

# TABLE OF CONTENTS

## Veterinary Anesthetic & Monitoring Equipment

List of Contributors

Preface

### **1 Medical Gas Cylinders and Pipeline Systems 1**

*Carl Bradbrook*

1.1 Medical Gas Cylinders 1

1.2 Liquid Oxygen Tanks 8

1.3 Oxygen Concentrators 9

1.4 Medical Gas Pipeline Systems 9

References 15

### **2 Oxygen Concentrators 17**

*Allan Williamson*

2.1 Introduction 17

2.2 Function 17

2.3 Product Gas 17

2.4 Clinical Use 18

2.5 Advantages 20

2.6 Disadvantages 20

2.7 Hazards 20

2.8 Summary 21

References 21

### **3 Small Animal Anesthetic Machines and Equipment 23**

*Craig Mosley and Amanda Shelby*

3.1 Introduction 23

3.2 Safety and Design 23

3.3 The Basic Veterinary Anesthetic Machine 23

3.4 Breathing Systems 33

3.5 Waste Gas Scavenge Systems 33

3.6 Routine Anesthesia Machine Checkout Procedures 33

References 34

### **4 Large Animal Anesthesia Machines and Equipment 35**

*Amanda Shelby*

4.1 History of the Large Animal Anesthesia Machine 35

4.2 Purpose 35

4.3 Standards 35

4.4 Similarity to Small Animal Machines 35

4.5 Components of the Anesthesia Machine 36

4.6 Large Animal Anesthesia Workstations 41

4.7 Common Commercially Available Machines 41

4.8 General Cautions 51

4.9 Miscellaneous Equipment for Large Animal Anesthesia 51

References 53

### **5 Anesthetic Vaporizers 55**

*Sharon Fornes, Kristen G. Cooley, and Rebecca A. Johnson*

5.1 Introduction 55

5.2 Vaporizer Physics 55

5.3 Vaporizer Classification 56

5.4 Other Factors Affecting Vaporizers 62

5.5 Maintenance and Repair	64
5.6 Current Vaporizer Standards	65
5.7 The Modern Vaporizer	65
5.8 Specific Vaporizers	66
5.9 Summary	71
References	71

## **6 Anesthetic Ventilators 73**

*Katrina Lafferty*

6.1 Introduction	73
6.2 Ventilator Function in the Breathing Circuit	73
6.3 Tidal Volume Delivery	73
6.4 Driving Gas	74
6.5 Bellows Construction	75
6.6 Pressure Limiting Controls	76
6.7 Gas Pressure Alarm	77
6.8 Exhaust Valve	77
6.9 Spill Valve	77
6.10 Ventilator Hose Connection or Ventilator Hose Switch	77
6.11 Ventilation Modes	78
6.12 Cleaning and Sterilization	79
6.13 Pressure Checking	79
6.14 General Concerns and Troubleshooting	80
6.15 Pediatric Ventilation	81
6.16 Basic Ventilator-Patient Set-up	82
6.17 Small Animal Mechanical Ventilators	82
6.18 Large Animal Mechanical Ventilators	85

