Noninvasive Ventilation. The Essentials
Under the Auspices of the International Association of Noninvasive Mechanical Ventilation
Series Editor: Antonio M. Esquinas

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Lucia Spicuzza
Raffaele Scala *Editors*

Noninvasive Ventilation Outside Intensive Care Unit

Rationale and Practice

Springer

Noninvasive Ventilation. The Essentials

Nowadays, there is clear evidence of the consolidation of Non-invasive Ventilation (NIV) in medical practice. This Series, titled "Noninvasive Ventilation. The Essentials, is the result of extensive prior publications on this topic.

The aim of this Series is to define the current and new clinical developments in technologies such as equipment and ventilator modes and to offer practical recommendations, primarily in Intensive Care Medicine, Pulmonary, Emergency, and Sleep Medicine studies.

As a result of the previous publications, a well-experienced group of Editors and top international Editors aim to offer new books based on a multidisciplinary approach and a comprehensive overview of thematic issues in the field of Non-invasive Ventilation.

The general and main aims of this Series are as follows:

To establish a scientific reference for the clinical practice of NIV from a basic perspective of pathophysiology, clinical indications, and evidence-based concepts.

To convey the most important advances in clinical disciplines such as Intensive Care Medicine, Pneumology, Anesthesiology, Sleep Medicine, Pediatrics, Hospital and Pre-hospital Healthcare Organization in the most prevalent forms of acute and chronic respiratory failure.

To analyze the most important advances in the field of NIV technology and complementary procedures associated with NIV applications such as aerosol therapy, humidification, and airway clearance secretions required for the correct application of NIV techniques.

To serve as a valuable teaching reference for a range of healthcare professionals, including professional residents, senior consultants, and allied healthcare professionals. It will also be useful for under-graduate and post-graduate students, as well as those participating in fellowship programs.

The launch of a Series edition provides an opportunity to produce focused thematic volumes which will offer in-depth coverage of a particular topic area. This will be achieved through the involvement of internationally recognized guest editors who will work to ensure that the latest advances in NIV are analyzed comprehensively and in detail across key fields, including ICM and Emergency Medicine, as well as Pulmonary and Sleep Medicine.

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Preface

Nowadays it is evident that a large number of patients admitted in respiratory failure that require mechanical ventilation have a significant annual impact on health systems, in different terms such as costs and other health-related aspects (e.g., *complications associated with mechanical ventilation, ventilator-associated pneumonia, ICU-acquired muscle weakness*).

In this scenario, the use of noninvasive mechanical ventilation systems and nasal high-flow oxygen, which attenuate the adverse effects of invasive mechanical ventilation and its complications, is widely recommended and is supported by a very high level of clinical evidence.

The current demonstrated results of noninvasive mechanical ventilation exemplify good clinical practice and serve as a "gold standard" for patients with COPD exacerbations, cardiac pulmonary edema, immunocompromised individuals, or patients who do not require endotracheal intubation that normally are more vulnerable.

Along with this great base and proven track record, a growing application has been observed outside the critical care units, due to different situations specific to the organization and internal resources of each hospital. Recent instances of hospital collapse caused by international epidemics (H1N1, COVID-19) and other catastrophes serve as clear examples and evidence of this situation and that it can be applied in a reasonable way, and with adequate measures of equipment, monitoring, and training by appropriate personnel in a properly selected population. However, this entails an original aspect of new knowledge of NIV, especially in terms of the methodology of use, selection criteria, and establishment of new response prediction models and the organization of the health system of each hospital (e.g., *monitoring, human and material resources*). Once again, clinical reality itself leads a technique to be evaluated outside the original environment in which it was designed. This is a great scientific and health challenge for many health professionals.

In this first book on this subject, entitled Noninvasive Ventilation Outside Intensive Care Unit: Rationale and Practice, the reader can learn an analysis of how to establish and develop noninvasive mechanical ventilation as indications, methodology, and patterns of good practice, in a book structured in sections and chapters, where these flowcharts of patients with NIV outside ICU are analyzed and with this an adequate planning and hospital organization that adapts to the peculiarities of each hospital health system can be found.

The second originality of this title is that it represents the first **thematic volume** of the *Non-invasive Ventilation. The Essentials Series*, a scientific project that will analyze those classic and controversial aspects that should be well known to all health professionals who decide to start and develop a clinical practice of noninvasive ventilation, supported by an adequate scientific knowledge of all the elements that are intended to achieve clinical excellence.

May this introduction serve as a tribute and expression of gratitude to several international scientific figures who decisively contributed at the educational, human, and scientific levels in the development of this technique that we know today; they include Professors **Robert M. Kacmarek** (Boston, USA), **Jordi Mancebo** (Barcelona, Spain), and **Paolo Pelosi** (Milan, Italy).

I wish this book to be a first step ... of a long and interesting endless story.

