# Contents


## SECTION 1 HISTORICAL PERSPECTIVES

1. **Evolution of Noninvasive Mechanical Ventilation ..... 3**
   *Atul Prabhakar Kulkarni, Kushal Rajeev Kalvit*

2. **Development of Invasive Mechanical Ventilation ..... 7**
   *Deven Juneja, Sahil Kataria, Prashant Nasa*

## SECTION 2 PHYSIOLOGY

3. **Physiology of Control of Breathing ..... 17**
   *Nimisha Majeed, Prashant Nasa*

4. **The Mechanics and Physics of Positive Pressure Ventilation ..... 23**
   *Farhad Kapadia, Pandurang Tekawade, Mikhail Tigga*

5. **Alveolar Ventilation ..... 33**
   *Jacob George*

6. **Physiology of Gas Exchange ..... 38**
   *Sanjoli Singhal, Keerthana K, Vijaya Patil*

7. **Compliance, Elastance, Resistance, and Inertance ..... 46**
   *Amandeep Singh, Supradip Ghosh*

8. **Work of Breathing ..... 51**
   *Ranajit Chatterjee, Lalit Gupta*

9. **Mechanical Power: Current Implications on Ventilator-induced Lung Injury ..... 60**
   *Ram E Rajagopalan*

10. **Pulmonary Circulation ..... 66**
    *Xavier Monnet*

11. **Hemodynamic Effects of Mechanical Ventilation ..... 72**
    *Jean-Louis Teboul, Mathieu Jozwiak*

12. **Physiology of Proning ..... 77**
    *JV Peter, Nazneen Makhbool*

## SECTION 3 TECHNOLOGY

13. **What is a Ventilator and how does it Work? ..... 89**
    *Jignesh Navinchandra Shah, Shivakumar S Iyer*

## SECTION 4 SECURING AIRWAY FOR MECHANICAL VENTILATION

**14. Endotracheal Intubation in the Critically Ill ..... 97**
*Atul Prabhakar Kulkarni, Shilpushp Jagannath Bhosale*

**15. Surgical and Percutaneous Tracheostomy ..... 104**
*Sachin Gupta, Deeksha Singh Tomar*

**16. Complications of Artificial Airway ..... 113**
*Balaji Kannamani, Shrikanth Srinivasan*

## SECTION 5 SEDATION, ANALGESIA, AND MUSCLE RELAXANTS IN A VENTILATED PATIENT

**17. Analgosedation During Mechanical Ventilation ..... 121**
*Ruchira Wasudeo Khasne, Atul Prabhakar Kulkarni*

**18. Muscle Relaxants and Their Use During Mechanical Ventilation ..... 128**
*Shilpushp Jagannath Bhosale, Atul Prabhakar Kulkarni*

**19. Care of a Sedated and Ventilated ICU Patient ..... 134**
*Kanwalpreet Sodhi, Jyoti Sharma, Manender Kumar*

**20. Nutrition in Mechanical Ventilation ..... 143**
*Radha Reddy Chada, Ganshyam Jagathkar*

## SECTION 6 ADJUNCTS TO MECHANICAL VENTILATION

**21. Humidification During Mechanical Ventilation ..... 153**
*Kushal Rajeev Kalvit, Atul Prabhakar Kulkarni*

**22. Aerosol Therapy during Mechanical Ventilation: Mucolytics, Bronchodilators, and Antibiotics ..... 159**
*Pankaj Anand, Hetal Manghwani, Nitesh Surolia*

**23. Endotracheal Suctioning of Mechanically Ventilated Patients ..... 172**
*Harjit Dumra, Mansi Dandnaik*

**24. Postural Drainage ..... 176**
*Natesh Prabu R, Muralidharan R, Sankar Ganesh*

**25. Fiberoptic Bronchoscopy in ICU ..... 182**
*Suresh Ramasubban, Subhajit Sen*

**26. Diaphragmatic Pacing ..... 189**
*Vikram Damaraju, Inderpaul Singh Sehgal*

**27. Surfactant Therapy ..... 195**
*Babu K Abraham, Balaji Venkatachalam, Venkatesh N*

**28. Inhaled Nitric Oxide ..... 202**
*Udhayachandar R, Subramani Kandasamy*

**29. Fluid Management in the Mechanically Ventilated Patient ..... 211**
*Siebe G Blok, Marcus J Schultz, Pieter R Tuinman*

