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A Handbook of Pediatric & Neonatal Mechanical Ventilation

Special Features

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- An Exclusive Handbook for PICU & NICU Residents and Fellows
- A Perfect Amalgamation of Theoretical and Clinical Aspects
- Original Ventilator Graphics Included

Foreword

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Binod Kumar Singh

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A Handbook of Pediatric & Neonatal Mechanical Ventilation

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Preface

With the advancement in medical science, the importance of life-saving devices is getting more and more crucial, and mechanical ventilator is one of them. In fact, the mechanical ventilator is one of the most important weapons in the armamentarium of any neonatal or pediatric intensive care unit. So, learning the art and science of mechanical ventilation is essential for postgraduate students of pediatrics, and neonatologists, intensivists as well as practicing pediatricians.

This handbook aims to provide the art and science of pediatric & neonatal mechanical ventilation. This book has been designed to address the needs of clinicians, residents and postgraduates. The **Latest Guidelines and Recommendations** have been incorporated throughout the text. The book comprises 24 chapters and covers almost all the aspects of pediatric & neonatal ventilation, such as working principle, physiology and modes of ventilation, initial ventilator settings and disease-specific ventilation, supportive care during ventilation, extubation, complications of ventilation, high frequency ventilation, and non-invasive ventilation (CPAP & HFNC).

Pulmonary graphics are dealt within detail along with adequate number of figures. I have consciously added arterial blood gas analysis to improve understanding in care of ventilated babies. The content of each chapter has been made lucid through liberal use of flow charts, tables and figures. The primary goal of this book is to improve the survival rate of critically ill neonates and children without causing significant residual handicap.

The contents of the book will guide practicing pediatricians to learn and start ventilation in smaller setups, too. It will certainly help those who want to start ventilation and improve the quality of care for the children requiring ventilation.

I am sure that the book will meet the expectations of the readers.

Saroj Kumar

Contents

CHAPTER 8

Respiratory Monitoring

INTRODUCTION

Monitoring of oxygenation and ventilation is of utmost importance in ventilated patients. Clinically, cyanosis is visible only when saturation falls in the range of 70%. Therefore, we need to depend upon pulse oximetry for oxygen saturation and capnography for CO_2 monitoring.

PULSE OXIMETRY

It is continuous, non-invasive measurement of oxygen saturation in arterial blood (Fig. 8.1).

Basic Principles

(Beer-Lambert Law):

Pulse oximetry is based on the Beer-Lambert Law, which states that the absorption of light of a given wavelength is proportional to the product of the solute concentration and the light path length. It is based on the principles of spectrophotometry and photoplethysmography.

- **Spectrophotometry:** Oxygenated hemoglobin and reduced hemoglobin have different absorption spectra at different wavelengths of light (red and near infrared). Oxyhemoglobin absorbs more infrared light and less red light. Deoxyhemoglobin has an inverse pattern of absorbance. Saturation is calculated by the ratio of red/infrared absorbencies.

Figure 8.1: Pulse oximeter

- **Photoplethysmography:** The amount of light absorbed by blood in the tissue changes with the arterial pulse. As arterial blood flow is pulsatile, blood volume increases in systole and so does the light absorption. Change in ratio of absorption between systole and diastole is used to calculate the arterial saturation. The light absorbed by non-pulsatile structure such as extravascular tissue and vein are constant and so eliminated as they represent a baseline. This is why pulse oximetry detects only arterial blood saturation.

Accuracy of Pulse Oximetry and Its Interpretation

At saturation greater than 70%, SpO_2 (measured by pulse oximeter) and SaO_2 (obtained by ABG) are within 2% of each other.

Pulse oximeter measures SpO_2 **NOT** PaO_2. Relationship between these two variables is not linear. Beyond PaO_2 of more than 90 mm Hg, oxyhemoglobin is nearly 100% saturated. Hence, SpO_2 values will not give any idea of PaO_2 beyond 90 mm Hg. That is why pulse oximetry does not detect hyperoxemia very well **(Table 8.1)**.

Demerits

- Poor accuracy in low perfusion state, hypothermia, nail polish.
- In very bright ambient light, it may not read the SpO_2 or show falsely low SpO_2.
- There may be motion artefact, especially during transport, during shivering or convulsion.
- It provides little information of ventilation and acid base status. Clinically significant change in pH and/or $PaCO_2$ may occur with little change in SpO_2.
- Falsely low or high SpO_2 reading due to abnormal hemoglobins.
  - In case of Carboxyhaemoglobin (COHb) – SpO_2 may be falsely high.
  - In case of Metahemoglobinemia SpO_2 may be falsely low. SPO_2 will drop as metHb concentration rises. Usually SpO_2 will not decrease below 85%.

