Effect of a Nasogastric Tube on Esophageal Pressure Measurement in Normal Adults*


We studied the correspondence between fluctuations of esophageal pressure measured before and after placement of a nasogastric (NG) tube in six normal volunteers. Flow, airway pressure, and esophageal pressure data from at least 20 breaths were recorded in seven ventilatory conditions in two body postures: 0° (supine) and 60° (upright). The conditions studied included normal quiet breathing, added resistance, reduced compliance, increased frequency, increased tidal volume, continuous positive airway pressure, and volume-cycled ventilation with positive pressure. During recording with the NG tube in place, the subject targeted the same tidal volume (VT), respiratory rate, and inspiratory time fraction (T1/TTOT) recorded before NG tube placement. A computer program selected for analysis only those recorded breaths with and without an NG tube that were "matched" within 5 percent for both VT and T1. We calculated average VT, T1, and esophageal pressure fluctuation (ΔPes) for the matched breaths from each subject during every condition. The ΔPes values with and without NG tube were not statistically different in any tested condition (p > 0.05). Our data indicate that the presence of an NG tube does not invalidate the accuracy of ΔPes measurements made using a well-positioned balloon catheter in the tested conditions.

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ΔPes = esophageal pressure; auto-PEEP = auto-positive end-expiratory pressure; C = compliance; CPAP = continuous positive airway pressure; ΔPes = fluctuation of esophageal pressure; FVC = forced vital capacity; FR = respiratory rate; NG = nasogastric; Pes = esophageal pressure; T1 = inspiratory time fraction; VT = tidal volume

Key words: esophageal pressure; intensive care; monitoring; nasogastric tube; respiratory mechanics

Fluctuations of esophageal pressure (ΔPes) reflect changes in average pleural pressure that occur during tidal breathing, passive inflation, or respiratory maneuvers. In the clinical setting, ΔPes has been measured to ascertain breathing effort, to assess and partition the impedance to inflation (compliance and resistance), and to quantify auto-PEEP during spontaneous breathing. Moreover, knowledge of esophageal pressure (Pes) can help to interpret such hemodynamic variables as the pulmonary artery occlusion pressure ( wedge) or to determine the pressure applied across the alveoli when high airway pressures are needed to ventilate patients with abnormal lung and chest wall mechanics.

The accuracy and stability of the ΔPes measurement depend on balloon volume and on such variables as the pattern of breathing, body posture, and position of the balloon within the esophagus. As exemplified by swallowing artifact, measurement accuracy may also depend on factors that influence the balloon's local (intrathoracic) environment. Although measurements made with specially designed combination esophageal/nasogastric tubes appear to reflect ΔPes with accuracy sufficient for clinical purposes, the need for placing such a specialized balloon/tube catheter is often difficult to anticipate. Moreover, other types of nasoenteric tubes designed for feeding are needed for intermediate and long-term nutritional support. Consequently, a nasogastric (NG) or feeding tube may be placed before or after inserting an esophageal balloon catheter. We questioned whether the presence of a nasoenteric tube used for decompression or feeding distorts the flaccid esophagus sufficiently to interfere with the Pes estimation of pleural pressure.

METHODS

Subjects and Apparatus

We studied six cooperative normal volunteers (five male, one female; ages 23 to 37 years) who understood the purpose of the study and protocol. Each had normal body habitus (within 10 percent of ideal body weight), no history of cardiopulmonary disease, and normal values during forced spirometry (mean [± SD] forced vital capacity [FVC] of 4.92 ± 0.80 L [106 ± 9 percent of predicted] and a mean [± SD] forced expiratory volume in 1 s [FEV1] of 3.97 ± 0.56 L [102 ± 9 percent of predicted]). In the first three subjects ("first set"), the specialized esophageal balloon catheter of a commercially available system for measuring lung mechanics (Smart Cath, Bicore Monitoring Systems, Irvine, Calif) was inserted transnasally, positioned by mouth occlusion technique, and attached to an integrated signal conditioning and display unit (Bicore CP-100, Irvine, Calif). In three
other subjects ("second set"), a conventional esophageal balloon catheter was positioned in similar fashion and connected to a pressure transducer (Validyne MP-45, Northridge, Calif) and display system. The distal end of each catheter was covered with a flaccid balloon (10 cm long) and filled with 0.8 to 1.0 ml of air during use. Both types of esophageal catheter were 7F in diameter and were perforated by multiple holes in the balloon-covered segment.

