed costs, mechanically ventilated patients have greater variable costs which include pharmaceuticals, blood products, laboratory tests, and supplies. These fixed and variable costs are compounded by the fact that Intubated Mechanical Ventilated (IMV) patients are at higher risk of costly complications. For example, ventilator associated pneumonia (VAP), central line associated blood stream infections (CLABSI), sepsis and gastrointestinal hemorrhages occur more commonly in intubated patients (Cooke, 2012).

Survivors of IMV have serious functional disabilities after hospital discharge, requiring long-term acute care (LTAC) hospitalizations, thus bringing a significant amount of long-term expenses to society (Zilberberg, Luippold, Sulsky, & Shorr, 2008). The clinical presentation of post-IMV long-term disability includes: poor mobility, lung function impairment, malnutrition, poor concentration, fatigue, anxiety, and depressed mood (Fan et al., 2014). In addition, during IMV the head of the bed is raised, increasing the risk of sacral pressure ulcers (Peterson et al., 2008). Also, swallowing dysfunction is common in post-extubated patients, affecting their ability to eat. Post-IMV functional deficits tend to resolve slowly. Indeed, it may take as long as five years for lung function to recover (Herridge et al. 2011).

In 2006, Unroe and colleagues tracked patients who required IMV for one year following their discharge from LTAC. Sixty-seven percent of patients required at least one readmission to LTAC, and 91% had some functional dependency. Overall, post-LTAC discharge patients spent 74% of days alive in a health care facility or receiving home health care. The mean cost per patient exceeded $300,000 (Unroe et al., 2010).

Noninvasive positive pressure ventilation can be a good alternative to artificial airway and IMV by minimizing the costs of care for patients with ARF without compromising clinical outcomes. For example, one meta-analysis concluded that NIPPV reduced hospital LOS in COPD patients by approximately 5 days, reduced the absolute rates of endotracheal intubation by 28%, and decreased in-hospital mortality by 10% (Keenan, Sinuff, Cook, & Hill, 2003). In a study by Ferrer and co-workers, in a group of patients with severe community-acquired pneumonia and hypoxemic respiratory failure, NIPPV was linked to significantly lower intubation rates and ICU mortality (Ferrer et al., 2003). Agarwal et al. conducted a meta-analysis of randomized controlled trials which showed that NIPPV, in addition to other forms of medical therapy in ARDS patients, reduces the intubation rate, shortens the ICU stay, and lowers ICU mortality (Agarwal, Aggarwal, & Gupta, 2006). A group of 20 patients who underwent solid organ transplant and developed ARF had better outcomes using NIPPV than another 20 patients who were on IMV. Antonelli and colleagues observed a significant reduction in the rate of ETT intubation (20% vs. 70%; P = .002), the rate of fatal complications (20% vs. 50%; P = .05), and the length of stay in ICU by survivors (mean [SD] days, 5.5 [3] vs. 9 [4]; P = .03). The ICU mortality rate was lower for NIPPV patients (20% vs. 50%; P = .05), but overall hospital mortality did not differ for either group (Antonelli, Conti, & Bufi, 2000).

In the United States, Medicare's costs per enrollee vary significantly from region to region - from $4,500 to nearly $12,000 in 2003. In Chicago, total Medicare reimbursements per enrollee (after adjusting for age, sex, and race) in the year 2010 were $11,856 (Dartmouth Atlas of Health Care, 2010). Unfortunately, the higher-spending regions do not have higher life expectancies or show any significant improvement in other measures of health (Fisher et al., 2003). In fact, some studies strongly suggest that many expensive medical treatments and services in the United States are provided to patients who could do just as well with less expensive care (Fisher et al., 2003).

In conclusion, the critical care team needs consider that early usage of NIPPV, in addition to effective medical interventions for the selected patient population will not just reduce medical costs but will also improve patient outcomes. Zilberberg et al. predicts that 2020 costs projections for IMV are cause for alarm. The important message from this study is: "efficiency improvements in the health system can no longer be viewed as an option" (Zilberberg & Shorr, 2008)

Evaluation of Treatment Plan

It is evident that Ms. C.C.'s treatment plan was successful and her clinical condition improved. Early recognition of ARF and the differential diagnosis of ARDS prompted clinicians to start therapeutic interventions early by adding NIPPV to other standard therapies. The hope was that NIPPV would help with oxygenation and prevent endotracheal intubation. Ms. C.C. was closely monitored in the ICU because with immunosuppressed and/or ARDS patients, NIPPV failure is associated with higher mortality rates. The treatment plan included NIPPV via helmet application in case the patient had poor tolerance of the BiPAP mask and/or the underlying disease grew more severe. This is indeed what happened 10 hours after NIPPV began. On the second day in

ICU, the patient required much ventilatory support. In the event of NIPPV failure, the MICU team was ready to intubate Ms. C.C. in order to avoid fatal complications.

Early and quick administration of antibiotics in concurrence with appropriate assessment of etiology of pulmonary infection was beneficial to the healing process. Antibiotic therapy was modified based on test results and the patient's clinical presentation.

The MICU team considered bronchoscopy for Ms. C.C. in the event of intubation. This would have allowed clinicians to test broncho-alveolar lavage fluid, determine the etiology of pulmonary infection and assess pro-inflammatory mediators of ARDS (Clark, Milberg, Steinberg, & Hudson, 1995).While the patient was on NIPPV, this procedure was too risky to perform.

