

Contents

1	Historical Aspects of Mechanical Ventilation	1
	References	6
2	The Indications for Mechanical Ventilation	9
2.1	Hypoxia	9
2.2	Hypoventilation	10
2.3	Increased Work of Breathing	11
2.4	Other Indications	12
2.5	Criteria for Intubation and Ventilation	12
	References	16
3	Physiological Considerations in the Mechanically Ventilated Patient	19
3.1	The Physiological Impact of the Endotracheal Tube	19
3.2	Positive Pressure Breathing	21
3.3	Lung Compliance	28
	3.3.1 Static Compliance	29
	3.3.2 Dynamic Compliance	32
3.4	Airway Resistance	34
3.5	Time Constants of the Lung	38
3.6	Alveolar Ventilation and Dead-Space	39
	3.6.1 Anatomical Dead-Space	40
	3.6.2 Alveolar Dead-Space	40
	3.6.3 Physiological Dead-Space	40
3.7	Mechanisms of Hypoxemia	46
	3.7.1 Hypoventilation	46
	3.7.2 V/Q Mismatch	50

3.7.3	Right to Left Shunt.....	52
3.7.4	Diffusion Defect.....	54
3.8	Hemodynamic Effects.....	55
3.9	Renal Effects.....	60
3.10	Hepatobiliary and Gastrointestinal Effects.....	62
3.10.1	Hepatobiliary Dysfunction.....	62
3.10.2	Gastrointestinal Dysfunction.....	63
	References.....	63

4 The Conventional Modes of Mechanical

	Ventilation	71
4.1	Mechanical Ventilators.....	71
4.1.1	Open-Loop and Closed-Loop Systems.....	72
4.1.2	Control Panel.....	72
4.1.3	Pneumatic Circuit.....	73
4.1.4	The Expiratory Valve.....	73
4.1.5	Variables.....	74
4.1.6	The Trigger Variable (“Triggering” of the Ventilator).....	75
4.1.7	Limit Variable.....	76
4.1.8	Cycle Variable.....	76
4.1.9	Baseline Variable.....	78
4.1.10	Inspiratory Hold.....	79
4.1.11	Expiratory Hold and Expiratory Retard.....	79
4.2	Volume-Targeted Modes.....	80
4.2.1	Volume Assist-Control Mode (ACMV, CMV).....	80
4.3	Intermittent Mandatory Ventilation.....	84
4.4	Pressure-Support Ventilation.....	89
4.5	Continuous Positive Airway Pressure.....	94
4.6	Bilevel Positive Airway Pressure.....	97
4.7	Airway Pressure Release Ventilation (APRV).....	97
4.7.1	Bi-PAP.....	98
4.8	Pressure-Controlled Ventilation.....	98
4.8.1	Proportional Assist Ventilation (PAV).....	101

4.9	Dual Breath Control	102
4.9.1	Intrabreath Control	102
4.9.2	Interbreath (DCBB) Control	103
4.9.3	Pressure Regulated Volume Control (PRVC)	103
4.9.4	Automode	106
4.9.5	Mandatory Minute Ventilation (MMV).	107
4.9.6	Volume Support (VS).	108
4.9.7	Adaptive Support Ventilation (ASV).	109
	References	110
5	Ventilator Settings	115
5.1	Setting the Tidal Volume	115
5.1.1	Volume-Targeted Ventilation	115
5.1.2	Pressure-Targeted Ventilation.	116
5.2	Setting the Respiratory Rate.	117
5.3	Setting the Flow Rate.	118
5.4	Setting the Ratio of Inspiration to Expiration (I:E Ratio).	119
5.5	Setting the Flow Profile	122
5.5.1	The Square Waveform	122
5.5.2	The Decelerating Waveform	123
5.5.3	The Accelerating Waveform	123
5.5.4	The Sine Waveform.	123
5.6	Setting the Trigger Sensitivity	123
5.7	Setting PEEP.	124
5.7.1	Improvement in Oxygenation.	124
5.7.2	Protection Against Barotrauma and Lung Injury.	125
5.7.3	Overcoming Auto-PEEP	126
5.8	Indications for PEEP	127
5.9	Forms of PEEP	127
5.10	Titrating PEEP	127
5.10.1	Other Advantages of PEEP.	130
5.10.2	Disadvantages of PEEP.	131
5.11	Optimizing Ventilator Settings for Better Oxygenation	131
5.11.1	Increasing the FIO ₂	131

