

Steven M. Donn
Sunil K. Sinha *Editors*

Manual of Neonatal Respiratory Care

Fourth Edition

 Springer

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ISBN 978-3-319-39837-2 ISBN 978-3-319-39839-6 (eBook)
DOI 10.1007/978-3-319-39839-6

Library of Congress Control Number: 2016955829

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Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Foreword

A successful transition from fetal to neonatal life is dependent upon the profound cardiorespiratory adaptations occurring at this time. Unfortunately, these events frequently require medical intervention, especially in preterm infants. The consequences of the resultant pathophysiologic changes and therapeutic interventions in such neonates may have long-lasting effects on the developing respiratory system and even the neurodevelopmental outcome of this high-risk population.

Recognition of the importance of neonatal respiratory management was an early milestone in the history of neonatology. The role of surfactant deficiency in the etiology of neonatal respiratory distress syndrome was sealed over 50 years ago, and this paved the way for the introduction of assisted ventilation for this population in the 1960s. I was privileged to be introduced to neonatal pediatrics in the early 1970s at a time when the advent of continuous positive airway pressure demonstrated how physiologic insight can be translated into effective therapy. The decade of the 1970s offered so many other innovations in neonatal respiratory care. These included noninvasive blood gas monitoring, xanthine therapy for apnea, and our first real understanding of the pathogenesis and management of meconium aspiration syndrome, group B streptococcal pneumonia, and persistent fetal circulation or primary pulmonary hypertension of the newborn, three frequently interrelated conditions. The decade ended in remarkable fashion with the introduction of exogenous surfactant therapy and recognition that the novel new technique of high-frequency ventilation allows effective gas exchange in sick neonates. However, many key questions in neonatal respiratory care still need to be addressed.

For preterm infants the enormous challenge remains to reduce the unacceptably high incidence of bronchopulmonary dysplasia which approaches 50% in the smallest survivors of neonatal intensive care. The current fourth edition meets this dilemma head on by clearly acknowledging such issues as the increasing role of noninvasive ventilatory techniques and the challenge of optimizing oxygenation, both in the delivery room and beyond. It remains to be seen, however, whether the latest supportive ventilatory measures, together with safe pharmacotherapy, can diminish morbidity in NICU graduates. New sections on data collection and quality improvement demonstrate their key roles in addressing these challenges.

For preterm or term infants with malformations of the respiratory system, advances in pre- and postnatal imaging and surgical techniques hold promise for improved outcome. Great strides are being made simultaneously in our understanding of the molecular basis for normal and abnormal lung development. Furthermore, it is being increasingly recognized that genotypic characteristics may greatly influence the consequences of subsequent environmental exposures on lung development. These scientific advances need to be translated into improving adverse neonatal outcomes, such as the unacceptably high rate of wheezing disorders and asthma in the survivors of neonatal intensive care. As care providers to neonates, it is our responsibility to encourage clinical trials and other patient-based investigation that will allow us to optimize the outcome of neonatal respiratory care.

The fourth edition of the *Manual of Neonatal Respiratory Care* is comprehensive and provides an important educational tool to address many of these challenges. It is, again, thoroughly edited by the accomplished trans-Atlantic team of Steven Donn and Sunil Sinha. Once again, they have assembled physician/scientist leaders in the field of Developmental Pulmonology, who provide a true international perspective to neonatal respiratory care. Both prior and new contributors provide a concise overview that spans neonatal physiology, pathogenesis of disease, and unique approaches to management of both simple and complex neonatal respiratory disorders. The result is a comprehensive text that provides a strongly international insight into neonatal respiratory care in a user-friendly, practical format.

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Preface

Since the publication of the third edition of this Manual in 2012, much has happened in the field of neonatal respiratory care. We are experiencing somewhat of a divergence—equipment continues to become more technologically advanced, but management philosophy is moving towards a more simplistic approach, characterized by an increasing popularity of noninvasive support. This edition of the *Manual of Neonatal Respiratory Care* encompasses both aspects of the change in neonatal practice.