Murcia, Spain — Antonio M. Esquinas
Catania, Italy — Lucia Spicuzza
Arezzo, Italy — Raffaele Scala

Contents

Abbreviations

6MWT	6 Minutes walking test
ACE	Acute Care for Elders
ACE-R	Addenbrooke's Cognitive Examination
ACRF	Acute on chronic respiratory failure
AD	Advance directive
ADLs	Activity of daily living
Ads	Administrator Support in Italy or Guardian
AECOPD	Acute exacerbation COPD
AH	Absolute humidity
AHCD	Advanced health care directives
AMI	Acute myocardial infarction
ARDS	Acute respiratory distress syndrome
ARF	Acute respiratory failure
BMI	Body mass index
BNP	Brain natriuretic peptide
BPAP	Bilevel positive airway pressure
Bpm	Breaths/minute
CAM	Confusion assessment method
CAP	Community-acquired pneumonia
CCIS	Charlson comorbidity index score
CDC	Centers for Disease Control
CFS	Clinical Frailty Scale
CGA	Comprehensive Geriatric Assessment
CHF	Congestive heart failure
COPD	Chronic obstructive pulmonary disease
COT	Conventional oxygen therapy
COVID-19	Coronavirus disease 2019
CPAP	Continuous positive airway pressure
CPE	Cardiogenic pulmonary edema
CWD	Chest wall disorders
DIC	Disseminated intravascular coagulation
DMC	Decision making capacity
DNI	Do not intubate
DSM-5	Diagnostic and Statistical Manual of Mental Disorders

EACP	European Association of Palliative Care
EELV	End expiratory lung volume
EPAP	Expiratory positive airway pressure
ERS	European Respiratory Society
ETI	Endotracheal intubation
FBS	Fiberoptic bronchoscopy
FDA	Food and Drug Administration
FEV1	Forced expiratory volume in the first second
FFM	Full face mask
FiO_2	Fraction of inspired oxygen
FiO_2	Inspiratory oxygen fraction
FVC	Forced vital capacity
HACOR index	Heart rate, Acidosis, Consciousness, Oxygenation, Respiratory rate
HAT	Health Assessment Tool
HFNC	High flow nasal cannula
HMV	Home mechanical ventilation
HR	Heart rate
HRQoL	Health related quality of life
IADL	Instrumental Activity of Daily Living
IC	Informed consent
ICP	Individual care plan
ICU	Intensive care unit
ILDs	Interstitial lung disease
OLDs	Obstructive lung diseases
IMV	Invasive mechanical ventilation
IPAP	Inspiratory positive airway pressure
IPF	Interstitial pulmonary fibrosis
IRCU	Intermediate respiratory care unit
LOX	Liquid oxygen
Lpm	Litres/minute
LTOT	Long term oxygen therapy
LVEF	Left ventricular ejection fraction
MMSE	Mini-Mental State Examination
MPI	Multidimensional prognostic index
NHS	National Health Service
NIMV	Noninvasive mechanical ventilation
NIRS	Noninvasive respiratory support
NIRT	Noninvasive respiratory therapies
NIV	Noninvasive mechanical ventilation
NIV	Noninvasive ventilation
NMDs	Neuromuscular disorders
NPI	Neuropsychiatric Inventory
NPPV	Noninvasive positive pressure ventilation
OHS	Obesity hypoventilation syndrome
OSA	Obstructive sleep apnea

OTI	Orotracheal intubation
$PaCO_2$	Arterial carbon dioxide partial pressure
PAFI	PaO_2/FiO_2 ratio
PaO_2	Arterial oxygen partial pressure
PaO_2	Arterial oxygen pressure
PAP	Positive airway pressure
PCV	Pressure control ventilation
PEEP	Positive end expiratory pressure
PH	Pulmonary hypertension
POCs	Portable oxygen concentrators
Pplat	Plateau pressure
PS	Pressure support = IPAP − EPAP
P-SILI	Patient self-inflicted lung injury
PSV	Pressure support ventilation
QoL	Quality of life
RHDCU	Respiratory high-dependence care units
RICUs	Respiratory intensive care units
RIICU	Respiratory intermediate intensive care units
RMUs	Respiratory monitoring units
ROX index	(SpO_2/FiO_2)/RR ratio
RR	Respiratory rate
SAFI	SpO_2/FiO_2 ratio
SAPS II	Simplified Acute Physiology Score II
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
SBT	Spontaneous breathing trial
SOFA	Sequential organ failure assessment
SpO_2	Oxyhemoglobin saturation
SWUs	Specialized weaning units
TV	Tidal volume
VT	Tidal volume
WC	Weaning centers

Part I

Epidemiology, Rationale and Indications of Noninvasive Ventilation Response Outside Intensive Care Unit

1 Noninvasive Mechanical Ventilation Outside Intensive Care Unit. Epidemiology

Biljana Lazovic, Radmila Dmitrovic, Isidora Simonovic, and Antonio M. Esquinas

Abstract

Noninvasive ventilation (NIV) is becoming more common in hospitals and at home around the world. The list of indications for its use is continually growing. In addition to the treatment of pulmonary conditions, it excelled in the treatment of specific cardiological conditions (ACPE), neuromuscular diseases, and even the therapy of acute respiratory disorders that occurred as a consequence of the treatment of various tumors. In this chapter, we will present epidemiological data on its application and effectiveness.

