SEVENTH EDITION

Pilbeam's Mechanical Ventilation

Physiological and Clinical Applications

J.M. CAIRO

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Dedication

In Memoriam: Cora May Savoy

A generation goes, and a generation comes, but the earth remains forever. The sun rises, and the sun goes down, and hastens to the place where it rises. (Ecclesiastes 1:4–5)

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Preface

As with previous editions of *Pilbeam's Mechanical Ventilation,* the goal of this text is to provide clinicians with a strong physiological foundation for making informed decisions when managing patients receiving mechanical ventilation. The subject matter covered is derived from current evidence-based practices and is written in a manner that allows this text to serve as a resource for both students and practicing clinicians. The seventh edition of *Pilbeam's Mechanical Ventilation* is presented in a concise manner that explains patient-ventilator interactions. Beginning with the most fundamental concepts and expanding to the more advanced topics, the text guides readers through a series of essential concepts and ideas, building upon the information as the reader progresses through the text.

It is apparent to critical care clinicians that implementing effective interprofessional care plans is required to achieve successful outcomes. Respiratory therapists are an integral part of effective interprofessional critical care teams. Their expertise in the areas of mechanical ventilation and respiratory care modalities is particularly valuable considering the pace at which technological advances are occurring in critical care medicine.

The application of mechanical ventilation principles to patient care is one of the most sophisticated respiratory care applications used in critical care medicine, making frequent reviewing helpful, if not necessary. *Pilbeam's Mechanical Ventilation* can be useful to all critical care practitioners, including practicing respiratory therapists, critical care residents and physicians, physician assistants, and critical care nurse practitioners.

Organization

This edition, like previous editions, is organized into a logical sequence of chapters and sections that build upon each other as a reader moves through the book. The initial sections focus on core knowledge and skills needed to apply and initiate mechanical ventilation, whereas the middle and final sections cover specifics of mechanical ventilation patient care techniques, including bedside pulmonary diagnostic testing, hemodynamic testing, pharmacology of patients receiving ventilation, and a concise discussion of ventilator-associated pneumonia, as well as neonatal and pediatric mechanical ventilatory techniques and long-term applications of mechanical ventilation. The inclusion of some helpful appendixes further assists the reader in the comprehension of complex material and an easy-access Glossary defines key terms covered in the chapters.

Features

The valuable learning aids that accompany this text are designed to make it an engaging tool for both educators and students. With clearly defined resources in the beginning of each chapter, students can prepare for the material covered in each chapter through the use of Chapter Outlines, Key Terms, and Learning Objectives.

Along with the abundant use of images and information tables, each chapter contains:

- **Case Studies**: Concise patient vignettes that list pertinent assessment data and pose a critical thinking question to readers to test their understanding of content learned. Answers can be found in Appendix A**.**
- **Critical Care Concepts**: Short questions to engage the readers in applying their knowledge of difficult concepts.
- **Clinical Scenarios**: More comprehensive patient scenarios covering patient presentation, assessment data, and treatment therapies. These scenarios are intended for classroom or group discussion.
- **Key Points:** Highlight important information as key concepts are discussed.

Each chapter concludes with:

- A bulleted Chapter Summary for ease of reviewing chapter content
- Chapter Review Questions (with answers in Appendix A**)**
- A comprehensive list of References at the end of each chapter for those students who wish to learn more about specific topics covered in the text

Finally, several appendixes are included to provide additional resources for readers. These include a Review of Abnormal Physiological Processes, which covers mismatching of pulmonary perfusion and ventilation, mechanical dead space, and hypoxia. A special appendix on Graphic Exercises gives students extra practice in understanding the interrelationship of flow, volume, and pressure in mechanically ventilated patients. Answer Keys to Case Studies and Critical Care Concepts featured throughout the text and the end-of-chapter Review Questions can help the student track progress in comprehension of the content.

This edition of *Pilbeam's Mechanical Ventilation* has been updated to reflect commonly used equipment and techniques to ensure it is in step with the current modes of therapy. Case Studies, Clinical Scenarios, and Critical Care Concepts are presented throughout the text to emphasize this new information.

