In the literature of pulmonary medicine we found dismaying diversity of and inconsistency in terms used to describe physiologic pressure gradients. Standardized terms, definitions, symbols, and equations published by the American Physiological Society, the American College of Chest Physicians, the American Thoracic Society, and the American Association for Respiratory Care have not been consistently used. Rather, researchers have often used their own definitions for transpulmonary pressure, transairway pressure, transthoracic pressure, transrespiratory pressure, and transdiaphragmatic pressure. We describe the variety of definitions and equations we found for those terms. We contend that it would benefit researchers, students, clinicians, and educators to define these terms precisely and use them consistently.

Key words: transpulmonary pressure, transairway pressure, transthoracic pressure, transrespiratory pressure, transdiaphragmatic pressure, terminology, respiratory mechanics/physiology

Introduction

A clear understanding of respiratory physiology is critical to the provision of competent respiratory care as well as the scientific advancement of the field. Comprehension of the pressure gradients involved in the mechanics of breathing is an important part of this understanding. There are, however, differences among the definitions, symbols, and equations used to convey this information in the medical literature, including respiratory care texts.

Although a standardized set of definitions, symbols and equations has been published by those who establish such standard terms, various medical authors, including those in respiratory care, have chosen to express these definitions, symbols, and equations differently from that standard. Additionally, the authors differ among themselves in expressing those terms. The differences among various authors have created confusion for many, particularly students, who depend on published standards to guide them in establishing a solid foundation. This foundation helps to achieve understanding of physiology and pathophysiology, from which flows critical components of their professional knowledge and skills.

The purpose of this article is to articulate these differences, as presented in the literature. Armed with this information, the respiratory care community will perhaps come to some consensus on the terminology of breathing mechanics and begin to use this terminology consistently.

The first attempt to document standard respiratory physiologic definitions and symbols was in 1950.1 In 1964, 1965, and 1986, the American Physiological Society published similar documents.2,3 In 1975 and 1997 the American College of Chest Physicians and the American Thoracic Society,4 and American Association for Respiratory Care5 also published similar documents. Despite these publications, there is still no agreement concerning definitions and symbols used in respiratory physiology, particularly those used to describe mechanics of breathing, among the many authors who publish in the medical literature.
Symbols

Symbols used in respiratory physiology to identify specific points of reference relating to pressure gradients and the understanding of breathing mechanics are also critical to ensure no impedance to rigorous scientific communication. We offer Table 1 to illustrate the variety of symbols discovered in our literature search. It’s our belief that even though it may be acceptable to use different symbols, it’s still confusing, especially to students, for whom the concepts of pressure gradients are not fully developed. Our contention is that although different symbols are used and commonly accepted, standardized symbols used by all authors would be beneficial to the field.

Pressure Gradients

A comprehensive review of major textbooks (Table 2) was performed.6-28 A brief synopsis is also provided below, organized by pressure gradient. One inconsistency we found was that some sources did not define or give equations for many pressure gradients critical in the illustration of respiratory mechanics. One example was the text by Slonim and Hamilton entitled Respiratory Physiology, which defined only transpulmonary pressure.15

Transpulmonary. Several pressure gradients are encountered in the respiratory system. Transpulmonary pressure (Table 3) is commonly defined as the pressure gradient from the alveolar to the pleural spaces (P_{alv} – P_{pl}). Although most agree on the spaces between which this gradient is defined, the text edited by Kacmarek et al7 reverses the symbols and, therefore, the direction of this gradient (P_{pl} – P_{alv}).

Expanding the review to include original peer-reviewed research articles revealed even greater confusion.29-40 For instance, Davis defined transpulmonary pressure as the difference between airway opening pressure and pleural pressure (as measured via esophageal balloon), rather than the difference between alveolar pressure and pleural pressure.29 Airway opening and alveolar pressure are equal under static conditions, as may be the case with specific research protocols (under controlled conditions). This is a special scenario, and casual extrapolation of this estimation may confound the reader. Davis’s review29 defined transpulmonary pressure within the context of the measurement of dynamic airway resistance, in which both pressure and flow were dynamic rather than static.