6.19 Conclusion 89

References 89

## **7 Humidification and Positive Pressure Equipment 91**

*Stephanie Keating and Stuart Clark-Price*

7.1 Humidification 91

7.2 Positive Pressure Equipment 96

References 98

## **8 Waste Anesthetic Gas Collection and Consequences 101**

*Heidi Reuss-Lamky*

8.1 Introduction 101

8.2 Occupational WAG Exposure 101

8.3 Physical Properties and Elimination 102

8.4 Pharmacodynamics 102

8.5 History of Governmental Regulations and Trace (Waste) Gas Exposure 104

8.6 WAG Exposure Level Recommendations 104

8.7 Reducing Environmental WAG Exposure 104

8.8 The Anesthetist's Responsibility 107

8.9 Monitoring WAG Exposure 112

8.10 Summary 112

References 113

## **9 Hazards of the Anesthetic Delivery System and Operating Room Fires 115**

*Odette O*

9.1 Hazards of the Anesthetic Delivery System 115

9.2 Operating Room Fires 123

References 125

## **10 Components of the Breathing System 127**

*Craig Mosley and Amanda Shelby*

10.1 Breathing Systems 127

10.2 Summary 139

References 139

## **11 Mapleson Breathing Systems 141**

*Tatiana Ferreira*

11.1 Introduction 141

11.2 Fresh Gas Flows (FGFs) 141

11.3 Advantages and Disadvantages 141

11.4 Choice of System 143

11.5 Specific System Types 143

11.6 Combined Systems 150

11.7 Respiratory Gas Monitoring 150

11.8 Potential Hazards 151

References 152

## **12 The Circle System 155**

*Geoffrey Truchetti and Trish Anne Farry*

12.1 Introduction 155

12.2 Components 155

12.3 Component Arrangement 162

12.4 Gas Flow 164

12.5 Resistance and Work of Breathing in the Circle System 166

12.6 Dead Space 166

12.7 Heat and Moisture 167

12.8 Maintenance 167

12.9 Advantages/Disadvantages 168

References 168

## **13 Laryngoscopes 171**

*Erin Wendt-Hornickle*

13.1 History 171

13.2 Laryngoscope Use 171

13.3 Description 171

13.4 Fiber Optic Endoscopes 174

13.5 Veterinary-Specific Laryngoscopes 175

13.6 Summary 175

References 176

## **14 Supraglottic Airway Devices and Tracheal Tubes and Stylets 177**

*Jennifer Sager*

14.1 Introduction 177

14.2 Laryngeal Mask Airway (LMA) 177

14.3 Veterinary-gel (v-gel®) Airway Device 178

14.4 Endotracheal Tubes 179

14.5 Large Animal Endotracheal Tubes 184

14.6 Reinforced Tubes 185

14.7 Laser Safe Tubes 185

14.8 Single Lung Intubation 186

14.9 Stylets 187

14.10 Cuff Pressure Manometers 188

14.11 Summary 190

References 190

## **15 Oxygen Delivery Systems 193**

*Jonathan Bach*

15.1 Introduction 193

15.2 Oxygen Supplementation Techniques 193

15.3 Hyperbaric Oxygen 197

References 197

## **16 Gas Monitoring 199**

*Louise O'Dwyer*

16.1 Introduction 199

16.2 Capnometry/Capnography 199

16.3 Oxygen Measurement 207

16.4 Nitrous Oxide and Inhalation Agent Analyzers 208

16.5 Blood Gas Analysis: Partial Pressures of Oxygen and CO<sub>2</sub> 210

16.6 Conclusion 210

References 210

## **17 Airway Volumes, Flows and Pressures 213**

*Andrew Claude and Alanna Johnson*

17.1 Introduction 213

17.2 Definitions 213

17.3 Volume and Flow Measurement Devices 214

17.4 The Ventilatory (Respiratory) Cycle 218

17.5 Airway Pressure Monitoring 219

17.6 Spirometry Loops 219

References 222

## **18 Pulse Oximetry 223**

*Odetta O*

18.1 Introduction 223

18.2 History 223

18.3 Importance of Pulse Oximetry 223

18.4 Function 224

18.5 Pulse Oximeter Probes 224

18.6 Uses	225
18.7 Oxyhemoglobin Dissociation Curves in Different Species	225
18.8 Patient Factors	226
18.9 Abnormal Hemoglobin	227
18.10 Sources of Error	227
18.11 Perfusion Index (PI) and Plethysmograph Variability Index (PVI)	228
18.12 Other Pulse Oximeter Models	229
18.13 Low Saturation Alarms	231
18.14 Pulse Oximetry Use in the Recovery Period	231
18.15 Summary	231
References	232