Learning Aids

Workbook

The Workbook for *Pilbeam's Mechanical Ventilation* is an easy-to-use guide designed to help the student focus on the most important information presented in the text. The workbook features clinical exercises directly tied to the learning objectives that appear in the beginning of each chapter. Providing the reinforcement and practice that students need, the workbook features exercises such as key term crossword puzzles, critical thinking questions, case studies, waveform analysis, and National Board for Respiratory Care (NBRC)-style multiple-choice questions.

For Educators

Educators using the Evolve website for *Pilbeam's Mechanical Ventilation* have access to an array of resources designed to work in coordination with the text and aid in teaching this topic. Educators may use the Evolve resources to plan class time and lessons, supplement class lectures, or create and develop student exams. These Evolve resources offer:

- More than 800 NBRC-style multiple-choice test questions in ExamView
- PowerPoint Presentation with more than 650 slides featuring key information and helpful images
- An Image Collection of the figures appearing in the book

Jim Cairo, New Orleans, Louisiana

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I would like to offer special thanks for the guidance provided by the staff of Elsevier throughout this project, particularly Senior Content Strategist, Yvonne Alexopoulos; Senior Content Development Manager, Ellen Wurm-Cutter; Content Development Specialist, Melissa Rawe; Project Manager, Janish Paul; and Publishing Services Manager, Deepthi Unni. Their dedication to this project has been immensely helpful and I feel fortunate to have had the opportunity to work with such a professional group.

I particularly wish to thank my wife, Rhonda for always providing love and support for me and all of our family. Her gift of unconditional love and encouragement inspires me every day.

CHAPTER 1

Basic Terms and Concepts of Mechanical Ventilation

LEARNING OBJECTIVES

On completion of this chapter, the reader will be able to do the following:

1. Define *ventilation, external respiration,* and *internal respiration.*
2. Draw a graph showing how intrapleural and alveolar (intrapulmonary) pressures change during spontaneous ventilation and during a positive pressure breath.
3. Define the terms *transpulmonary pressure, transrespiratory pressure, transairway pressure, transthoracic pressure, elastance, compliance,* and *resistance.*
4. Provide the value for intraalveolar pressure throughout inspiration and expiration during normal, quiet breathing.
5. Write the formulas for calculating compliance and resistance.
6. Explain how changes in lung compliance affect the peak pressure measured during inspiration with a mechanical ventilator.
7. Describe the changes in airway conditions that can lead to increased resistance.
8. Calculate the airway resistance given the peak inspiratory pressure, a plateau pressure, and the flow rate.

9. Using a figure showing abnormal compliance or airway resistance, determine which lung unit will fill more quickly or with a greater volume.
10. Compare several time constants, and explain how different time constants will affect volume distribution during inspiration.
11. Give the percentage of passive filling (or emptying) for one, two, three, and five time constants.
12. Briefly discuss the principle of operation of negative pressure, positive pressure, and high-frequency mechanical ventilators.
13. Define peak inspiratory pressure, baseline pressure, positive end-expiratory pressure, and plateau pressure.
14. Describe the measurement of plateau pressure.

KEY TERMS

- Acinus
- Airway opening pressure
- Airway pressure
- Alveolar distending pressure
- Alveolar pressure
- Ascites
- Auto-PEEP
- Bronchopleural fistulas
- Compliance
- Critical opening pressure

- Elastance
- Esophageal pressure
- External respiration
- Extrinsic PEEP
- Fast lung unit
- Functional residual capacity
- Heterogeneous
- High-frequency jet ventilation
- High-frequency oscillatory ventilation
- High-frequency positive pressure ventilation
- Homogeneous
- Internal respiration
- Intrapulmonary pressure
- Intrinsic PEEP
- Manometer
- Mask pressure
- Mouth pressure
- Peak airway pressure
- Peak inspiratory pressure
- Peak pressure
- Plateau pressure

- Positive end-expiratory pressure (PEEP)
- Pressure gradient
- Proximal airway pressure
- Resistance
- Respiration
- Slow lung unit
- Static compliance/static effective compliance
- Time constant
- Transairway pressure
- Transpulmonary pressure
- Transrespiratory pressure
- Transthoracic pressure
- Upper airway pressure
- Ventilation

Physiological Terms and Concepts Related to Mechanical Ventilation

The purpose of this chapter is to provide a brief review of the physiology of breathing and a description of the pressure, volume, and flow events that occur during the respiratory cycle. The effects of changes in lung characteristics (e.g., respiratory compliance and airway resistance) on the mechanics of breathing are also discussed.