Oxygen Saturation Gap

It is the difference between the calculated oxygen saturation from ABG machine (SaO_2) and the reading from a pulse oximeter (SpO_2). If oxygen saturation gap is more than 5%, it indicates abnormal hemoglobins, like carbon monoxide poisoning, methemoglobinemia, sulfhemoglobinemia.

Table 8.1: Relationship between PaO_2 and SaO_2

PaO_2 (mm Hg)	SaO_2%
0	0
10	10
26.6	50
40	75
60	91
100	97.5
150	98.8

END TIDAL CARBON DIOXIDE MONITORING

Capnography

It is the measurement and graphical display of amount of CO_2 in respired gases. $ETCO_2$ is the alveolar CO_2 at the end of exhalation **(Fig. 8.2)**.

Capnography is based on the principle of infrared absorption spectrophotometry. In clinical practice, Time capnography is commonly used.

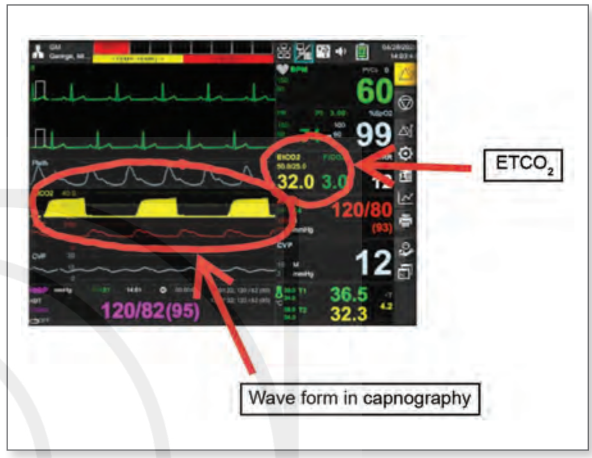

Figure 8.2: End tidal carbon dioxide monitoring

Time Capnography

CO_2 concentration in inspiratory and expiratory gas is plotted against time **(Fig. 8.3)**. It consists of four phases:

- **Phase I:** It is beginning of expiration, gases from anatomical dead space which are free of CO_2, are exhaled.
- **Phase II:** Alveolar gas mixed with dead space, CO_2 rapidly rises
- **Phase III:** CO_2 elimination from alveoli. CO_2 is maximal at the end of tidal breath known as $ETCO_2$. Therefore, $ETCO_2$ is measured at the maximal point of phase III.
- **Phase IV:** Inspiratory phase

