



New Models of Hospital Organization of Noninvasive Mechanical Ventilation: Step-Down Unit, Respiratory Intensive Care Units

78

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Contents

78.1 Introduction.....	829
78.2 Step-Down Units: Outcomes and Costs.....	830
78.3 Noninvasive Mechanical Ventilation and New Models of Hospital Organization.....	831
References.....	833

78.1 Introduction

Intensive care medicine has a history of almost 70 years. The concept of specially dedicated wards for threatening critically ill patients was introduced during the well-known poliomyelitis epidemic in the 1950s of the past century when the first unit was established to treat the patients with respiratory failure. The “father” of the intensive care unit was the famous anesthesiologist Dr Bjorn Ibsen from Copenhagen, Denmark [1]. Since then, intensive care medicine has become one of the fastest growing branches of medicine.

After the establishment of general intensive care units in many hospitals in Europe and the United States, the specialized respiratory intensive care units (RICUs) were introduced in hospital organizations in the 1960s in the United States run by the respiratory specialists [2]. During the 1980s, in this country, the noninvasive respiratory care units (NRCUs) and high dependency units (HDUs) were developed [3].

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829

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The main indications for RICUs admission were acute respiratory failure (ARF) or acute-on-chronic respiratory failure (RF). The RICUs were the solution for lower costs, as according to the survey in many countries, the exacerbation of chronic RF (due to chronic obstructive pulmonary disease–COPD) was the main reason for the ICU treatment [4]. Patients with acute exacerbations of COPD (AECOPD) treated in ICUs had numerous complications connected with mechanical ventilation use. The guidelines that introduced noninvasive positive pressure ventilation (NPPV) as a first line of treatment for AECOPD contributed to the RICUs establishment in many countries [5]. In Europe, the introduction of the RICUs was started at the end of the twentieth century, admitting patients with acute RF and acute-on-chronic RF, mainly in Italy, the country with the largest experience in this field of respiratory medicine. The results of the national prospective cohort study by Confalonieri and colleagues [6] indicated two types of units according to the nurse–patient ratio among 26 units included in the study. More than half of the units had a nurse–patient ratio of 1:2 or 1:3, and according to the Italian Association of Hospital Pulmonologists (AIPO), these units can be defined as RICUs, while the rest of the units (nurse–patient ratio of 1:4) should be considered as NRCUs or noninvasive respiratory units. In NRCUs, patients are usually not invasively ventilated; if intubation is required, those patients are transferred to the adjacent ICU. This study also pointed that the survival of 85% for patients treated in RICUs in Italy showed the importance of NIPPV use and close monitoring regarding the outcomes.

78.2 Step-Down Units: Outcomes and Costs

The role of RICUs was also apostrophized in other studies, especially for the patients with acute respiratory failure or those with the acute exacerbation of chronic respiratory failure (e.g., exacerbation of COPD) and indications for NIPPV. The presence of RICUs in hospital can contribute to avoiding a lower level of care on general wards, and on the other hand, increase the availability of ICU beds. Furthermore, this type of organization in general hospitals can save costs [7].

Another study by Confalonieri and colleagues in 2015 [8] showed a significantly lower in-hospital mortality rate in RICUs versus internal medicine units (IMUs) for the patients with ARF, AECOPD, and community acquired pneumonia (CAP), with reduced transfer to the ICU, shorter hospital stay and time for NIV application. These results are very important for better understanding the importance of RICUs as dedicated units in the light of managing patients with ARF as a one of the most frequent reason for hospitalization. In a retrospective cohort study from the USA [9], in two academic tertiary care hospitals, the authors investigated the association between opening the four bed Step-Down Unit (SDU) and outcomes (hospital mortality, hospital and ICU length of stay (LOS), and time to transfer to the ICU) in the interventional hospital versus control hospital without the SDU. The results of this study revealed no association of lowering the in-hospital mortality or hospital LOS after SDU opening in the interventional hospital, but the ICU LOS and time to transfer to the ICU were significantly reduced ($p = 0.019$ and $p = 0.014$, respectively).

In a multicenter European cohort study [10], the aim of the investigation was the in-hospital mortality in hospitals with so called Intermediate Care Units (IMCU), defined as independent units with the level of care lower than in the ICU but higher than at the general ward. In this study, which included 167 units from 17 European countries with more than 6000 admissions to the ICUs, the authors concluded that the higher risk of hospital death was associated with severity of illness at ICU admission, infection, hospital stay longer than 7 days before ICU admission, and unplanned admission to the ICU. The mortality was significantly lower in hospitals with IMCU (odds ratio of mortality 0.63 (95% CI 0.45 to 0.88, $p = 0.007$) except in cases where the reason for admission was just the observation of the patients (e.g., after surgery).