## SECTION 7 MONITORING DURING MECHANICAL VENTILATION

**30. Oximetry, Time, and Volumetric Capnography ..... 227**
*Suhail Sarwar Siddiqui, Satish Vishnu Sarode*

**31. Arterial Blood Gas Analysis ..... 238**
*Srinivas Samavedam, Dinesh Kumar Gontla*

**32. Esophageal Pressure and Transpulmonary Pressure Monitoring ..... 248**
*Sanjith Saseedharan*

**33. Monitoring Cardiac Function During Mechanical Ventilation ..... 253**
*Antoine Vieillard-Baron*

**34. Electrical Impedance Tomography ..... 258**
*Sameer Jog, Prasanna Marudwar, Kaushal Shantikumar Shah*

**35. Ventilator Graphics ..... 269**
*Jigeeshu V Divatia, Kushal Rajeev Kalvit*

**36. Cuff Pressure Measurement ..... 277**
*Jignesh Navinchandra Shah, Manoj Raju Prabandhankam*

**37. Ultrasonography in a Ventilated Patient ..... 284**
*Anant Vikram Pachisia, Deepak Govil*

## SECTION 8 INDICATIONS FOR INITIATION OF MECHANICAL VENTILATION

**38. Indications for Mechanical Ventilation ..... 295**
*Nirmal Jaiswal*

**39. Initiating Volume-Controlled Ventilation ..... 298**
*Nikhil Balankhe*

**40. Pressure Control Ventilation ..... 304**
*Pradyut Bag, Rajesh Pande*

## SECTION 9 CONVENTIONAL MODES OF INVASIVE MECHANICAL VENTILATION

**41. Assist-Control Ventilation ..... 313**
*Rajesh Chawla, Haritha Indulekha, Aakanksha Chawla Jain*

**42. Intermittent Mandatory Ventilation and Synchronized Intermittent Mandatory Ventilation ..... 320**
*Swarna Deepak Kuragayala, Laxminarayana T, Khalid Ismail Khatib*

**43. Pressure Support Ventilation ..... 325**
*Jayant Shelgaonkar*

**44. Cardiopulmonary Physiology of Positive End-expiratory Pressure ..... 328**
*Lauren T Thornton, John J Marini*

## SECTION 10 NONCONVENTIONAL MODES OF MECHANICAL VENTILATION

**45. Inverse Ratio Ventilation and Airway Pressure Release Ventilation ..... 341**
*Dhruva Chaudhry, Samruddhi D Chougale*

**46. Proportional Assist Ventilation ..... 346**
*Sanjay Walke, Dilip R Karnad*

**47. Neurally Adjusted Ventilatory Assist ..... 351**
*GC Khilnani, Suman Banerjee, Vinnie Sarah Ch Sangma*

**48. Mid-frequency Ventilation ..... 360**
*Kushal Rajeev Kalvit, Atul Prabhakar Kulkarni*

**49. High-frequency Oscillatory Ventilation ..... 364**
*Rakesh Mohanty, Atul Prabhakar Kulkarni*

**50. Average Volume-assured Pressure Support Ventilation ..... 377**
*Kayanoosh Kadpatti, Jayant Mane*

**51. Volume Support ..... 380**
*Atul Prabhakar Kulkarni, Gagana BN*

**52. Adaptive Support Ventilation ..... 383**
*Yeldho Eason Varghese, Praveen Kumar Ghisulal*

**53. Proportional Assist Ventilation ..... 387**
*Bharath Kumar P, Palepu B Gopal*

**54. Mandatory Minute Ventilation ..... 391**
*Saurabh Nanda, Yatin Mehta*

**55. Automatic Tube Compensation ..... 396**
*Shweta Ram Chandankhede, Atul Prabhakar Kulkarni*

**56. SmartCare®/PS ..... 400**
*Adam Gary Bennett, Praveen Kumar Ghisulal*

**57. Transtracheal Gas Insufflation and Transtracheal Jet Ventilation ..... 403**
*Khusrav Bajan, Shradha K Bajan*

**SECTION 11 NONINVASIVE VENTILATION**

**58. High-flow Nasal Cannula ..... 415**
*Ruchira Wasudeo Khasne, Kalpesh Parekh, Atul Prabhakar Kulkarni*

**59. Noninvasive Ventilation in the Critically Ill ..... 422**
*Khalid Ismail Khatib, Subhal Bhalchandra Dixit*

**SECTION 12 EXTRACORPOREAL THERAPIES**

**60. Extracorporeal Carbon Dioxide Removal ..... 431**
*Arpan Chakraborty*

**61. Extracorporeal Membrane Oxygenation ..... 439**
*Nilesh Purushottam Mahale, Deepak Sethia, Kaushal Shantikumar Shah*