To reduce lung injury, Ms. C.C. received high doses of prednisone. It is hard to determine if the patient's condition got better due to the high dose of steroids, because she received multiple interventions during that time.

In addition to NIPPV, steroid and antibiotic therapy, Ms. C.C. received daily hemodialysis. The goal was to achieve a negative fluid balance as soon as possible because in ARDS, fluid overload is associated with worse clinical outcomes. Fortunately, Ms. C.C. was hemodynamically stable and tolerated hemodialysis well. On the third day in ICU her fluid balance was net negative 6L and her clinical condition improved dramatically.

An early nutritional support for Ms. C.C. helped offset catabolic losses caused by the increased work of breathing and stress (Martindale et al., 2009). The patient was able to drink supplements in addition to her liquid renal diet through a straw while on NIPPV via helmet. Also, Ms. C.C.'s blood sugar was closely monitored and corrected by administrating insulin subcutaneously. Insulin therapy can improve patient outcomes in the ICU because hyperglycemia is associated with higher mortality rates (Falciglia et al., 2009).

The goal for DVT prophylaxis for Ms. C.C. was to reduce the risk of pulmonary embolism. Heparin administration was particularly important for her, because she had DVT in the past and was at great risk of getting it again.

Proton pump inhibitors (PPI) were used to prevent gastrointestinal bleeding by blocking gastric acid secretion. GI bleeding is very common in ICU patients (up to 15 % of patients without stress ulcer prophylaxis) (Cook et al., 2001). While Ms. C.C. was receiving PPI she was also monitored for potential adverse effects, including nosocomial pneumonia and clostridium difficile infection (Bateman et al., 2013), (Kwok et al., 2012).

In conclusion, the treatment plan for Ms. C.C. was ongoing and fluctuated as her condition changed. She received meticulous supportive care and stayed complication free during her hospital stay.

APN Role

Health care in the United States is changing rapidly and the need for cost-effective, high-quality care has gained national attention. As a result, advanced practice nurses (APN's) have an opportunity to expand their role in both primary and tertiary care sites. Advanced practice refers to nurses who have acquired the knowledge base and practical experience to prepare them to specialize, expand, and advance in different roles, such as clinical nurse specialist, nurse practitioner, nurse midwife, and nurse anesthetist (AACN Scope and Standards, 2012).

Direct clinical practice is a fundamental competency of any APN role, although the actual skill set varies according to the needs of the patient population. Significant overlap in acute care and primary care NP competencies exist for adult-gerontology acute care nurse practitioners (AGACNP). The care is provided to ICU patients who are "physiologically unstable, technologically dependent, and/or are highly vulnerable to complications" (AACN Scope and Standards, 2012). The role of the AGACNP includes broad patient care skills which include disease prevention, management and stabilization of critically ill patients, complication prevention, health restoration, and/or palliative care establishment (AACN, 2012). APNs must be able to generate theoretical, scientific, and up-to-date clinical knowledge, correctly diagnose, treat and manage health care problems and, when appropriate, refer patients to other health care providers (AACN, 2012).

To provide the best care for ICU patients, APNs need to combine the skills of multiple personnel: clinical expert, case manager, educator, leader, researcher, and patient advocate. Competencies accomplished by the APN role within Ms. C.C.'s case included: analytical skills, critical thinking, accurate and timely decision making, maintaining a holistic perspective, coaching through the acute illness phase, and participating in health promotion, health protection, disease prevention and treatment.

In MICU, physicians and APNs worked very closely to provide optimal service to Ms. C.C. Also, ICU attendings, fellows and APNs provided exceptional teaching to the house staff about disease treatment, unit activities, protocols, procedures, and standards. These two roles interacted efficiently and optimized outcomes, thus minimizing complications for Ms. C.C.

In MICU, APNs independently write orders and progress notes, hold patient/family meetings, and distribute daily tasks/needs to the house and bedside staff. APNs demonstrate a higher level of nursing practice in every clinical decision and situation. They are self-sufficient on the unit most of the time however they are dependent in their role with the collaborating MD.

It has long been known that a multidisciplinary team approach involving physicians, APNs, social workers, physical and occupational therapists, staff nurses, and nutritionists provides the best care for the diverse and complex patient population in ICU. Multiple times each day, the MICU team and other services review and establish treatment goals for every patient on the unit. MICU attending leads rounds with open input from the APN's and house staff teams. This collaborative multidisciplinary approach for APNs serves as a stimulus for both unit learning and individual self-growth through constant reflection and critical analysis of thoughts and actions.

Summary

Deciding the correct treatment for an immunosuppressed patient with ARF is a complex, multifactorial process. Numerous studies have demonstrated that recipients of solid-organ or bone-marrow transplants with ARF have decreased rates of intubation, lower ICU mortality rates and shorter ICU stays when treated with NIPPV when compared with patients who received conventional therapy.

The key to the successful application of NIPPV is an appropriate and timely selection of patients who will benefit from it. Medical staff should make a clinical judgment based on the etiology of the ARF, the human factor, signs of success and failure, technical aspects, and the level of the ICU team’s experience. As the use of

NIPPV expands, clinicians will gain more knowledge and success rates will remain stable or improve. Even when clinicians are in doubt, a brief, cautious trial of NIPPV can be attempted for severely ill patients, with plans and readiness to intubate if the patient's condition worsens.

In conclusion, medical professionals and hospital administrators should implement safe practices where trained and experienced intensive care unit team members take specific steps in choosing whether to treat selected ARF patients with NIPPV without jeopardizing clinical outcomes.

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