5.11.2	Increasing the Alveolar Ventilation	132
5.12	PEEP	132
5.12.1	Flow Waveforms	132
5.12.2	Inspiratory Time	133
5.12.3	Inverse Ratio Ventilation.....	133
5.12.4	Prone Ventilation	134
5.12.5	Reducing Oxygen Consumption.....	134
5.12.6	Increasing Oxygen Carrying Capacity	134
5.12.7	Footnote.....	135
References	.....	136
6	Ventilator Alarms	141
6.1	Low Expired Minute Volume Alarm	141
6.2	High Expired Minute Volume Alarm.....	143
6.3	Upper Airway Pressure Limit Alarm.....	144
6.4	Low Airway Pressure Limit Alarm.....	146
6.5	Oxygen Concentration Alarms	146
6.6	Low Oxygen Concentration (FIO ₂) Alarm ...	146
6.7	Upper Oxygen Concentration (FIO ₂) Alarm.....	147
6.8	Power Failure.....	147
6.9	Apnea Alarm.....	147
6.10	Two-Minute Button	148
References	.....	148
7	Monitoring Gas Exchange in the Mechanically Ventilated Patient	149
7.1	The Arterial Oxygen Tension	149
7.2	Pulse Oximetry	156
7.2.1	Principle of Pulse Oximetry.....	160
7.3	Transcutaneous Blood Gas Monitoring.....	169
7.4	Monitoring Tissue Oxygenation	171
7.4.1	Oxygen Extraction Ratio and DO _{2crit}	172
7.5	Capnography	175
References	.....	183

8	Monitoring Lung Mechanics in the Mechanically Ventilated Patient	189
8.1	Ventilator Waveforms.	189
8.2	Scalars.	190
	8.2.1 The Pressure–Time scalar	190
	8.2.2 Flow–Time Scalar	196
	8.2.3 Volume–Time Scalar.	200
8.3	The Loops	203
	8.3.1 Pressure–Volume Loop	203
	8.3.2 The Flow–Volume Loop	215
8.4	Patient–Ventilator Asynchrony	223
	8.4.1 Level of Ventilator Support and Work of Breathing.	223
	8.4.2 Complete Support.	224
	8.4.3 Partial Support	224
	8.4.4 Patient–Ventilator Asynchrony	225
	8.4.5 Triggering Asynchrony.	226
	8.4.6 Flow Asynchrony	227
	References	238
9	Mechanical Ventilation in Specific Disorders.	241
9.1	Myocardial Ischemia	241
9.2	Hypovolemic Shock	244
9.3	Neurological Injury.	245
9.4	Acute Respiratory Distress Syndrome (ARDS).	248
	9.4.1 Primary and Secondary ARDS	249
	9.4.2 Pathophysiology	250
	9.4.3 Ventilatory Strategies.	252
9.5	Obstructive Lung Disease	266
	9.5.1 PaCO ₂	268
	9.5.2 Modes of Ventilation in Obstructed Patients	269
	9.5.3 Ventilator Settings in Airflow Obstruction	272
	9.5.4 Bronchopleural Fistula.	278
9.6	Neuromuscular Disease	279
	9.6.1 Lung Function.	282