Normal Mechanics of Spontaneous Ventilation

Ventilation and Respiration

Spontaneous **ventilation** is simply the movement of air into and out of the lungs. A spontaneous breath is accomplished by contraction of the muscles of inspiration, which causes expansion of the thorax. During a quiet inspiration, the diaphragm descends and enlarges the vertical size of the thoracic cavity while the external intercostal muscles raise the ribs slightly, increasing the circumference of the thorax. Contraction of the diaphragm and external intercostal muscles provides the energy to move air into the lungs and therefore perform the "work" required to overcome the impedance offered by the lungs and chest wall. During a maximal spontaneous inspiration, the accessory muscles of breathing are also used to increase the volume of the thorax.

During a normal quiet expiration, the inspiratory muscles simply relax, the diaphragm moves upward, and the ribs return to their resting position. The volume of the thoracic cavity decreases, and air is forced out of the alveoli. To achieve a maximum expiration (below the end-tidal expiratory level), the accessory muscles of expiration must be used to compress the thorax. Box 1.1 lists the various accessory muscles of breathing.

Respiration involves the exchange of oxygen and carbon dioxide between an organism and its environment. Respiration is typically divided into two components: **external respiration** and **internal respiration**. External respiration involves the diffusion of oxygen and carbon dioxide between the alveoli and the pulmonary capillaries. Oxygenated blood leaving the pulmonary capillaries is carried by the pulmonary veins to the left heart and distributed to the cells of the body via the systemic arteries and capillaries. Internal respiration occurs at the cellular level and involves the exchange of oxygen and carbon dioxide between the systemic capillaries and the cells of the body. At the cellular level, oxygen diffuses into the cells, where it is used in the oxidation of available substrates (e.g., carbohydrates and lipids) to produce energy. Carbon dioxide, which is a major by-product of aerobic metabolism, diffuses out of the cells into the systemic capillaries. Blood from the systemic capillaries is returned by bulk flow via the systemic veins back to the right heart, the pulmonary arteries, and the pulmonary capillaries.

BOX 1.1 Accessory Muscles of Breathing

Inspiration

Scalene (anterior, medial, and posterior)
Sternocleidomastoids
Pectoralis (major and minor)
Trapezius

Expiration

Rectus abdominis
External oblique
Internal oblique
Transverse abdominal
Serratus (anterior, posterior)
Latissimus dorsi

Gas Flow and Pressure Gradients During Ventilation

For air to flow through a tube or airway, a **pressure gradient** must exist (i.e., pressure at one end of the tube must be higher than pressure at the other end of the tube). Air will always flow from the high-pressure point to the low-pressure point.

Consider what happens during a normal quiet breath. Lung volumes change as a result of gas flow into and out of the airways caused by changes in the pressure gradient between the airway opening and the alveoli. During a spontaneous inspiration, contraction of the inspiratory muscles causes enlargement of the thorax resulting in a decrease (more negative) in intrapleural and alveolar pressure. The alveolar pressure therefore becomes less than the pressure at the airway opening (i.e., the mouth and nose), and gas flows into the lungs. Conversely, during a quiet expiration, relaxation of the inspiratory muscles causes in a decrease in thoracic volume (i.e., diaphragm and external intercostal muscles return to their resting position) and an increase in alveolar pressure. Gas flows out of the lungs during expiration because the pressure in the alveoli is higher than the pressure at the airway opening. It is important to recognize that when the pressure at the airway opening and the pressure in the alveoli are the same, as occurs at the end of expiration, bulk gas flow does not occur because the pressures across the conductive airways are equal (i.e., there is no pressure gradient).

