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New Developments in Mechanical Ventilation

Edited by M. Ferrer and P. Pelosi



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New Developments in Mechanical Ventilation

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Edited by M. Ferrer and P. Pelosi

Editor in Chief
T. Welte

This book is one in a series of *European Respiratory Monographs*. Each individual issue provides a comprehensive overview of one specific clinical area of respiratory health, communicating information about the most advanced techniques and systems needed to investigate it. It provides factual and useful scientific detail, drawing on specific case studies and looking into the diagnosis and management of individual patients. Previously published titles in this series are listed at the back of this Monograph.



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Guest Editors



M. Ferrer

M. Ferrer is currently a consultant physician at the Respiratory Intensive and Intermediate Care Unit in the Pneumology Department within the Hospital Clinic of Barcelona (Barcelona, Spain). He gained his degree in medicine from the University of Barcelona in 1985. After this, he specialised in pneumology at the Hospital Clinic of Barcelona from 1987 to 1990, and subsequently obtained a doctorate in medicine in 1993. He attained the position of staff physician within the Pneumology Department in 1992 and is also Clinic Professor in the Department of Medicine at the University of Barcelona. M. Ferrer is a member of the research group Applied Research in Respiratory Diseases of the Institute of Biomedical Investigations August Pi i Sunyer (IDIBAPS), as well as a member of the Network of Biomedical Research in Respiratory Diseases (CIBERES) of the “Carlos III” Health Institute, Spanish Ministry of Science and Technology. He currently participates in several activities related to scientific societies, including the Spanish Society of Pneumology and Thoracic Surgery (SEPAR), and was a member of the committee that developed the Spanish guidelines for Hospital-Acquired Pneumonia published in 2011. As an active European Respiratory Society (ERS) member he is part of the Noninvasive Ventilatory Support Group within the ERS Respiratory Intensive Care Assembly and is part of the long-range planning committee for this Assembly. He is also involved in the Harmonised Education in Respiratory Medicine for European Specialists (HERMES) Critical Care Project and is part of the ERS and American Thoracic Society (ATS) Task Force on the indications of use for noninvasive ventilation in acute respiratory failure.

M. Ferrer’s research interests include noninvasive ventilation, weaning from invasive mechanical ventilation, severe community-acquired pneumonia and nosocomial pneumonia in the intensive care unit. He has authored or co-authored some 170 articles, including original investigations, reviews, editorials and book chapters.



P. Pelosi

P. Pelosi grew up in Milan (Italy) and attended the University of Milan, graduating as *magna cum laude* in medicine and surgery. After graduation, he completed his studies first as a specialist in anaesthesia and intensive care and then as Research Fellow at the University of Milan. He served as Associate Professor in Anaesthesia and Intensive Care Medicine at the University of Insubria (Varese, Italy) from 1999 to 2010. He is currently Chief Professor in Anaesthesia and Intensive Care and Director of the Speciality School in Anaesthesiology at the University of Genoa (Genoa, Italy) and Head of the Intensive Care Unit at the IRCCS Azienda Ospedaliera San Martino Genoa – IST. His professional activities have always been directed both at the clinical and research fields.

P. Pelosi’s main research interests are respiratory physiology during anaesthesia and respiratory failure. He has developed numerous collaborations with European and international countries for research in the field of mechanical ventilation. He is actively involved in the Fellow and Resident educational programme at the University of Genoa. He is the current Head of the Respiratory Intensive Care Assembly of the ERS. He is author or co-author of over 170 medical and scientific peer review papers, 60 book chapters, and has lectured in more than 800 national and international meetings on ventilation management during the perioperative period and on the pathophysiology and treatments of acute respiratory failure.

Preface



There is no other discipline in medicine that has developed as quickly as intensive care medicine has in recent decades. Substantial progress has mainly been made in the field of mechanical ventilation. Thirty years ago, it was thought that it was not possible to survive for more than one week on a ventilator due to ventilator-associated lung injury (VALI) on the one hand, and ventilator-associated infections on the other. Since then, we have learnt a lot about the pathophysiology of VALI, leading to the concept of ventilation-induced volutrauma (an injury from excess distension) and atelectrauma (local shear injury from tidal opening and closing). Stretch and shear forces induce inflammation and initiate a myriad of signalling cascades, which enhance lung damage and worsen the long-term prognosis of patients.