9.6.2	Inspiratory Muscle Recruitment in Neuromuscular Disease	284
9.6.3	Expiratory Muscle Recruitment in Neuromuscular Disease	284
9.6.4	Bulbar Muscles Involvement in Neuromuscular Disease	285
9.6.5	Assessment of Lung Function	286
9.6.6	Mechanical Ventilation in Neuromuscular Disease	286
9.7	Nonhomogenous Lung Disease	288
9.8	Mechanical Ventilation in Flail Chest	289
	References	290
10	The Complications of Mechanical Ventilation	305
10.1	Peri-Intubation Complications	306
10.1.1	Laryngeal Trauma	306
10.1.2	Pharyngeal Trauma	306
10.1.3	Tracheal or Bronchial Rupture	307
10.1.4	Epistaxis	307
10.1.5	Tooth Trauma	308
10.1.6	Cervical Spine Injury	308
10.1.7	Esophageal Intubation	309
10.1.8	Esophageal Perforation	310
10.1.9	Right Main Bronchial Intubation	310
10.1.10	Arrhythmias	311
10.1.11	Aspiration	312
10.1.12	Bronchospasm	312
10.1.13	Neurologic Complications	312
10.2	Problems Occurring Acutely at any Stage	312
10.2.1	Endotracheal Tube Obstruction	313
10.2.2	Airway Drying	313
10.2.3	Upward Migration of the Endotracheal Tube	314
10.2.4	Self-Extubation	314
10.2.5	Cuff Leak	315
10.2.6	Ventilator-Associated Lung Injury (VALI) and Ventilator-Induced Lung Injury (VILI)	318
10.3	Delayed Complications (Fig. 10.5)	322
10.3.1	Sinusitis	322

10.3.2	Tracheoesophageal Fistula	323
10.3.3	Tracheoinnominate Artery Fistula	325
10.3.4	Tracheocutaneous Fistula	326
10.4	Oxygen-Related Lung Complications	327
10.4.1	Tracheobronchitis	328
10.4.2	Adsorptive Atelectasis	328
10.4.3	Hyperoxic Hypercarbia	329
10.4.4	Diffuse Alveolar Damage	332
10.4.5	Bronchopulmonary Dysplasia	333
10.4.6	Ventilator-Associated Pneumonia	333
	References	334
11	Ventilator-Associated Pneumonia	343
11.1	Incidence	345
11.2	Microbiology	345
11.3	Risk Factors	347
11.3.1	The Physical Effect of the Endotracheal Tube	347
11.3.2	Alteration of Mucus Properties	348
11.3.3	Microaspiration	349
11.3.4	Biofilms	349
11.3.5	Ventilator Tubings	350
11.3.6	Gastric Feeds	351
11.3.7	Sinusitis	352
11.3.8	Respiratory Therapy Equipment	354
11.4	Position	354
11.5	Diagnosis of VAP	355
11.5.1	Sampling Methods	357
11.5.2	Interpretation of the Sample	358
11.6	Prevention of NP/VAP	360
11.6.1	Hand-Washing	360
11.6.2	Feeding and Nutrition	361
11.6.3	Stress Ulcer Prophylaxis	362
11.6.4	Topical Antibiotics	362
11.7	Interventions Related to the Endotracheal Tube and Ventilator Circuit	363
11.8	Treatment of Nosocomial Sinusitis	364
11.9	Treatment	365
11.9.1	Antibiotic Resistance	365

11.9.2	Pharmacokinetics	368
11.9.3	Duration of Therapy	371
11.9.4	Lack of Response to Therapy	373
11.9.5	Drug Cycling	374
References	. . . . .	376
12	Discontinuation of Mechanical Ventilation	391
12.1	Weaning Parameters	393
12.2	Parameters that Assess Adequacy of Oxygenation	394
12.2.1	The PaO ₂ :FIO ₂ Ratio	395
12.2.2	The A-a DO ₂ Gradient	396
12.2.3	The PaO ₂ /PAO ₂ Ratio	396
12.3	Parameters that Assess Respiratory Muscle Performance	396
12.3.1	PI _{max}	396
12.3.2	Vital Capacity	397
12.3.3	Minute Ventilation	398
12.3.4	Respiratory Rate	398
12.4	Parameters that Assess Central Respiratory Drive	399
12.4.1	Airway Occlusion Pressure	399
12.4.2	Mean Inspiratory Flow (V _t /T _i)	399
12.5	Respiratory System Compliance and Work of Breathing	400
12.5.1	Work of Breathing	400
12.5.2	Compliance of the Respiratory System	401
12.6	Integrative Indices	401
12.6.1	Simplified Weaning Index (SWI)	403
12.7	Methods of Weaning	404
12.7.1	Trials of Spontaneous Breathing (T-Piece Weaning)	405
12.7.2	Synchronized IMV	406
12.7.3	Pressure Support Ventilation (PSV)	407
12.7.4	Noninvasive Positive Pressure Ventilation (NIPPV)	409