Standard chapters have been updated to reflect advances in both equipment and practice. We have eliminated chapters dealing with equipment which is no longer in use and replaced them with newer chapters that reflect the worldwide approaches to neonatal respiratory failure, such as sustained inflation, optimization of lung volume, and the use of volumetric capnography, aerosol therapy, and management of chylothorax. A major addition is an expansive chapter on disorders of the neonatal airway. We have expanded our contributors to include experts from all over the world. A special emphasis has been placed on noninvasive ventilation, including CPAP, nasal cannula therapy, nasal intermittent positive pressure ventilation, and associated devices.

New additions to the book also include chapters on assessment of large databases and implementation of quality improvement programs in neonatal respiratory care. Chronic ventilation of the baby with nonrespiratory ventilator dependency is now also addressed.

A major feature that we have added to this edition is the adoption of a standard taxonomy to classify mechanical ventilators. We have long felt that this has been a shortcoming within the industry, and that manufacturers often refer to the same thing by different and confusing terminology, frequently resulting in jeopardy to patient safety. We were very fortunate to enlist the services of Rob Chatburn in this regard. He has been a champion of a singular classification system. Not only did he author a chapter on this (chapter 44), he graciously and painstakingly co-edited the chapters on mechanical ventilation and inserted a “Mode Map” for each of the devices included in this edition. We are most grateful to him for taking the time and effort to do so.

Others participating in the preparation of this edition are also due a debt of gratitude, including Susan Peterson, who standardized the format and appearances of 100 chapters from more than 100 contributors; Brian Halm, our development editor at Springer; Andy Kwan, our publishing editor at

Springer; and Shelley Reinhardt, a former acquisitions editor at Springer, who was instrumental in continued support of the Manual at the inception of the fourth edition. Most of all, we thank our esteemed group of contributors for continuing to share their time and expertise in the hope of improving the care of newborns in respiratory distress.

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Contents

Section I Lung Development and Maldevelopment

- 1 Development of the Respiratory System** 3
Vinod K. Bhutani
- 2 Malformations, Deformations, and Disorders
of the Neonatal Airway** 13
Janet Lioy, Elizabeth Greubel, and Steven Sobol
- 3 Developmental Lung Anomalies** 37
Mohammad A. Attar and Subrata Sarkar

Section II Principles of Mechanical Ventilation

- 4 Spontaneous Breathing** 43
Vinod K. Bhutani
- 5 Pulmonary Gas Exchange** 51
Vinod K. Bhutani
- 6 Oxygen Therapy** 59
Win Tin
- 7 Oxygen Toxicity** 65
Ola Didrik Saugstad
- 8 Pulmonary Mechanics and Energetics** 71
Anton H.L.C. Van Kaam and Vinod K. Bhutani
- 9 Basic Principles of Mechanical Ventilation** 83
Colm P. Travers, Waldemar A. Carlo,
Namasivayam Ambalavanan, and Robert L. Chatburn
- 10 Classification of Mechanical Ventilation Devices** 95
Colm P. Travers, Waldemar A. Carlo,
Namasivayam Ambalavanan, and Robert L. Chatburn
- 11 Ventilator Parameters** 103
Colm P. Travers, Waldemar A. Carlo,
Namasivayam Ambalavanan, and Robert L. Chatburn

12	Respiratory Gas Conditioning and Humidification	109
	Andreas Schulze	

Section III Procedures and Techniques

13	Cardiorespiratory Examination	119
	Avroy A. Fanaroff and Jonathan M. Fanaroff	
14	Neonatal Resuscitation	129
	Gary M. Weiner	
15	Laryngoscopy and Endotracheal Intubation	137
	Steven M. Donn	
16	Vascular Access	143
	Steven M. Donn	
17	Tracheostomy	147
	Steven M. Donn	

Section IV Monitoring the Ventilated Patient

18	Continuous Monitoring Techniques	153
	Christian F. Poets	
19	Clinical Controversies: Pulse Oximetry	159
	Win Tin and Samir Gupta	
20	Interpretation of Blood Gases	163
	Steven M. Donn	
21	Volumetric Capnography in Critically Ill Neonates and Children	171
	Joachim Zobel, Klaus Pfurtscheller, and Gerfried Zobel	
22	Neonatal Pulmonary Graphics	179
	Mark C. Mammel and Steven M. Donn	
23	Diagnostic Imaging	193
	Ramon Sanchez and Javier Lucaya	
24	Transillumination	219
	Steven M. Donn	
25	Echocardiography	223
	Jonathan P. Wyllie	
26	Bronchoscopy	233
	Neil N. Finer	