## **19 Cardiovascular Monitoring 235**

*Anderson Favaro da Cunha and Rebecca A. Johnson*

19.1 Introduction	235
19.2 Definitions	235
19.3 Measurement Techniques	235
19.4 Patient Point of View	244
19.5 Central Venous Pressure (CVP)	245
19.6 Cardiac Output Monitoring	246
19.7 Conclusion	248
References	248

## **20 Electrocardiography 253**

*Tracey Lawrence*

20.1 Overview	253
20.2 The ECG Machine	253
20.3 Lead Systems	254



20.4 Mean Electrical Axis (MEA) 257

20.5 ECG Cycle 258

20.6 Electrode Placement 260

20.7 ECG Filters 263

20.8 Evaluating the ECG 264

20.9 Equipment Maintenance 268

20.10 Summary 268

References 269

## **21 Neuromuscular Transmission Monitoring 271**

*Molly Allen and Rebecca A. Johnson*

21.1 Introduction 271

21.2 Neuromuscular Transmission 271

21.3 Peripheral Nerve Stimulation 271

21.4 Monitoring Techniques 275

21.5 Other Equipment 279

References 280

## **22 Temperature Regulation and Monitoring 285**

*Caroline Baldo and Darci Palmer*

22.1 Introduction 285

22.2 Heat and Thermodynamics 285

22.3 Thermoregulation 285

22.4 Types of Heat Loss 286

22.5 Heat Loss During Anesthesia 287

22.6 Effects of Hypothermia and Hyperthermia 288

22.7 Re-Warming 289

22.8 Temperature Monitoring Devices 290

22.9 Sites of Temperature Monitoring	291
22.10 Warming Devices	293
22.11 Active Warming Devices	293
22.12 Other Techniques to Minimize Heat Loss	298
22.13 High-Risk Heating Methods	299
References	300

## **23 Fluid Regulation and Monitoring 303**

*Julie Walker*

23.1 Overview of Fluid Physiology	303
23.2 Assessment of Fluid Balance	304
23.3 Advanced Fluid Balance Monitoring Techniques	307
23.4 Fluid Therapy	311
23.5 Equipment for Fluid Therapy	312
23.6 Summary	319
References	319

## **24 Anesthetic Records 323**

*Thomas Riebold*

24.1 Introduction	323
24.2 Maintaining Anesthetic Records	323
24.3 Monitoring Recommendations	323
24.4 Paper Anesthetic Records	324
24.5 Electronic Anesthetic Records	324
24.6 Transitioning from Paper to Electronic Medical Records	327
24.7 Specific Types of Anesthetic Monitoring Software	328
24.8 Patient Management and Digital Records	330
24.9 Automated Dispensing Systems and Record Keeping	333