Participants were requested to breathe through a mouthpiece connected to a rotameter-calibrated pneumotachograph. Inspiratory and expiratory flows were recorded either from a Fleisch-style pneumotachograph (Hans Rudolph Model No. 4719, Kansas City, Mo) or from a variable orifice flow transducer (VarFlex, Bicore Monitoring Systems, Irvine, Calif). Lateral airway pressure was tapped at the mouthpiece. A nose clip sealed the airway. Tidal volume excursions were recorded independently, using a DC-coupled inductive plethysmograph (Noninvasive Monitoring Systems, Respigraph, Miami Beach).

All signals were recorded on the integrated system (Bicore CP-100) in "first set" subjects and independently (independent system) in "second set" subjects. The independent system allowed simultaneous storage of analog pressure and flow data on a digital recorder (Astromeq MT 95000, West Warwick, RI) and on digital audiotape in analog format (TEAC RD-111T, Tokyo, Japan). This information was used to determine tidal volume (VT), inspiratory time (Tı), inspiratory time fraction (Tı/Tı/Tot), respiratory frequency (f), and APes for those subjects in whom the Bicore CP-100 unit was not in use.

Protocol

Each volunteer was tested under a variety of breathing patterns and imposed loads, before and after NG tube placement. To impose resistive loading, an orificial resistor (5.6-mm internal diameter) was attached beyond the pneumotachograph. To impose threshold loading, a continuous positive airway pressure (CPAP) valve (5 cm H2O, Vital Signs model No. 170227-1, Totowa, NJ) was attached in the same position. To reduce compliance, the chest and upper abdomen were wrapped with tight elastic bandages.

We studied all subjects in the supine (0°) and semi-Fowler's (60°) positions in the following order: normal quiet breathing; resistance loading (breathing through an orificial resistor); tac-
from the beginning to the end of inspiration (as determined by the points of zero flow). Because these zero-flow points can be precisely identified, and because this inspiratory pressure deflection is generally of more physiologic and clinical interest than the $\Delta$Pes of the entire respiratory cycle, we used this definition of $\Delta$Pes for data obtained from those "second set" subjects. During inspiration, the deflection of Pes is negative during spontaneous breathing and positive during passive ventilation. Because $\Delta$Pes reflects the result of subtracting an inspiratory value from an expiratory value, it will be positive in spontaneous breathing and negative during the ventilation of a passive subject with positive pressure.

In the absence of dynamic hyperinflation, a simplified inspiratory equation of motion for the lung during spontaneous ventilation can be written as follows: $\Delta$Pes = (VT/Ti) Rl + VT/C where Rl and C are the inspiratory resistance and compliance, respectively. For the purpose of comparing pressure deflections with and without an NG tube for a similar inspiratory effort, we attempted to match both VT and Ti and assumed Rl and C to be constant. For each condition, a computerized program (LabVIEW 2, National Instruments, Austin, Tex) determined those recorded breaths with and without an NG tube that were "matched" within 5 percent for both VT and Ti in "first set" subjects and for VT alone in "second set" subjects. Matching on Ti was not required for the zero-flow comparison, which reflected only the elastic pressure difference. We calculated average VT, Ti, and $\Delta$Pes for the matched breaths from each subject during every condition and analyzed the resulting data by paired t tests.

**RESULTS**

Tables 1 and 2 compare results from matched breaths for all subjects and ventilatory conditions in the upright and supine positions. The mean values for VT and Ti did not differ for paired breaths in any condition (p > 0.05), indicating successful matching of these parameters. The $\Delta$Pes values with and without NG tube for these matched breaths were not significantly different statistically in any of the tested conditions (p > 0.05). Figure 1 displays the correlations between $\Delta$Pes values measured in the presence and absence of an NG tube in the tested conditions, both supine and upright. In most conditions, the majority of points centered along the line of identity, with correlation coefficients between 0.75 and 0.98 (Tables 1 and 2). Although correlations were generally excellent, $\Delta$Pes data points from two subjects in the supine position were not close to the identity line in the increased VT condition (Fig 1). The graph for positive pressure ventilation shows generally positive values for $\Delta$Pes, indicating that most subjects were not breathing passively, thereby introducing an unintended element of variability related to effort.