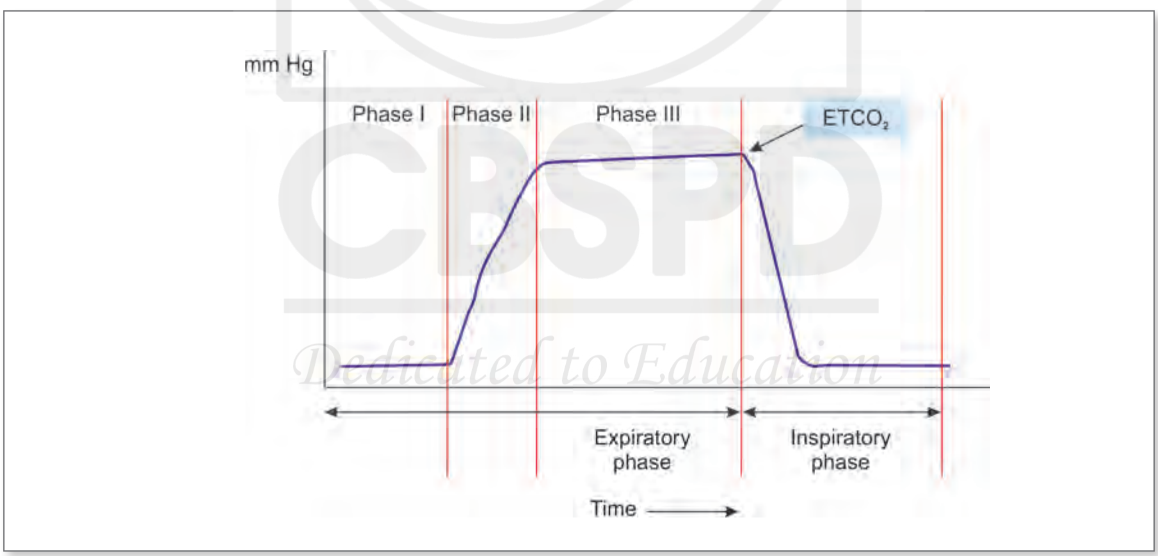

Figure 8.3: Time capnography

Usually the difference between arterial PCO_2 (in ABG) and alveolar PCO_2 ($ETCO_2$ from capnograph) is 2–5 mm Hg.

Interpretation of Various Waveforms in Capnography

- **Normal waveform (Fig. 8.4):**

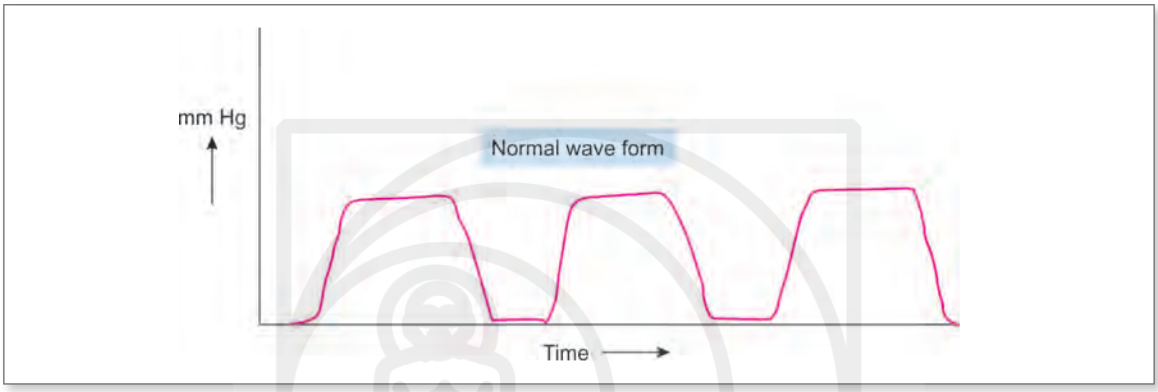

Figure 8.4: Normal waveform

- **Shark fin waveform (Fig. 8.5):** In case of airway obstruction (asthma)
  Obstruction in the airway causes a turbulent mixing of dead space air with alveolar air. This mixing softens the rapid rise in CO_2 concentration in exhaled air leading to shark fin waveform.

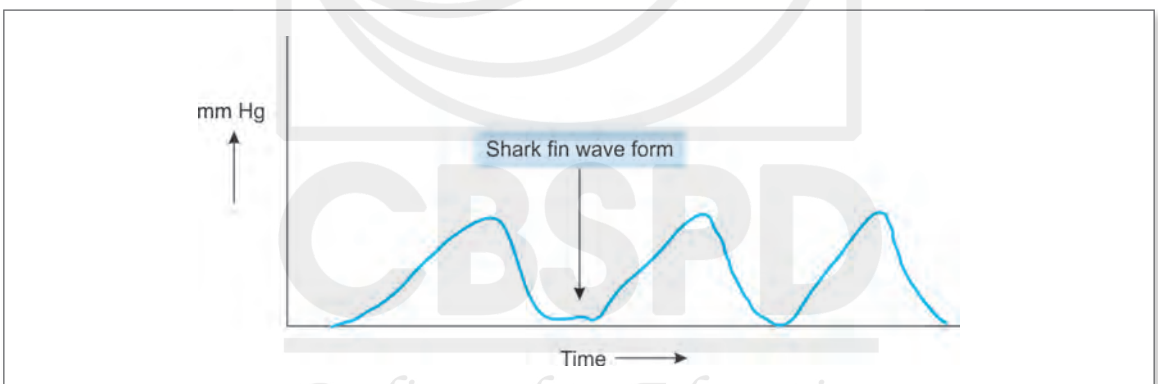

Figure 8.5: Shark fin waveform

- **Spontaneous inspiratory efforts (Fig. 8.6):**
  A commonly seen abnormal capnogram results when the patient make spontaneous respiratory efforts before next mechanical inspiration. This produces a characteristic notch in the alveolar plateau.