Transairway. Transairway pressure (Table 4) is described alternately as the pressure gradient between the alveolar space and either the mouth or the airway opening (P_{m} – P_{alv}, or P_{ao} – P_{alv}).41,42 The direction of the gradient was reversed in the text for our own course in cardiopulmonary physiology: Respiratory Care Anatomy and Physiology by Beachey.6 Munakata et al describe transairway pressure as the difference between “airway opening and alveolar pressure,” without regard to direction.41 Hicks states that transairway and transrespiratory pressure are synonymous and expressed as P_{rs} = P_{A} – P_{B}.28

Transthoracic. Perhaps the greatest confusion regarding respiratory pressure gradients surrounds transthoracic pressure (Table 5).32-43-47 The equation for and definition of the transthoracic pressure gradient is inconsistent, even within the same textbook. For example, the equation P_{pl} – P_{a} appears in Chapter 9 of both the 7th and 8th editions of Egan’s Fundamentals of Respiratory Care.12,13 However, Chapter 40 of the 8th edition states that transthoracic pres-
Table 2. Comparison of Pressure Gradient Terms and Equations Used in Respiratory Care Texts

<table>
<thead>
<tr>
<th>First Author</th>
<th>Transairway</th>
<th>Transrespiratory</th>
<th>Transpulmonary</th>
<th>Transthoracic</th>
<th>Transdiaphragmatic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beachey</td>
<td>$P_{es} = P_A - P_{hs}$</td>
<td>$P_L = P_A - P_{pl}$</td>
<td>$P_W = P_{pl} - P_{hs}$</td>
<td>No equation, definition, or symbol</td>
<td></td>
</tr>
<tr>
<td>Kacmarek</td>
<td>“alveolar minus body surface pressure”</td>
<td>“pressure difference across the lung-thorax system . . . alveolar-body surface pressure”</td>
<td>“pressure difference across the lung (pleural minus alveolar pressure)”</td>
<td>“pressure difference across the thorax, including chest and diaphragm (pleural-body surface pressure)”</td>
<td></td>
</tr>
<tr>
<td>Martin</td>
<td>“Transairway (pressure) = Pm − Palv = pressure driving air into or out of the lungs”</td>
<td>No equation, definition, or symbol</td>
<td>“Transpulmonary = Palv − Ppl = pressure tending to inflate or deflate the lungs”</td>
<td>“Transthoracic = Palv − Pbs = pressure tending to inflate or deflate the lungs and chest wall together”</td>
<td>No equation, definition, or symbol</td>
</tr>
<tr>
<td>Des Jardins</td>
<td>$P_a = P_m = P_{palv}$</td>
<td>No equation, definition, or symbol</td>
<td>$P_{tp} = P_{palv} - P_{pl}$</td>
<td>$P_a = P_{palv} - P_{bs}$</td>
<td>No equation, definition, or symbol</td>
</tr>
<tr>
<td>Cottrell</td>
<td>$P_a = P_m = P_a$</td>
<td>No equation, definition, or symbol</td>
<td>$P_{tp} = P_{palv} - P_{pl}$</td>
<td>Ptt = Ppl − Pbs Pbs = Patm</td>
<td>No equation, definition, or symbol</td>
</tr>
<tr>
<td>Pilbeam</td>
<td>$P_{TA} = P_{aw} - P_A$</td>
<td>$P_{TR} = P_{awo} - P_{bs}$</td>
<td>$P_L = P_A - P_{pl}$</td>
<td>$P_W = P_A - P_{hs}$</td>
<td>No equation, definition, or symbol</td>
</tr>
<tr>
<td>Ruppel</td>
<td>No equation, definition, or symbol</td>
<td>No equation, definition, or symbol</td>
<td>$P_L = P_{palv} - P_{pl}$</td>
<td>$P_W = P_{pl} - P_{hs}$</td>
<td>No equation, definition, or symbol</td>
</tr>
<tr>
<td>Ruppel</td>
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<td>No equation, definition, or symbol</td>
<td>$P_L = P_{palv} - P_{pl}$</td>
<td>$P_W = P_{pl} - P_{hs}$</td>
<td>No equation, definition, or symbol</td>
</tr>
<tr>
<td>Op’t Holt</td>
<td>$P_a = P_{aw} - P_{palv}$</td>
<td>No equation, definition, or symbol</td>
<td>$P_W = P_{palv} - P_{pl}$</td>
<td>No equation, definition, or symbol</td>
<td></td>
</tr>
<tr>
<td>Slonim</td>
<td>No equation, definition, or symbol</td>
<td>No equation, definition, or symbol</td>
<td>No equation, definition, or symbol</td>
<td>No equation, definition, or symbol</td>
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<tr>
<td>Op’t Holt</td>
<td>No equation, definition, or symbol</td>
<td>No equation, definition, or symbol</td>
<td>No equation, definition, or symbol</td>
<td>No equation, definition, or symbol</td>
<td></td>
</tr>
<tr>
<td>Grippi</td>
<td>No equation, definition, or symbol</td>
<td>No equation, definition, or symbol</td>
<td>Pts = Palv − Pbs Pdi = Pab − Ppl</td>
<td>No equation, definition, or symbol</td>
<td></td>
</tr>
<tr>
<td>Loring</td>
<td>Not defined as “transairway pressure”; however, $P_{aw} = flow$ resistive pressure in the airways; $P_{awo} = P_{ao} - P_{palv}$</td>
<td>No equation, definition, or symbol</td>
<td>Not defined as such; however, $P_{CW}$ is the pressure difference “across the chest wall”; $P_{CW} = P_{pl} - P_{bs}$</td>
<td>PDi = Ppl − Pab</td>
<td></td>
</tr>
<tr>
<td>Chatburn</td>
<td>“$P_{transairway \ldots airway opening pressure minus lung pressure}$”</td>
<td>$P_{transpulmonary} = P_{transairway} + P_{transpulmonary}$</td>
<td>(derived) $P_{transthoracic} = P_{transairway} - P_{transpulmonary} = P_{transpulmonary} - P_{airway \ldots lung pressure minus body surface pressure}$</td>
<td>No equation, definition, or symbol</td>
<td></td>
</tr>
</tbody>
</table>