Section V Noninvasive Ventilatory Techniques

27	Nasal Interfaces for Noninvasive Ventilation	239
	Sherry Courtney	

28	Humidified High-Flow Nasal Cannula Therapy	241
	Andrea Lampland and Mark C. Mammel	
29	Continuous Distending Pressure	247
	Nicolas Bamat, Colin J. Morley, and Haresh Kirpalani	
30	Sustained Inflations	257
	Helmut D. Hummler	
31	Non-invasive Ventilation: An Overview	263
	Brigitte Lemyre and Haresh Kirpalani	
32	Nasal Intermittent Positive Pressure Ventilation	269
	Vineet Bhandari	
33	Precision Flow Vapotherm	275
	N. Kevin Ives	
 Section VI Ventilatory Modes and Modalities		
34	Intermittent Mandatory Ventilation	283
	Steven M. Donn and Sunil K. Sinha	
35	Synchronized Intermittent Mandatory Ventilation	289
	Steven M. Donn and Sunil K. Sinha	
36	Assist/Control Ventilation	293
	Steven M. Donn and Sunil K. Sinha	
37	Pressure Support Ventilation	297
	Sunil K. Sinha and Steven M. Donn	
38	Volume-Targeted Ventilation	301
	Steven M. Donn and Sunil K. Sinha	
39	Volume Guarantee Ventilation	305
	Martin Keszler	
40	Pressure Control Ventilation	311
	Steven M. Donn	
 Section VII High-Frequency Ventilation		
41	High-Frequency Ventilation: General Concepts	315
	J. Bert Bunnell	
42	High-Frequency Jet Ventilation	329
	Martin Keszler	
43	High-Frequency Oscillatory Ventilation	337
	Reese H. Clark	

Section VIII Commonly Used Neonatal Ventilators

44 Ventilator Mode Classification	349
Robert L. Chatburn	
45 VIP BIRD Gold Ventilator	353
Steven M. Donn	
46 AVEA Ventilator	359
Steven M. Donn and Anthony Iannetta	
47 Twinstream Ventilator	369
Gerfried Zobel	
48 Puritan Bennett 840 and Puritan Bennett 980 Ventilators	375
Robert L. Chatburn and Cyndy Miller	
49 Draeger VN500	381
Manuel Sanchez Luna	
50 SERVO-i Ventilator and NAVA	391
Jennifer Beck, Louis Fuentes, and Howard McDonald	
51 SLE5000 and SLE4000 Infant Ventilators	407
David G. Tingay, Barbara Pilgrim, and Sunil K. Sinha	
52 Stephanie and Sophie Ventilators	413
Helmut D. Hummler and Christian F. Poets	
53 Leoni Plus Ventilator	431
Felix Neunhoeffer and Christian F. Poets	
54 Bunnell Life Pulse High-Frequency Jet Ventilator	435
Martin Keszler	
55 High Frequency Oscillatory Ventilators	439
David G. Tingay	

Section IX Adjunctive Therapies

56 Hemodynamic Support	453
Keith J. Barrington	
57 Nutritional Support in Respiratory Failure	459
David H. Adamkin	
58 Surfactant Administration	477
Fernando Moya and Kathryn Colacchio	
59 Pharmacologic Agents	487
Varsha Bhatt-Mehta and Steven M. Donn	
60 Automatic Control of the Fraction of Inspired Oxygen	499
Nelson Claude and Eduardo Bancalari	