Units of Pressure

Ventilating pressures are commonly measured in centimeters of water pressure (cm H_2O). These pressures are referenced to atmospheric pressure, which is given a baseline value of zero. In other words, although atmospheric pressure is 760 mm Hg or 1034 cm H_2O (1 mm Hg = 1.36 cm H_2O) at sea level, atmospheric pressure is designated as 0 cm H_2O. For example, when airway pressure increases by +20 cm H_2O during a positive pressure breath, the pressure actually increases from 1034 to 1054 cm H_2O. Other units of measure that are becoming more widely used for gas pressures, such as arterial oxygen pressure (P_aO_2) and arterial carbon dioxide pressure (P_aCO_2), are the torr (1 Torr = 1 mm Hg) and the kilopascal ([kPa]; 1 kPa = 7.5 mm Hg). The kilopascal is used in the International System of units. (Box 1.2 provides a summary of common units of measurement for pressure.)

Definitions of Pressures and Gradients in the Lungs

Airway opening pressure (P_{awo}) is most often called **mouth pressure** (P_M) or **airway pressure** (P_{aw}) (Fig. 1.1). Other terms that are often used to describe the airway opening pressure include **upper-airway pressure**, **mask pressure**, and **proximal airway pressure**. [1] Unless pressure is applied at the airway opening, P_{awo} is zero or atmospheric pressure.

BOX 1.2 Pressure Equivalents

1 mm Hg = 1.36 cm H_2O
1 kPa = 7.5 mm Hg
1 Torr = 1 mm Hg
1 atm = 760 mm Hg = 1034 cm H_2O

A similar measurement is the pressure at the body surface (P_{bs}). This is equal to zero (atmospheric pressure) unless the person is placed in a pressurized chamber (e.g., hyperbaric chamber) or a negative pressure ventilator (e.g., iron lung).

Intrapleural pressure (P_{pl}) is the pressure in the potential space between the parietal and visceral pleurae. P_{pl} is normally about −5 cm H_2O at the end of expiration during spontaneous breathing. It is about −10 cm H_2O at the end of inspiration. Because P_{pl} is often difficult to measure in a patient, a related measurement is used, the **esophageal pressure** (P_{es}), which is obtained by placing a specially designed balloon in the esophagus; changes in the balloon pressure are used to estimate pressure and pressure changes in the pleural space. (See Chapter 10 for more information about esophageal pressure measurements.)