12.7.5	Extubation.....	409
References	.....	411
13	Noninvasive Ventilation in Acute	
	Respiratory Failure	415
13.1	NIV and CPAP	415
13.2	Mechanism of Action	415
13.2.1	Interface.....	418
13.2.2	Modes.....	420
13.2.3	Devices.....	421
13.2.4	Humidification with NIV (see also Chap. 15)	422
13.3	Air Leaks.....	422
13.4	Indications for NIV.....	424
13.4.1	Hypoxemic Respiratory Failure	424
13.4.2	Hypercapnic Respiratory Failure	426
13.4.3	Miscellaneous Indications	427
13.4.4	Steps for the Initiation of NIV	428
13.4.5	Complications	429
13.4.6	Contraindications	432
13.4.7	Outcomes.....	432
References	.....	433
14	Negative Pressure Ventilation	441
14.1	Tank Ventilator (Iron Lung)	442
14.2	The Body Suit (Jacket Ventilator, Poncho-Wrap, Pulmo-Wrap).....	442
14.3	Chest: Shell (Cuirass).....	443
14.4	Modes of Negative Pressure Ventilation	444
14.5	Drawbacks of NPV.....	445
References	.....	446
15	Airway Humidification in the Mechanically	
	Ventilated Patient	449
15.1	The Role of the Nasal Mucosa	449
15.2	The Isothermic Saturation Boundary.....	449
15.3	The Effect of the Endotracheal Tube.....	450
15.3.1	Overheated Air	451

15.4	Heated Humidifiers	453
15.5	Heat-Moisture Exchangers (HMEs)	454
15.6	Airway Humidification During Noninvasive Ventilation	456
	References	457
16	Aerosol Therapy in the Mechanically Ventilated Patient	463
16.1	Terminology	463
16.2	The Behavior of Particles	464
16.3	Devices for Aerosol Delivery	464
16.3.1	Jet Nebulizers (Syn: Pneumatic Nebulizers)	464
16.3.2	Ultrasonic Nebulizers	468
16.3.3	Vibrating Mesh Nebulizers (VMNs)	469
16.3.4	Nebulization in the Ventilated Patient	469
16.3.5	Nebulization of Other Drugs	471
16.3.6	Pressurized Metered-Dose Inhalers (MDIs)	471
	References	473
17	Nonconventional Modes and Adjunctive Therapies for Mechanical Ventilation	479
17.1	High-Frequency Ventilation	480
17.2	High-Frequency Positive Pressure Ventilation (HFPPV)	482
17.3	High-Frequency Jet Ventilation (HFJV)	482
17.4	High-Frequency Oscillatory Ventilation (HFOV)	484
17.5	High-Frequency Percussive Ventilation (HFPV)	485
17.6	Extracorporeal Life Support (ECLS)	486
17.6.1	Extracorporeal Membrane Oxygenation (ECMO)	486
17.6.2	Extracorporeal CO ₂ Removal	487
17.6.3	Indications for ECLS	487
17.6.4	Contraindications to ECLS	488

17.7	Nitric Oxide	488
17.8	Surfactant Therapy	491
17.9	Helium–Oxygen Mixtures	493
17.10	Liquid Ventilation	494
	17.10.1 Total Liquid Ventilation	496
	17.10.2 Partial Liquid Ventilation	496
17.11	NAVA	497
17.12	Conclusion	497
	References	498
18	Case Studies	505
18.1	Case 1	505
18.2	Case 2	508
18.3	Case 3	510
18.4	Case 4	511
18.5	Case 5	512
18.6	Case 6	513
18.7	Case 7	516
18.8	Case 8	517
18.9	Case 9	518
18.10	Case 10	520
18.11	Case 11	522
18.12	Case 12	523
	Subject Index	527



<http://www.springer.com/978-1-84882-868-1>

Understanding Mechanical Ventilation

A Practical Handbook

Hasan, A.

2010, XXI, 543 p. 14 illus. in color., Softcover

ISBN: 978-1-84882-868-1