61	Aerosolization and Nebulization	505
	Jan Mazela	
62	Sedation and Analgesia	523
	Jenna Deeming and Elaine M. Boyle	
63	Inhaled Nitric Oxide Therapy	535
	John P. Kinsella	
64	Extracorporeal Membrane Oxygenation	543
	Robert E. Schumacher	
65	Liquid Ventilation for Neonatal Respiratory Failure	551
	Ronald B. Hirschl	
 Section X Management of Common Neonatal Respiratory Diseases		
66	Mechanisms of Respiratory Failure	557
	Anne Greenough and Anthony D. Milner	
67	Tissue Hypoxia	561
	Anne Greenough and Anthony D. Milner	
68	Indications for Mechanical Ventilation	565
	Anne Greenough and Anthony D. Milner	
69	Respiratory Distress Syndrome	567
	Steven M. Donn and Sunil K. Sinha	
70	Pneumonia in the Newborn Infant	573
	Thomas Hooven, Tara M. Randis, and Richard A. Polin	
71	Meconium Aspiration Syndrome	593
	Thomas E. Wiswell	
72	Persistent Pulmonary Hypertension of the Newborn	599
	Joseph O’Connell, Robert E. Schumacher, and Steven M. Donn	
73	Congenital Diaphragmatic Hernia	605
	Nitesh Singh and David Field	
74	Pulmonary Hypoplasia/Agensis	611
	Nitesh Singh and David Field	
75	Chylothorax	615
	Mohammad A. Attar	
76	Apnea, Bradycardia, and Desaturation	619
	Mary Elaine Patrinos and Richard J. Martin	
77	Optimizing Lung Volume	627
	Gianluca Lista and Francesca Castoldi	
78	Weaning and Extubation	633
	Steven M. Donn and Sunil K. Sinha	

Section XI Bronchopulmonary Dysplasia

- 79 Etiology and Pathogenesis** 643
Alexandra M. Smith and Jonathan M. Davis
- 80 Bronchopulmonary Dysplasia: Clinical Management** 651
Eduardo Bancalari
- 81 Long-Term Outcomes of Newborns
with Bronchopulmonary Dysplasia** 657
Sumesh Thomas, Prashanth Murthy, and Saroj Saigal

Section XII Complications Associated with Mechanical Ventilation

- 82 Thoracic Air Leaks** 665
Jennifer R. Bermick and Steven M. Donn
- 83 Patent Ductus Arteriosus** 673
Jonathan P. Wyllie
- 84 Neonatal Pulmonary Hemorrhage** 679
Tonse N.K. Raju
- 85 Retinopathy of Prematurity** 687
Alistair Fielder
- 86 Neurologic Complications of Mechanical Ventilation** 695
Vivien Yap and Jeffrey M. Perlman

Section XIII Other Considerations

- 87 Nursing Care of the Ventilated Neonate** 703
Kimberly LaMar
- 88 Transport of Ventilated Babies** 711
Steven M. Donn and Molly R. Gates
- 89 Role of the Respiratory Therapist in the NICU** 721
Timothy Myers
- 90 Long-Term Ventilator Dependency in Infants
Without Lung Disease** 729
Stamatia Alexiou and Joseph Piccione
- 91 Chronic Home Mechanical Ventilation** 733
Wan Chong Tsai
- 92 Discharge Planning and Follow-Up of the NICU Graduate** 737
Win Tin and Mithilesh Lal