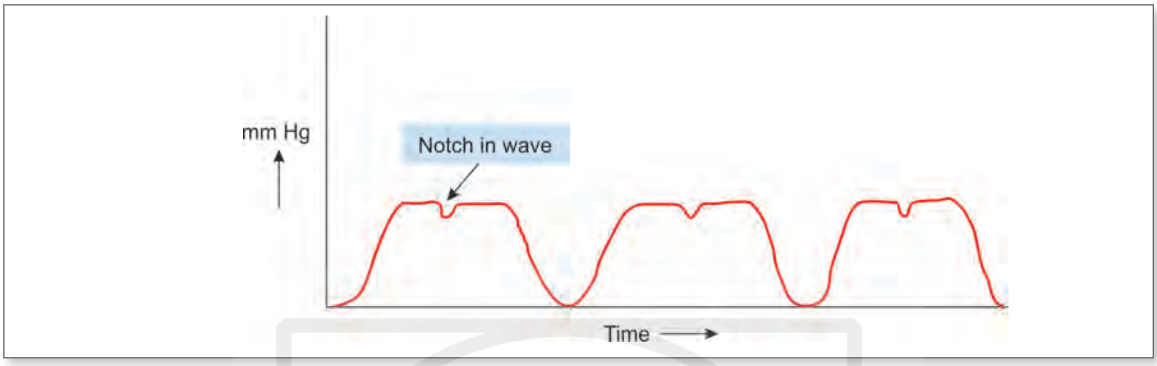

Figure 8.6: Spontaneous inspiratory efforts

- **Sudden loss of waveform in case of dislodged ET tube (Fig. 8.7):**
  Capnograph depends on air movement in and out of lungs. In case of dislodged ET tube there will be no movement of air and so loss of waveform.

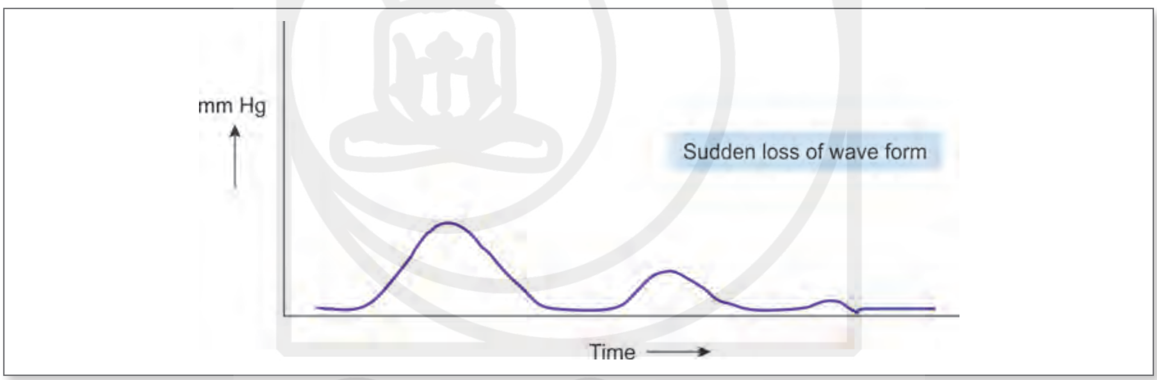

Figure 8.7: Sudden loss of waveform in case of dislodged endotracheal tube

- **Leak around ET tube (Fig. 8.8):**
  Capnography waveform with a peaked, triangular appearance suggests that there is a significant leak around the endotracheal tube.