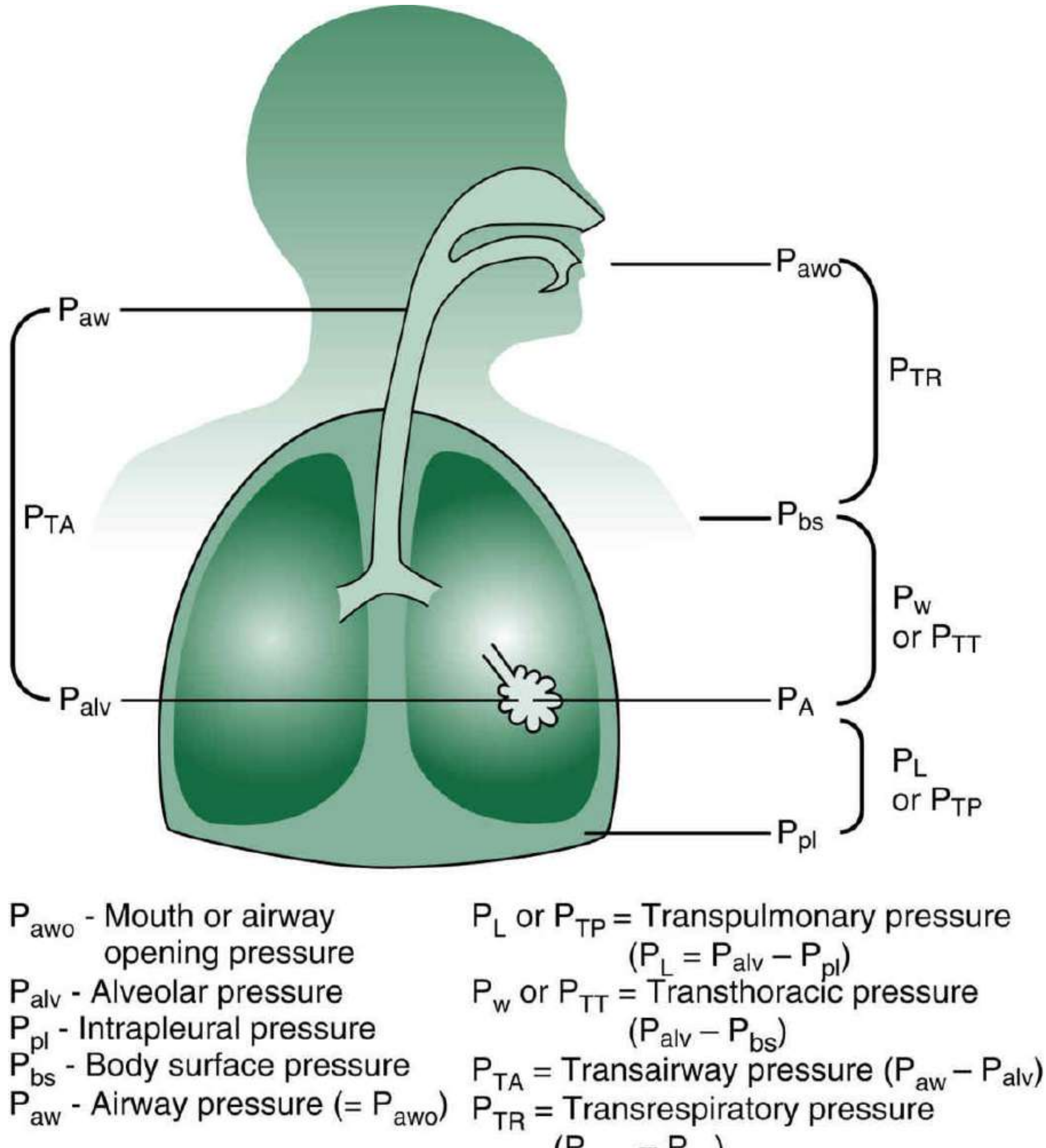

FIG. 1.1 Various pressures and pressure gradients of the respiratory system.
From Kacmarek RM, Stoller JK, Heuer AJ, eds. *Egan's Fundamentals of Respiratory Care.* 11th ed. St. Louis, MO: Elsevier; 2017.

Another commonly measured pressure is alveolar pressure (P_{alv}). This pressure is also called *intrapulmonary pressure* or *lung pressure.* Alveolar pressure normally changes as the intrapleural pressure changes. During spontaneous inspiration, P_{alv} is about −1 cm H_2O, and during exhalation it is about +1 cm H_2O.

Four basic pressure gradients are used to describe normal ventilation: transairway pressure, transthoracic pressure, transpulmonary pressure (or transalveolar pressure), and transrespiratory pressure (Table 1.1; also see Fig. 1.1).

Transairway Pressure

Transairway pressure (P_{TA}) is the pressure difference between the airway opening and the alveolus: $P_{TA} = P_{awo} - P_{alv}$. It is therefore the pressure gradient required to produce airflow in the conductive airways. It represents the pressure that must be generated to overcome resistance to gas flow in the airways (i.e., airway resistance).

Transthoracic Pressure

Transthoracic pressure (P_W or P_{TT}) is the pressure difference between the alveolar space or lung and the body's surface (P_{bs}): P_W (or P_{TT}) = $P_{alv} - P_{bs}$. It represents the pressure required to expand or contract the lungs and the chest wall at the same time.