Section XIV Ethical and Legal Considerations

93 Initiation of Life Support at the Border of Viability 747
 Naomi Laventhal, Joanne Lagatta, and William Meadow

**94 Withdrawal of Ventilatory Support:
 Clinical and Ethical Considerations..... 751**
 Malcolm L. Chiswick

95 Medical Liability, Documentation, and Risk Management 759
 Steven M. Donn and Jonathan M. Fanaroff

Section XV Research, Quality, and the Literature

96 Interpreting Clinical Research..... 765
 C. Omar Kamlin and Peter G. Davis

97 Data Collection and Assessment of Respiratory Outcomes..... 769
 Alan R. Spitzer

98 Practical Quality Improvement in the NICU 777
 Michelle Nemshak and Rebecca Vartanian

99 Contemporary Classics in Neonatal Respiratory Care 781
 Rachel L. Chapman

Section XVI Ventilatory Case Studies

100 Ventilatory Case Studies..... 789
 Brooke D. Vergales and Jay P. Goldsmith

Erratum to:..... E1

Appendix..... 803

Index..... 805

Abbreviations

\dot{V}	Flow
\ddot{V}	Rate of change of flow
°C	Degrees Celsius (Centigrade)
°K	Degrees, Kelvin
a	Arterial
A	Alveolar
a/A	Arterial/alveolar ratio
A/C	Assist/control
AAC	Automatic airway compensation
A-aDO ₂	Alveolar-arterial oxygen gradient
ABG	Arterial blood gas
ACT	Activated clotting time
ADP	Adenosine diphosphate
AH	Absolute humidity
ALTE	Apparent life-threatening event
AM	Morning
AMP	Adenosine monophosphate
Ao	Aortic
AOI	Apnea of infancy
AOP	Apnea of prematurity
AP	Antero-posterior
ARDS	Adult (or acute) respiratory distress syndrome
ASD	Atrial septal defect
ATP	Adenosine triphosphate
ATPS	Ambient temperature and pressure, saturated with water vapor
BAER	Brainstem audiometric evoked responses
BP	Blood pressure
BPD	Bronchopulmonary dysplasia
BPM (bpm)	Beats or breaths per minute
BR	Breath rate
BTPS	Body temperature and pressure, saturated with water vapor
C	Compliance
C20	Compliance over last 20 % of inflation
CCAM	Congenital cystic adenomatoid malformation
cAMP	Cyclic adenosine monophosphate

CBF	Cerebral blood flow
CBG	Capillary blood gas
cc	Cubic centimeter
C _D or C _{DYN}	Dynamic compliance
CDH	Congenital diaphragmatic hernia
CDP	Constant distending pressure
CF	Cystic fibrosis
cGMP	Cyclic guanosine monophosphate
CHAOS	Congenital high airway obstruction syndrome
CHD	Congenital heart disease
C _L	Compliance
CLD	Chronic lung disease
CLE	Congenital lobar emphysema
cm	Centimeter
CMV	Cytomegalovirus
CMV	Conventional mechanical ventilation
CNS	Central nervous system
CO	Cardiac output
CO ₂	Carbon dioxide
CO-Hb	Carboxyhemoglobin
COPD	Chronic obstructive pulmonary disease
CPAP	Continuous positive airway pressure
CPL	Congenital pulmonary lymphangiectasis
CPR	Cardiopulmonary resuscitation
CPT	Chest physiotherapy
CRP	C-reactive protein
CSF	Cerebrospinal fluid
C _{ST}	Static compliance
CT	Computed tomography
CVP	Central venous pressure
CXR	Chest x-ray (radiograph)
D	End-diastole
D5W	Dextrose 5% in water
DCO ₂	Gas transport coefficient for carbon dioxide
DIC	Disseminated intravascular coagulation
dL	Deciliter
DNA	Deoxyribonucleic acid
DPG	Diphosphoglycerate
DPPC	Dipalmitoyl phosphatidyl choline
DR	Delivery room
E	Elastance
ECG	Electrocardiogram
ECMO	Extracorporeal membrane oxygenation
EDRF	Endothelial-derived relaxing factor
EEG	Electroencephalogram
EF	Ejection fraction
ELBW	Extremely low birth weight
EMG	Electromyogram

EMLA	Eutectic mixture of Lidocaine and Prilocaine
ERV	Expiratory reserve volume
ET	Endotracheal
ETCO ₂	End-tidal carbon dioxide
ETCPAP	Endotracheal continuous positive airway pressure
ETT	Endotracheal tube
F or f	Frequency
F or Fr	French
FCV	Flow control valve, flow-cycled ventilation
FDA	Food and Drug Administration (US)
FDP	Fibrin degradation products
FGF	Fibroblast growth factor
FiO ₂	Fraction of inspired oxygen
FIO ₂	Fraction of inspired oxygen
FOE	Fractional oxygen extraction
FRC	Functional residual capacity
FSP	Fibrin split products
FTA	Fluorescent treponemal antibody
g	Gram
G	Gravida
g	Gauge
GA	Gestational age
GBS	Group B streptococcus
GER	Gastro-esophageal reflux
GERD	Gastro-esophageal reflux disease
GIR	Glucose infusion rate
gm	Gram
GNP	Gross national product
GTP	Guanosine triphosphate
GUI	Graphics user interface
h or hr	Hour
H ₂ O	Water
Hb	Hemoglobin
HCH	Hygroscopic condenser humidifiers
HCO ₃ ⁻	Bicarbonate
HFNC	High flow nasal cannula
HFO	High-frequency oscillation
HFOV	High-frequency oscillatory ventilation
HFV	High-frequency ventilation
Hg	Mercury
Hgb	Hemoglobin
HME	Heat and moisture exchanger
HR	Heart rate
HSV	Herpes simplex virus
Hz	Hertz
I	Inertance
I:E	Inspiratory:expiratory ratio
IC	Inspiratory capacity