Some studies reported unfavorable results regarding the step-down unit outcomes. A study from Scotland [11], which was conducted over 10 years and with more than 6000 admissions to the single mixed medical-surgery ICU, concluded that a higher APACHE II score and discharge to a step-down unit were the independent risk factors for early ICU re-admission, and therefore higher mortality. In a retrospective cohort study of data from 28 ICUs in the Netherlands and patients admitted because of the severe sepsis [12], the results revealed that the presence of an IMCU in hospital was associated with higher in-hospital mortality.

Vincent and Rubenfeld [13] wrote a viewpoint about the intermediate care units and their advantages and disadvantages, with the analysis of the effects of intermediate care on outcomes and costs through the results of several studies and from the experts' perspectives. They concluded there is a lack of studies about cost savings and better outcomes for patients hospitalized in the IMCUs and who never need ICU care.

78.3 Noninvasive Mechanical Ventilation and New Models of Hospital Organization

Noninvasive positive pressure ventilation (NPPV) was initially established as a therapy of choice for patients with chronic RF, e.g., neuromuscular disorders. The indications for NIPPV were extended to other causes of RF such as the acute exacerbation of chronic obstructive pulmonary diseases (AECOPD). Today, NIPPV is a routine therapy for patients with different causes of RF outside ICUs – in the step-down units, IMCUs or RICUs – which is a great contribution to liberate the ICU capacities and free up ICU beds [14].

Invasive mechanical ventilation is connected with complications such as ventilator induced pneumonia (VAP), barotrauma or volutrauma of the lungs, with weaning problems and long-term tracheostomy. On the other hand, NIPPV is a mode of ventilation that avoids almost all these complications; therefore, it has become one of the most used ventilatory supports for numerous indications, including acute RF and acute-on-chronic RF. Together with progress using NIPPV, the question of where to perform it arises. According to the results of several studies, NIPPV should be performed in locations of care that can provide adequate monitoring of the

patients and should be close to the ICU [15, 16]. Several factors influence the NIPPV outcomes. One is the results of gas analysis regarding the degree of hypoxemia and respiratory acidosis, where the $\text{pH} < 7.25$ is a very powerful prognostic factor for NIPPV failure in patients with AECOPD [17]. The other very important factor is sufficient staff with experience [18]. The review about the implementation and delivery of NIPPV in patients with AECOPD from the National Confidential Enquiry into Patient Outcome and Death (NCEPOD) in the UK [19] concluded that patient selection is very important. Mortality was higher in patients with pneumonia who were ventilated in the general wards and 91% of patients with $\text{pH} < 7.25$ were not treated in the High Dependency Unit, with the highest mortality (59%) for patients who started the NIPPV in general wards. Similar results were published in the study from our hospital [20], which is a tertiary teaching pulmonary hospital with a six-bed HDU. The study included 138 patients, with mainly AECOPD as an indication for NIPPV (85%). NIPPV was applied in 86 patients in the HDU. NIPPV failure was associated with the presence of consolidation in two or more quadrants and application of NIPPV in the general ward.

While expanding the indications for NIPPV, the need for defining the settings for noninvasive ventilation opened as a new frontier. It is clear that patients with acute RF or acute-on-chronic RF have to be ventilated in the units with adequate equipment, trained staff, and availability to properly monitor the vital parameters. Regarding the ventilators and modes of ventilation, enormous progress has been made in the past 30 years [21].

The COVID-19 pandemic had a big impact on use of NIPPV in patients with COVID-19 pneumonia and acute RF. At the beginning of the pandemic, NIPPV was not advocated for the patients with severe acute respiratory syndrome owing to generating aerosols and relying on the experience from previous pandemics. In a study from Wuhan [22], the authors reported significantly higher mortality in patients invasively ventilated than in patients with NIPPV (98% vs. 40.8%). As the pandemic was ongoing, using noninvasive respiratory treatment modalities for acute RF increased, especially the use of NIPPV and high-flow nasal oxygen. It changed the organization of the hospitals, and most of the units became units for treating patients with acute RF due to COVID-19 pneumonia. The hospitals' administration faced the need to reorganize the hospital settings, especially the respiratory intermediate units or step-down units, which served as units for treating severe RF due to COVID-19 [23].

Key Messages

- Expanded indications for NIPPV changed the everyday practice in hospitals
- NIPPV has to be applied in adequately equipped units with trained staff
- Understanding the respiratory failure physiology is very important for implementing NIPPV in various indications, which has become apparent during the COVID-19 pandemic
- The new models of hospital organization regarding the implementation of noninvasive ventilation become mandatory

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