**SECTION 13 VENTILATION IN SPECIFIC SITUATIONS**

**62. Mechanical Ventilation in the Neonatal and Pediatric Patients ..... 453**
*Sudivya Sharma, Shilpushp Jagannath Bhosale*

**63. Independent Lung Ventilation ..... 460**
*Afzal Azim, Teenu Singh*

**64. Patient with Bronchopleural Fistula ..... 468**
*Abhishek Samprathi, Manu Varma MK, Mohan Gurjar*

**65. Mechanical Ventilation in Acute Respiratory Distress Syndrome ..... 476**
*Jigeeshu V Divatia, Kushal Rajeev Kalvit*

**66. Asthma and Mechanical Ventilation ..... 482**
*Pradip Kumar Bhattacharya, Tushar Kumar*

**67. Mechanical Ventilation in Chronic Obstructive Pulmonary Disease Patients ..... 488**
*Shrirang Nagorao Bamne, Atul Prabhakar Kulkarni, Kapil Gangadhar Zirpe*

**68. Mechanical Ventilation in Patients with Restrictive Pulmonary Disorders ..... 497**
*Adarsh Kulkarni, Sunil Karanth*

**69. Mechanical Ventilation in Patients with Severe Traumatic Brain Injury ..... 502**
*Charu Mahajan, Indu Kapoor, Hemanshu Prabhakar*

**70. Ventilating a Patient with Neuromuscular Disorders ..... 508**
*Binila Chacko, Anju Susan Jacob*

**71. Transport of Mechanically Ventilated Patients ..... 519**
*Manish Munjal, Samaresh Das, Sumit Bajaj*

**72. Home Mechanical Ventilation ..... 527**
*Raj Kumar Mani*

**SECTION 14 CARING FOR A VENTILATED PATIENT**

**73. Patient–Ventilator Asynchrony ..... 533**
*Sumalatha Arunachala, Jeevan J, Atul Prabhakar Kulkarni*

**74. Recruitment Maneuvers ..... 547**
*Bhuvana Krishna, Dipali Anand Taggarsi*

**75. Early Mobilization and Physical Activity in Mechanically Ventilated Patients ..... 556**
*Alisha Chaudhury, Swagata Tripathy*

**76. Psychosocial Care for Intensive Care Unit Survivors ..... 560**
*Thiruchengodu Raju Kanmani, Birudu Raju*

**77. Sleep Deprivation and Solutions for a Ventilated Patient ..... 569**
*Anshu Punjabi, Pavankumar Biraris, Ravindra M Mehta*

**78. Speaking During Mechanical Ventilation in Patients with a Tracheostomy: A Clinical Practice Guide from an International Perspective ..... 579**
*PH Egbers, Anna-Liisa Sutt, Sarah Wallace*

**79. Liberation and Weaning from Mechanical Ventilation ..... 601**
*Tài Pham, Valentine Le Stang, Martin Dres, Rémi Coudroy*

**80. Extubation in a Critically Ill Patient ..... 612**
*Kushal Rajeev Kalvit, Atul Prabhakar Kulkarni*

## SECTION 15 VENTILATOR-ASSOCIATED CONDITIONS

**81. Ventilator-induced Lung Injury ..... 621**
*Subhash Todi, Chandan Biswas, Amit Das*

**82. Patient Self-inflicted Lung Injury ..... 626**
*Urvi Shukla, Archana Gautam, George Savio Chalam*

**83. Sinus Infections in a Ventilated Patient ..... 634**
*Pradeep Michael D'Costa*

**84. Ventilator-associated Tracheitis and Pneumonia ..... 643**
*Darshana Rathod, Rahul Pandit*

**85. Oxygen Toxicity ..... 650**
*Neelmani Ahuja, Ruchi Gupta, Sumit Ray*

**86. Diaphragmatic Dysfunction ..... 659**
*Amol Trimbakrao Kothekar, Anand Vinaykumar Joshi, Sallyanne Strathdee*

**87. Intensive Care Unit-acquired Weakness in Ventilated Patients ..... 669**
*Ross Freebairn, Elizabeth Bennett*

*Index ..... 679*