Ig	Immunoglobulin
IL	Interleukin
IMV	Intermittent mandatory ventilation
INO	Inhaled Nitric Oxide
IO	Intraosseous
IP	Inspiratory pressure
IPPV	Intermittent positive pressure ventilation
IRV	Inspiratory reserve volume
IUGR	Intrauterine growth restriction
IV	Intravenous
IVC	Inferior vena cava (I)
IVH	Intraventricular hemorrhage
IVS	Interventricular septum
K	Constant
kDa	Kilodalton
kg	Kilogram
kPa	Kilopascal
L	Liter
LA	Left atrium
LBW	Low birth weight
LCD	Liquid crystalline display
LED	Light emitting diode
LHR	Ratio of lung diameter to head circumference
LOS	Length of stay
LPM (lpm)	Liters per minute
LVEDD	Left ventricular end-diastolic dimension
LVID	Left ventricular internal diameter
LVIDD	Left ventricular internal diameter at diastole
LVIDS	Left ventricular internal diameter at systole
LVO	Left ventricular output
m	Meter
MAP	Mean airway pressure
MAP	Mean arterial pressure
MAS	Meconium aspiration syndrome
mcg	Microgram
MD	Minute distance
mEq	Milliequivalent
MetHb	Methemoglobin
mg	Milligram
MIC	Mean inhibitory concentration
min	Minute
mL (ml)	Milliliter
mm	Millimeter
MMV	Mandatory minute ventilation
mo	Month
mOsm	Milliosmoles
MRI	Magnetic resonance imaging
MSAF	Meconium-stained amniotic fluid

msec	Millisecond
MV	Minute ventilation
NAVA	Neurally adjusted ventilatory assist
NEC	Necrotizing enterocolitis
NICU	Neonatal intensive care unit
NIPPV	Noninvasive positive pressure ventilation
NIRS	Near-infrared spectroscopy
NO	Nitric Oxide
NO ₂	Nitrogen Dioxide
NOS	Nitric oxide synthase
O ₂	Oxygen
OI	Oxygenation index
OSI	Oxygen saturation index (100 xPaw x FiO ₂ /SpO ₂)
P	Pressure
P50	Point of 50 % saturation of hemoglobin with oxygen
Pa-ACO ₂	Arterial to alveolar CO ₂ gradient
PACO ₂	Partial pressure of carbon dioxide, alveolar
PaCO ₂	Partial pressure of carbon dioxide, arterial
Pa-etCO ₂	Arterial to end-tidal CO ₂ gradient
PAO ₂	Partial pressure of oxygen, alveolar
PaO ₂	Partial pressure of oxygen, arterial
PAV	Proportional assist ventilation
Paw	Airway pressure
Pāw	Mean airway pressure
PB	Periodic breathing
PC	Pressure control
PCA	Post-conceptual age
PCR	Polymerase chain reaction
PDA	Patent ductus arteriosus
PE	Elastic pressure
PECO ₂	Partial pressure of mean expiratory CO ₂
PEEP	Positive end-expiratory pressure
PetCO ₂	Partial pressure of end-tidal CO ₂
PFC	Persistent fetal circulation, perfluorocarbon
PG	Prostaglandin
PH ₂ O	Partial pressure of water vapor
PI	Inspiratory pressure
P _i	Pressure, inertial
PICC	Percutaneous intravenous central catheter
PIE	Pulmonary interstitial emphysema
PIP	Intrapleural pressure
PIP	Peak inspiratory pressure
PL	Pressure limit
PLV	Partial liquid ventilation
PMA	Post-menstrual age
PMA	Pre-market approval (US)
PN ₂	Partial pressure of nitrogen
PPHN	Persistent pulmonary hypertension of the newborn