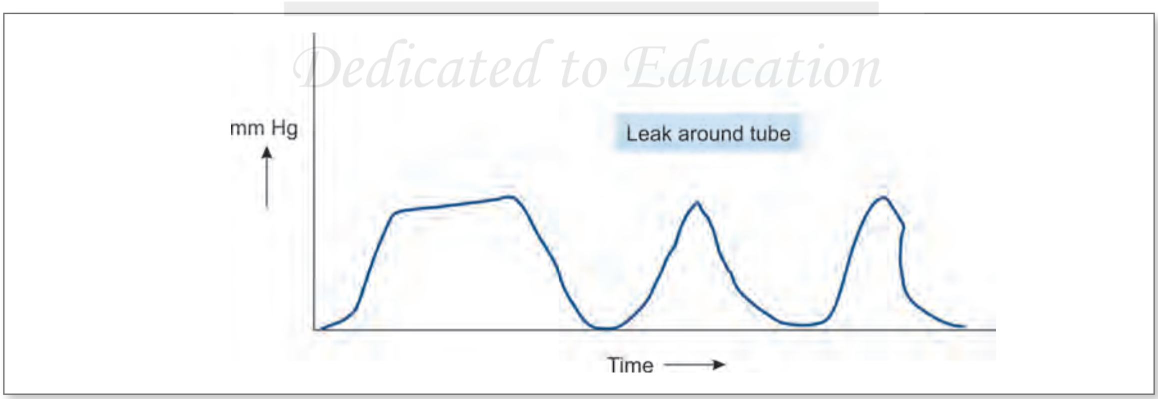

Figure 8.8: Leak around endotracheal tube

- **Rebreathing in case of faulty expiratory valve or insufficient expiratory time (Fig. 8.9):** In this condition CO_2 does not get completely washed out and that is why wave form is not reaching the baseline.

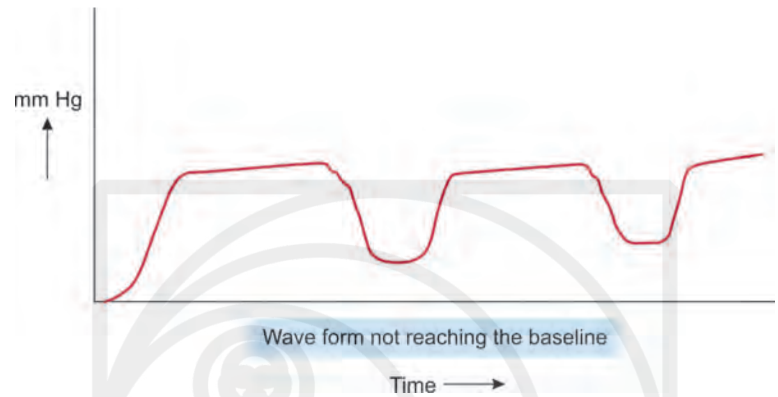

Figure 8.9: Rebreathing in case of faulty expiratory valve

Importance of $ETCO_2$ during CPR

- It is used to evaluate the quality of CPR
- During high quality chest compression, $ETCO_2$ value is 10–20 mm Hg
- Low $ETCO_2$ value of <10 mm Hg during CPR of intubated patient indicates inadequate chest compression.

FURTHER READINGS

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A Handbook of

Pediatric & Neonatal Mechanical Ventilation

Salient Features

- Written by an eminent and highly experienced AIIMS alumnus
- This handbook presents a bird's eye view of the required mechanical ventilation modes specific to the neonates
- The handbook keeps its focus on the use of different ventilators in PICU and NICU for the benefits of the readers
- It comprises eye-catching colored illustrations, tables and images to ease the study
- It contains original ventilator graphics to enhance the understanding
- Excerpts of the most recent Cochrane Database of Systemic Reviews are included to augment the utilities of this handbook
- Clinical Implications are incorporated in this handbook to know the reason behind a clinical situation
- Under Applied Aspect Boxes, a situation is discussed with explanation for critical thinking
- Thumb Rule and Note boxes have been included to highlight the most important points to be kept in mind while using a technique or equipment

About the Author

Saroj Kumar *MBBS, MD (Pediatrics), PGPN (Boston University),* is currently working as an Assistant Professor in the Department of Pediatrics, Nalanda Medical College & Hospital, Patna and as Deputy Superintendent, Nalanda Medical College & Hospital, Patna (Bihar). He has brilliant academic career spanning 12 years after his completion of MD in Pediatrics. He is also currently serving in the Association of Pediatricians as Honorary Secretary of Indian Academy of Pediatrics, Bihar state branch. He has been a prolific researcher. He has also been contributing as an Associate Editor in Journal of Clinical Pediatrics. He is a well-recognized pediatrician, public health expert and teacher with pivotal contributions to Indian Academy of Pediatrics. He has published more than 20 original articles in various national and international journals. The author has contributed many chapters in different books of national repute. He has been awarded prestigious SHISHU SHIROMANI award of East zone by honorable health minister of Bihar, Sri Mangal Pandey (2018) and PRATIBHA SAMMAN award by honorable minister Dr C P Thakur (2017). He has significant online presence through YouTube channel on Pediatric Health care named DR SAROJ KUMAR.

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