With the fast technical development of ventilator technology, protective mechanical ventilation that avoids lung distension and tidal opening became possible. In 2000, the NIH ARDS (National Institute of Health Acute Respiratory Distress Syndrome) Network was able to demonstrate for the first time the tremendous effect of such ventilatory modes on patient morbidity and mortality. Since then, mortality in ARDS patients has come down from close to 50% to about 25%, and it is still dropping.

While research focused on the initial ventilation phase for decades, the process of weaning patients from the ventilator eventually began to receive more and more attention. It was recognised that the weaning process is normally longer than the period of acute respiratory failure. A better understanding of the pathophysiology of weaning failure, which no longer focused only on the lung but also took the respiratory muscle pump and pulmonary haemodynamics into account, led to further development of new ventilator modes supporting the patient's own breathing efforts and allowing earlier determination of analgosedation. In a similar manner to protective ventilation in the acute phase of respiratory failure, the improvement and standardisation of the weaning process had an impressive impact on the long-term prognosis of ventilated patients.

Optimisation of both parts of ventilation, the period of acute lung injury and the weaning phase, is still not complete. New ventilatory modes, *i.e.* high-frequency oscillatory ventilation for the acute phase or neurally adjusted ventilatory assistance for the weaning period, have been demonstrated to reduce complications of mechanical ventilation and may therefore improve long-term outcome. Nevertheless, the next step in development has yet to begin. Extracorporeal lung assist (ECLA) systems that remove carbon dioxide and improve oxygenation have become far smaller and offer better handling than 20 years ago. Complications such as massive bleeds or cytokine burst due to activation of the inflammatory cells by the device itself have been

reduced. ECLA systems can now be used for weeks and allow a further reduction in the pressure applied by the ventilator. The amount of inflammation seems to be reduced in comparison with ventilation alone. Close to the time of writing, implementation of awake extracorporeal membrane oxygenation in patients on the lung transplant waiting list, with no analgesia and intubation for critical hypoxaemia, was reported, and a 30% improvement in survival was shown in comparison with a historical control group.

The future vision of this kind of development is the engineering of a biocompatible membrane for lung assist, which can be used in chronic cases for months and years. This may take time; however, 30 years ago nobody even considered this possibility.

This volume of the *European Respiratory Monograph* provides a summary of the current state-of-the-art in mechanical ventilation, beginning with the actual pathophysiological concepts and ending with developing technologies.

I want to congratulate the Guest Editors of this excellent *Monograph*, which will be of interest to basic scientists and clinicians, and may have an impact on clinical practice in intensive care medicine. I am convinced that this *Monograph* will be useful in daily practice.

T. Welte
Editor in Chief

Introduction

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Severe acute respiratory failure is one of the most frequent causes for patient admission to the intensive care unit (ICU). In the most severe conditions, invasive mechanical ventilation is required life support in these patients.

The polio epidemic that occurred in Denmark in 1952 demonstrated how careful airway management and the application of positive-pressure ventilation could dramatically reduce mortality in patients presenting with paralysis of the respiratory muscles. The focus on airway care and ventilator management encouraged the way forward for critical care facilities. Technological advances in the 1960s led to the development of sophisticated, physiological monitoring equipment. Later, further developments were introduced that included: improved understanding of mechanical ventilation pathophysiology in patients with severe-acute respiratory failure; the production of ventilators with improved technology, new ventilator modes that were aimed at improving patient outcomes; and since the early 1990s, the introduction of noninvasive ventilation (NIV) as a less invasive mode of ventilatory support in patients with intermediate severity of respiratory failure.

Mechanical ventilation is currently the life support technique most frequently used in critically ill patients who are admitted to the ICU, and an extensive body of literature has been published within this topic. The appropriate knowledge on mechanical indications and settings is mandatory in order to develop and implement protective ventilation strategies and avoid possible iatrogenic effects.

This *European Respiratory Monograph* is intended as an update on various aspects and novel developments that have occurred in recent years within the field of mechanical ventilation. Topics that have been included are conventional and innovative ventilator modalities, adjuvant therapies that include sedation and analgesia, modes of extracorporeal support, weaning from mechanical ventilation, ventilator strategies in different clinical conditions, complications of mechanical ventilation and prevention, and NIV.

As Guest Editors we invited international experts to write up-to-date reviews based on their expertise and long-time experiences within this field. We would like to take this opportunity to warmly thank all the contributors for their enthusiasm and hard work. We are also indebted to Professor Tobias Welte, Editor in Chief of the *European Respiratory Monograph*, as well as all those at the European Respiratory Society Publications Office for their excellent technical help with producing this fifty-fifth issue of the *European Respiratory Monograph*.