(Continued)
sure is $P_{bs} - P_{alv}$. Other authors add to the confusion by variously defining this gradient as $P_{alv} - P_{bs}$, $P_{A} - P_{bs}$, and "difference between gastric pressure... and the pleural pressure... at the end of expiration."44

The equation that uses alveolar pressure minus body surface pressure, in its various forms, is the same as that used by other authors to define transrespiratory pressure.$^{5,7,12,13}$

As a summary, we found the following various equations or relationships from the various authors for transthoracic pressure: $P_{pl} - P_{bs}$, $P_{alv} - P_{bs}$, $P_{bs} - P_{alv}$, $P_{transrespiratory} = P_{transairway}$.20 esophageal pressure
Transrespiratory. In the 7th edition of *Egan’s Fundamentals of Respiratory Care*, transrespiratory pressure (during spontaneous breathing) was similarly defined in Chapters 9 and 39 as the difference between pressure in the alveoli and the mouth (airway opening or body surface). In comparison, the 8th edition had a completely different equation for transrespiratory (and transthoracic) pressure. Chapter 9 of both editions defines transrespiratory pressure as $P_{alv} - P_{bs}$ or as $P_{alv} - P_{ao}$ (for spontaneous breathing), and Chapter 40 of the 8th edition defines it as $P_{ao} - P_{bs}$. Chapter 9 of both editions defines transthoracic pressure as $P_{pl} - P_{bs}$ and Chapter 40 of the 8th edition defines it as $P_{bs} - P_{alv}$. Additionally, other authors state that transrespiratory pressure equals transairway pressure (Table 6).
As we understand these concepts, they may be equivalent in some cases, because pressure at the body surface ($P_{bs}$) and pressure at the “airway opening” (or “mouth” or “airway”) is equivalent in spontaneous breathing. However, this would not be true if, for example, an endotracheal tube was in place. In such a case, it would be incorrect to say that the pressure at “the mouth” of this patient is equivalent to “airway” or “airway opening.” The pressure in the mouth of this patient would be barometric pressure ($PB$) or body surface pressure ($P_{bs}$). Depending on the text, transairway pressure may qualitatively equal trans-thoracic pressure9 or transairway pressure may equal trans-respiratory pressure.6,28

Transdiaphragmatic. One essential gradient, especially in spontaneous breathing mechanics, has rarely been described in textbooks. This is transdiaphragmatic pressure (Table 7), which has been described in only 4 textbooks,7,17,18,28 “Transdiaphragmatic pressure is defined by Kacmarek et al as “the pressure difference across the diaphragm (abdominal – pleural pressure).”” Grippi defined transdiaphragmatic pressure as “the pressure generated across the diaphragm during inspiration. It is calculated as the difference between intraabdominal pressure ($P_{ab}$) and pleural pressure ($P_{pl}$).”7,17 Consideration of this pressure gradient is not only beneficial but essential in the description and understanding of breathing mechanics.

**Summary**

Our review of the literature exposed great variability in the definition and symbolic representation of pressure gradients among experts and researchers involved in respiratory medicine. The extent of this variability is made evident by conflicting descriptions found in the medical literature and even in chapters of the same textbook. Although the ultimate impact of these discrepancies is not profound, it is our contention that this wide variability is confusing and unnecessary. Agreement among authors and consistent use of these terms will advance the understanding of pressure gradients, improve clarity, and allow for reliable scientific communication among students, clinicians, researchers, and educators.

**REFERENCES**