**DISCUSSION**

Knowledge of intrapleural pressure is required for a variety of scientific and clinical applications. Esophageal pressure measurement remains the only seminvasive method available to estimate fluctuations in average pleural pressure in the clinical setting. Elegant work conducted several decades ago clearly demonstrated the potential for distortions of esophageal anatomy and increases in esophageal tone to reduce the accuracy of such measurements.4-6,9 This sensitivity has again been emphasized in recent studies confirming differences in the accuracy of Pes measurements before and after paralysis.12 Despite these apparent problems, a combined esophageal balloon/nasogastric tube catheter appears to yield $\Delta$Pes estimates similar to those obtained using a standard esophageal balloon of much smaller diameter.10,11

In the clinical setting, the need arises frequently to measure Pes when a second catheter shares the lumen. Nasogastric tubes are often needed for ongoing evacuation of the stomach, and smaller-diameter,
more flexible tubes are routinely placed for enteral feeding. Often, it is not feasible or practical to remove such catheters before placing an esophageal balloon. Although a combined NG-esophageal balloon catheter might be placed in such circumstances, specialized esophageal catheters that do not give the option of serving a second function, eg, the Bicore Smart Cath used in this work, are required for certain sophisticated clinical measurements of respiratory mechanics. With few exceptions, our findings indicate that ΔPes can be effectively measured, despite the presence of a second relatively large and stiff luminal catheter.

Many investigators have suggested that Pes is measured more accurately in the upright position than in the supine position. This positional variation is attributed to the shifting weight of mediastinal contents bearing on the esophagus in the latter position. Dechman et al have clearly shown that a change in posture may alter the pressure acting on the rib cage and that the consequent change of pleural pressure distorts mediastinal soft tissues, including the esophagus. Nevertheless, fluctuations in the pressure recorded from a properly positioned esophageal balloon may track pleural pressure changes acceptably well for clinical purposes. Potentially, the presence of an NG tube may directly interfere with the action of the lower esophageal sphincter, allowing regurgitation of air and gastric contents that can distort Pes, especially in the supine position. Moreover, the presence of a catheter in the pharynx tends to increase the relaxation frequency of the lower esophageal sphincter. These events do not occur frequently and may not always be associated with reflux. However, such relaxations may transiently create a common pressure cavity between the stomach and the esophagus, therefore, interfering with accuracy of pleural pressure estimation. Although our study did not show a significant postural difference in the correspondence of ΔPes measurements made with and without an NG tube in place, all subjects were studied while fasting and none had a history of gastroesophageal disease or reflux.

In the resistive loading condition, the ΔPes data were distributed in two clusters along the line of identity (Fig 1). This grouping was consistent with the difference in the calculation method of ΔPes in the two sets of subjects. In “first set” subjects, ΔPes reflected all elements of the inspiratory equation of motion, including the flow-resistive component, as well as a variable amount of inspiratory effort. In “second set” subjects, ΔPes was determined between points of zero flow and, therefore, reflected only the tidal elastic component of inspiratory effort. In neither group, however, was there a significant difference in ΔPes with and without an NG tube.

In the increased VT condition, ΔPes was significantly different with and without NG in only two

Figure 1. Correspondence between esophageal pressure fluctuations (ΔPes) with and without a nasogastic (NG) tube. Closed circles= integrated system, upright; open circles= integrated system, supine ("first set"); closed diamonds= independent system, supine ("second set").
upright subjects (Fig 1). These points are positioned on opposite sides of the line of identity and we have no clear explanation for these discrepancies. We speculate, however, that they may have arisen from undetected leakage of balloon air.

In conclusion, our results show that the presence of an NG tube does not routinely invalidate the accuracy of ΔPes recordings in most tested ventilatory conditions. However, we caution conditions. We speculate, however, with no known pulmonary or gastroesophageal disease. The results of such studies may not apply to persons with chest wall abnormality, obesity, lung disease, or critical illness. Further studies of this nature need to be completed on patients in the clinical setting.

REFERENCES
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