Keywords

Noninvasive ventilation · Epidemiology · Indications · Effectiveness · Prevalence · History

Noninvasive mechanical ventilation (NIV) is the delivery of ventilatory support without the use of an invasive artificial airway, endotracheal, or tracheostomy tube. According to data from the literature, the use of NIV has been increasing during the last two decades, from 2001 to 2004. It grew from 4% to 11%, primarily in European countries [1]. Acute hypercapnic respiratory failure (AHRF), arguably its most

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significant and important indication; acute exacerbation of chronic obstructive pulmonary disease (AECOPD); obesity hypoventilation syndrome (OHS); acute cardiogenic pulmonary edema (ACPE); neuromuscular disorders; and post-extubation ventilatory support are the key indications for NIV. NIV has been recommended as a palliative treatment in cancer patients to improve dyspnea. NIV is particularly useful in the treatment of AECOPD and end-stage neuromuscular disease [2]. The history of NIV could be traced back more than a century, but the modern NIV could be traced back to 1987 when Delaubier and Rideau successfully ventilated a patient with Duchenne Muscular Dystrophy [3]. Pulmonologists (52.9%) were the most likely to prescribe NIV, followed by anesthesiologists (34.3%) and, finally, other specialists (12.6%) [4]. Home ventilation with NIV can be very beneficial in chronic respiratory failure (CRF), particularly in COPD, where NIV use improves survival and reduces readmissions and exacerbations. When comparing NIV and long-term oxygen therapy, data revealed the following: mortality rates in the COPD and OHS groups were 61.3% and 21.2%, respectively; treatment durations ranged from 5.3 years in COPD patients to 11.4 years in restrictive chest wall disease patients [5]. In children with neuromuscular disease, which puts them at risk of alveolar hypoventilation, the respiratory muscles are usually spared. The most common neuromuscular diseases requiring NIV are spinal muscular atrophy and Duchenne muscular dystrophy, which are also known as collagen 6 myopathies or selenopathies and are characterized by a predominant weakness of the diaphragm [6]. According to some epidemiology data from a study conducted in North Ireland, acute neuromuscular failure, like the most common life-threatening complication in this child, had an incidence rate of approximately 2.81 (2.12 to 3.66) cases per million person-year and a mortality rate of approximately 0.26 (0.08 to 0.60) deaths per million person-years [7]. Home mechanical ventilation (HMV) improves these patients' quality of life and survival. According to certain research, the estimated prevalence of HMV is 7.3/100,000 population, and a minimal budget of roughly 168€/patient/year (504€/100,000 population) including the cost of the equipment should address the expense of HMV equipment in low-income nations [8]. Acute respiratory failure associated with cancer therapy complications is common in cancer patients. The researchers recruited 121 individuals with hematological and solid plasmas who were separated into two groups: those on IMV (56 (46.28%)) and those on NIV (65 (53.72%)). The overall mortality rate was 47.9%; however, the mortality rate for patients with hematological and solid neoplasms in acute respiratory failure was reduced in NIV patients (27.8% and 24.1% vs. 82.4% and 69.2%) [9].

Conclusion

NIV is an effective therapy option in both hospital and home settings. Because of CRF, an increasing number of patients are receiving NIV or IMV via tracheotomy to treat symptoms and improve their quality of life. Although the use of this sort of treatment is growing, particularly in Western countries, more research is needed to demonstrate its effectiveness.

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Noninvasive Mechanical Ventilation: Rationale Physiology

2

Maria João Vieira Silva

Abstract

Noninvasive ventilation (NIV) is a type of ventilation that uses a noninvasive airway interface. and has two major modes of supplying support: bilevel positive airway pressure (BiPAP) or continuous positive airway pressure (CPAP). Since, in CPAP, pressure is constant it does not generate flow and does not increase volume, and cannot be considered a form of NIV in a strict sense (Torres et al., Cochrane Database Syst Rev (9):CD010355, 2015).

NIV will provide respiratory, neurological, muscular, and cardiovascular effects, depending on the pathophysiology of the respiratory failure.

Keywords

Noninvasive ventilation · Physiology · Cardiovascular effects · Respiratory effects · Positive pressure

Noninvasive ventilation (NIV) exerts its effects through several forms, namely, by increasing intrathoracic pressure, preventing alveolar collapse, increasing functional residual capacity and arterial oxygenation, and reducing respiratory workload and cardiac preload [1]. It is used to support gas exchange and acid–base homeostasis when the respiratory muscles are unable to maintain normal pulmonary ventilation in the face of acute or chronic respiratory dysfunction [2].

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