Transpulmonary Pressure

Transpulmonary pressure or transalveolar pressure (P_L or P_{TP}) is the pressure difference between the alveolar space and the pleural space (P_{pl}): P_L (or P_{TP}) = $P_{alv} - P_{pl}$. P_L is the pressure required to maintain alveolar inflation and is therefore sometimes called the **alveolar distending pressure**.[2-4] (NOTE: An airway pressure measurement called the **plateau pressure** [P_{plat}] is sometimes substituted for P_{alv}. P_{plat} is measured during a breath-hold maneuver during mechanical ventilation, and the value is read from the ventilator manometer. P_{plat} is discussed in more detail later in this chapter.)

TABLE 1.1

Terms, Abbreviations, and Pressure Gradients for the Respiratory System

Abbreviation	Term	
C	Compliance	
R	Resistance	
R_{aw}	Airway resistance	
P_M	Pressure at the mouth (same as P_{awo})	
P_{aw}	Airway pressure (usually upper airway)	
P_{awo}	Pressure at the airway opening; mouth pressure; mask pressure	
P_{bs}	Pressure at the body surface	
P_{alv}	Alveolar pressure (also P_A)	
P_{pl}	Intrapleural pressure	
C_{st}	Static compliance	
C_{dyn}	Dynamic compliance	
Pressure Gradients		
Transairway pressure (P_{TA})	Airway pressure − alveolar pressure	$P_{TA} = P_{aw} - P_{alv}$
Transthoracic pressure (P_W)	Alveolar pressure − body surface pressure	P_W (or P_{TT}) $= P_{alv} - P_{bs}$
Transpulmonary pressure (P_L)	Alveolar pressure − pleural pressure (also defined as the *transalveolar pressure*)	P_L (or P_{TP}) $= P_{alv} - P_{pl}$
Transrespiratory pressure (P_{TR})	Airway opening pressure − body surface pressure	$P_{TR} = P_{awo} - P_{bs}$

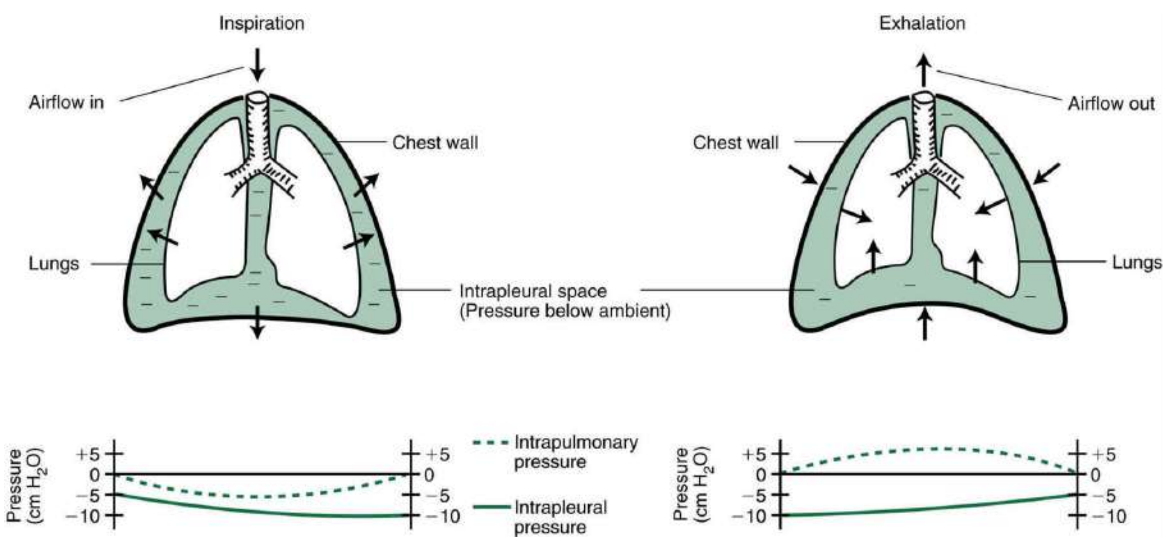

FIG. 1.2 The mechanics of spontaneous ventilation and the resulting pressure waves (approximately normal values). During inspiration, intrapleural pressure (P_{pl}) decreases to −10 cm H_2O. During exhalation, P_{pl} increases from −10 to −5 cm H_2O. (See the text for further description.)