References 333

## **25 Equipment for the Magnetic Resonance Imaging System 335**

*Kris Kruse-Elliott*

25.1 Basic Principles of Magnetic Resonance Imaging 335

25.2 Regulations 337

25.3 MRI Hazard Classification 337

25.4 Types of Metal 338

25.5 Gauss Lines and Safety Zones 338

25.6 Specific Hazards 339

25.7 Compatible MRI Equipment 340

25.8 Anesthetic Machines 340

25.9 Vaporizers 341

25.10 Ventilators 342

25.11 Laryngoscopes 342

25.12 Endotracheal Tubes and Airway Devices 342

25.13 Monitors 342

25.14 Miscellaneous Items 345

25.15 Summary 346

References 346

## **26 Equipment for Environmental Extremes and Field Techniques 349**

*David Brunson and Kristen G. Cooley*

26.1 Environmental Extremes 349

26.2 Temperature 349

26.3 Atmospheric Pressure 351

26.4 Drug Delivery Systems 352

26.5 Monitoring Equipment 356

26.6 Field Techniques 358

26.7 Anesthesia for Situations with Limited Means 358

26.8 Stress 362

26.9 Summary 363

References 363

## **27 Equipment Checkout and Maintenance 365**

*Molly Allen and Lesley Smith*

27.1 Introduction 365

27.2 Daily Checks 365

27.3 Other Equipment 373

27.4 End of Case 373

27.5 Preventative Maintenance 374

References 374

## **28 Equipment Cleaning and Sterilization 377**

*Cristina de Miguel Garcia and Kristen G. Cooley*

28.1 Introduction 377

28.2 The Decontamination Process 378

28.3 Recommendations for Cleaning and Disinfecting Specific Items 384

References 388

## **29 Unique Species Considerations: Dogs and Cats 391**

*Turi Aarnes*

29.1 Introduction 391

29.2 Intubation 391

29.3 Breathing System 392

29.4 Monitoring 392

29.3 Recovery 393

29.6 Anesthetic Risk 393

References 394

**30 Unique Species Considerations: Ruminants and Swine 395**

*Denise Radkey, Lindsey Snyder, and Rebecca A. Johnson*

Part I: Ruminants 395

30.1 Introduction 395

30.2 Handling and Restraint 395

30.3 IV Catheterization 396

30.4 Induction Equipment 397

30.5 Tracheal Insufflation and Demand Valves 403

30.6 Padding and Positioning 404

30.7 Monitoring Equipment 406

30.8 Commercial Anesthetic Machines 408

30.9 Anesthetic Circuit 408

30.10 Anesthetic Recovery 409

30.11 Summary 410

Part II: Swine 410

30.12 Introduction 410

30.13 Handling and Restraint 410

30.14 Intravenous Catheter Placement 411

30.15 Induction Equipment 412

30.16 Monitoring Equipment 414

30.17 Anesthetic Circuit 415

30.18 Anesthetic Recovery 416

30.19 Summary 416

References 416

### **31 Unique Species Considerations: Equine 419**

*Carolyn Kerr*

31.1 Introduction 419

31.2 Sedation and Pre-Anesthetic Period Considerations 419

31.3 General Anesthesia 426

31.4 Recovery Period 437

31.5 Medical Records 437

References 438

### **32 Unique Species Considerations: Avian 441**

*Carrie Schroeder*

32.1 Introduction 441

32.2 Anesthetic Considerations 443

32.3 Venous Access 445

32.4 Anesthetic Monitors 446

32.5 Anesthetic Circuits 447

32.6 Maintenance of Body Temperature 448

32.7 Anesthetic Recovery 448

References 449

### **33 Unique Species Considerations: Rabbits 451**

*Katrina Lafferty*

33.1 Introduction 451

33.2 Intubation 451

33.3 Breathing Circuits 454

33.4 Monitors 454

33.5 Thermal Support 458

33.6 Summary 458

References 458

### **34 Unique Species Considerations: Rodents 461**

*Mario Arenillas Baquero and Rebecca A. Johnson*

34.1 Introduction 461

34.2 Anesthetic Machines 461

34.3 Anesthetic Induction Chambers 462

34.4 Masks 464

34.5 Endotracheal Intubation and Intubation Devices 466

34.6 Ventilators 469

34.7 Monitoring Equipment 469

34.8 Warming Devices 473

34.9 Summary 474

References 474

### **35 Unique Species Considerations: Fish and Amphibians 477**

*Kurt Sladky*

35.1 Introduction 477

35.2 Fish and Amphibian Anesthesia: Induction and Maintenance 477

35.3 Anesthetic Monitoring 483

References 486

### **36 Unique Species Considerations: Reptiles 489**

*Christoph Mans*

36.1 Introduction 489

36.2 Anesthetic Induction 489

36.3 Airway Intubation 489

36.4 Anesthetic Monitoring 491

36.5 Summary 495

References 495

**37 Unique Species Considerations: Non-Human Primates 497**

*Stephen Cital*

37.1 General Anatomy 497

37.2 Taxonomy 497

37.3 Immobilizing Equipment 497

37.4 Anesthetic Machines 497

37.5 Monitors 498

37.6 Summary 501

References 502

Index 503.