ppm	Parts per million
PR	Resistive pressure
prbc	Packed red blood cells
PRVC	Pressure-regulated volume control
PSI	Pounds per square inch
PSIG	Pounds force per square inch gauge
PST	Static pressure
PSV	Pressure support ventilation
PT	Prothrombin time
PTP	Transpulmonary pressure
PTT	Partial thromboplastin time
PTV	Patient-triggered ventilation
PUFA	Polyunsaturated fatty acids
PV-IVH	Periventricular-intraventricular hemorrhage
PVL	Periventricular leukomalacia
PvO ₂	Mixed central venous oxygen tension
PvO ₂	Partial pressure of oxygen, venous
PVR	Pulmonary vascular resistance
q	Every
Q	Perfusion
r	Radius
R	Resistance
R _{AW}	Airway resistance
RBC	Red blood cell
RCT	Randomized controlled trial
RDS	Respiratory distress syndrome
RE	Expiratory resistance
REM	Rapid eye movement
RH	Relative humidity
RI	Inspiratory resistance
ROP	Retinopathy of prematurity
ROS	Reactive oxygen species
RR	Respiratory rate, relative risk
RSV	Respiratory syncytial virus
RV	Reserve volume
RVO	Right ventricular output
S	End-systole
S1 (2,3,4)	First (second, third, fourth) heart sound
SaO ₂	Arterial oxygen saturation
sec	Second
sGC	Soluble guanylate cyclase
SIDS	Sudden infant death syndrome
SIMV	Synchronized intermittent mandatory ventilation
SNAP	Score for neonatal acute physiology
SOD	Superoxide dismutase
SP	Surfactant protein
SpO ₂	Pulse oximetry saturation

SpO ₂ /FiO ₂	Ratio of pulse oximetry oxygen saturation to fraction of inspired oxygen
sq	Square
STPD	Standard temperature and pressure, dry
SV	Stroke volume
SVC	Superior vena cava (l)
SvO ₂	Venous oxygen saturation
SVR	Systemic vascular resistance
T	Temperature
TBW	Total body water
TcPCO ₂	Transcutaneous carbon dioxide level
TCPL (V)	Time-cycled, pressure-limited (ventilation)
TcPO ₂	Transcutaneous oxygen level
TCT	Total cycle time
T _E or T _e	Expiratory time
TEF	Tracheo-esophageal fistula
TGF	Transforming growth factor
TGV	Total or thoracic gas volume
THAM	Tris-hydroxyaminomethane
T _I or T _i	Inspiratory time
TLC	Total lung capacity
TLV	Total liquid ventilation
TPN	Total parenteral nutrition
TPV	Time to peak velocity
TRH	Thyroid releasing hormone
TTN, TTNB	Transient tachypnea of the newborn
TTV	Targeted tidal volume
U	Units
UAC	Umbilical artery catheter
V	Volume, velocity
μm	Micrometer
HFJV	High-frequency jet ventilation
V/Q	Ventilation/perfusion
V _A	Alveolar ventilation
VA	Anatomic volume
V-A	Veno-arterial
VAP	Ventilator-associated pneumonia
VAPS	Volume assured pressure support
VC	Vital capacity
VCF	Velocity of circumferential fiber shortening
VCO ₂	Carbon dioxide elimination
VCV	Volume controlled ventilation
VD	Dead space volume
VD _{alv}	Alveolar dead space
VD _{aw}	Airway dead space
VD _{phys}	Physiologic dead space
VDRL	Venereal disease research laboratory
VECO ₂	Expiratory CO ₂ volume per breath

VEGF	Vascular endothelial growth factor
VILI	Ventilator-induced lung injury
VLBW	Very low birthweight
VS	Volume support
VSD	Ventricular septal defect
V_T	Tidal volume
V_{TE}	Expired tidal volume
V_{TI}	Inspired tidal volume
VTI	Velocity time interval
V-V	Venovenous
WBC	White blood cell
wks	Weeks
yrs	Years

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