All modes of ventilation increase P_{TP} during inspiration, by either decreasing P_{pl} (negative pressure ventilators) or increasing P_{alv} by increasing pressure at the upper airway (positive pressure ventilators). During negative pressure ventilation, the pressure at the body surface (P_{bs}) becomes negative and this pressure is transmitted to the pleural space, resulting in a decrease (more negative) in intrapleural pressure (P_{pl}) and an increase in transpulmonary pressure (P_L). During positive pressure ventilation, the P_{bs} remains atmospheric, but the pressures at the airway opening (P_{awo}) and in the conductive airways (airway pressure, or P_{aw}) become positive. Alveolar pressure (P_{alv}) then becomes positive, and transpulmonary pressure (P_L) is increased. *

Transrespiratory Pressure

Transrespiratory pressure (P_{TR}) is the pressure difference between the airway opening and the body surface: $P_{TR} = P_{awo} - P_{bs}$. Transrespiratory pressure is used to describe the pressure required to inflate the lungs during positive pressure ventilation. In this situation, the body surface pressure (P_{bs}) is atmospheric and usually is given the value zero; thus P_{awo} becomes the pressure reading on a ventilator gauge (P_{aw}).

Transrespiratory pressure has two components: transthoracic pressure (the pressure required to overcome elastic recoil of the lungs and chest wall) and transairway pressure (the pressure required to overcome airway resistance). Transrespiratory pressure can therefore be described by the equations $P_{TR} = P_{TT} + P_{TA}$ and $(P_{awo} - P_{bs}) = (P_{alv} - P_{bs}) + (P_{aw} - P_{alv})$.

Consider what happens during a normal, spontaneous inspiration (Fig. 1.2). As the volume of the thoracic space increases, the pressure in the pleural space (intrapleural pressure) becomes more negative in relation to atmospheric pressures. (This is an expected result according to Boyle's law. For a constant temperature, as the volume increases, the pressure decreases.) The intrapleural pressure drops from about −5 cm H_2O at end expiration to about −10 cm H_2O at end inspiration. The negative intrapleural pressure is transmitted to the alveolar space, and the intrapulmonary, or alveolar (P_{alv}), pressure becomes more negative relative to atmospheric pressure. The transpulmonary pressure (P_L), or the pressure gradient across the lung, widens (Table 1.2). As a result, the alveoli have a negative pressure during spontaneous inspiration.

The pressure at the airway opening or body surface is still atmospheric, creating a pressure gradient between the mouth (zero) and the alveolus of about −3 to −5 cm H_2O. The transairway pressure gradient (P_{TA}) is approximately (0 − [−5]), or 5 cm H_2O. Air flows from the mouth or nose into the lungs and the alveoli expand. When the volume of gas builds up in the alveoli and the pressure returns to zero, airflow stops. This marks the end of inspiration; no more gas moves into the lungs because the pressure at the mouth and in the alveoli equals zero (i.e., atmospheric pressure) (see Fig. 1.2).

During expiration, the muscles relax and the elastic recoil of the lung tissue results in a decrease in lung volume. The thoracic volume decreases to resting, and the intrapleural pressure returns to about −5 cm H_2O. Notice that the pressure inside the alveolus during exhalation increases and becomes slightly positive (+5 cm H_2O). As a result, pressure is now lower at the mouth than inside the alveoli and the transairway pressure gradient causes air to move out of the lungs. When the pressure in the alveoli and that in the mouth are equal, exhalation ends.

TABLE 1.2

Changes in Transpulmonary Pressure [a] Under Varying Conditions

Pressure	End Expiration	End Inspiration
Passive Spontaneous Ventilation		
Intraalveolar (intrapulmonary)	0 cm H_2O	0 cm H_2O
Intrapleural	-5 cm H_2O	-10 cm H_2O
Transpulmonary	$P_L = 0 - (-5) = +5$ cm H_2O	$P_L = 0 - (-10) = 10$ cm H_2O
Negative Pressure Ventilation		
Intraalveolar (intrapulmonary)	0 cm H_2O	0 cm H_2O
Intrapleural	-5 cm H_2O	-10 cm H_2O
Transpulmonary	$P_L = 0 - (-5) = +5$ cm H_2O	$P_L = 0 - (-10) = 10$ cm H_2O
Positive Pressure Ventilation		
Intraalveolar (intrapulmonary)	0 cm H_2O	9-12 cm H_2O[b]
Intrapleural	-5 cm H_2O	2-5 cm H_2O[b]
Transpulmonary	$P_L = 0 - (-5) = +5$ cm H_2O	$P_L = 10 - (2) = +8$ cm H_2O[b]

[a] $P_L = P_{alv} - P_{pl}$.

[b] Applied pressure is +15 cm H_2O.

Lung Characteristics

Normally, two types of forces oppose inflation of the lungs: elastic forces and frictional forces. Elastic forces arise from the elastic properties of the lungs and chest wall. Frictional forces are the result of two factors: the resistance of the tissues and organs as they become displaced during breathing and the resistance to gas flow through the airways.

Two parameters are often used to describe the mechanical properties of the respiratory system and the elastic and frictional forces opposing lung inflation: *compliance* and *resistance.*

Compliance

The **compliance** (C) of any structure can be described as the relative ease with which the structure distends. It can be defined as the inverse of **elastance** (e), where *elastance* is the tendency of a structure to return to its original form after being stretched or acted on by an outside force. Thus $C = 1/e$ or $e = 1/C$. The following examples illustrate this principle. A balloon that is easy to inflate is said to be very compliant (it demonstrates reduced elasticity), whereas a balloon that is difficult to inflate is considered not very compliant (it has increased elasticity). In a similar way, consider the comparison of a golf ball and a tennis ball. The golf ball is more elastic than the tennis ball because it tends to retain its original form; a considerable amount of force must be applied to the golf ball to compress it. A tennis ball, on the other hand, can be compressed more easily than the golf ball, so it can be described as less elastic and more compliant.

In the clinical setting, compliance measurements are used to describe the elastic forces that oppose lung inflation. More specifically, the compliance of the respiratory system is determined by measuring the change (Δ) of volume (V) that occurs when pressure (P) is applied to the system: $C = \Delta V/\Delta P$. Volume typically is measured in liters or milliliters and pressure in centimeters of water pressure. It is important to understand that the compliance of the respiratory system is the sum of the compliances of both the lung parenchyma and the surrounding thoracic structures. In a spontaneously breathing individual, the total respiratory system compliance is about 0.1 L/cm H_2O (100 mL/cm H_2O); however, it can vary considerably, depending on a person's posture, position, and whether he or she is actively inhaling or exhaling during the measurement. It can range from 0.05 to 0.17 L/cm H_2O (50 to 170 mL/cm H_2O). For intubated and mechanically ventilated patients with normal lungs and a normal chest wall, compliance varies from 40 to 50 mL/cm H_2O in men and 35 to 45 mL/cm H_2O in women to as high as 100 mL/cm H_2O in either gender (Key Point 1.1).

Key Point 1.1

Normal compliance in spontaneously breathing patients: 0.05 to 0.17 L/cm H_2O or 50 to 170 mL/cm H_2O

Normal compliance in intubated patients: Males: 40 to 50 mL/cm H_2O, up to 100 mL/cm H_2O; Females: 35 to 45 mL/cm H_2O, up to 100 mL/cm H_2O

Changes in the condition of the lungs or chest wall (or both) affect total respiratory system compliance and the pressure required to inflate the lungs. Diseases that reduce the compliance of the lungs or chest wall increase the pressure required to inflate the lungs. Acute respiratory distress syndrome and kyphoscoliosis are examples of pathological conditions associated with reductions in lung compliance and thoracic compliance, respectively. Conversely, emphysema is an example of a pulmonary condition in which pulmonary compliance is increased as a result of a loss of lung elasticity. With emphysema, less pressure is required to inflate the lungs.

Critical Care Concept 1.1 presents an exercise in which students can test their understanding of the compliance equation.