Malposition of Left-sided Double-lumen Endobronchial Tubes

To the Editor:—We read with interest the clinical report by Brodsky et al. concerning "Malposition of Left-sided Double-lumen Endobronchial tubes"; we wish to reinforce their impression that obstruction of the left upper lobe bronchus is a potential hazard when using a left-sided double-lumen tube. Brodsky et al. comment on the need for careful auscultation over the area of the upper lung fields to determine correct positioning of the tube and suggest that fiberoptic bronchoscopy is only required when auscultation is "difficult." We would like to describe a case of left upper-lobe obstruction that occurred when using a left-sided polyvinylchloride double-lumen tube. Careful auscultation after placement of the tube and after positioning of the patient revealed satisfactory and equal breath sounds over all areas of the chest including the axilla. However, at left thoracotomy it was immediately evident that the left upper lobe was not being ventilated. Fiberoptic bronchoscopy was immediately performed and the bronchial cuff could not be seen. Therefore, both cuffs were deflated and the tube withdrawn under direct bronchoscopic vision until the bronchial cuff became visible. Ventilation immediately returned to the left upper lobe.

Breath sounds can be transmitted from one region of the lung to adjacent areas. Benumof has suggested that auscultation in the axillary region decreases the likelihood of hearing such transmitted sounds. However, our case suggests that the presence of breath sounds in this area may be misleading. We feel that the only reliable method of confirming correct positioning of the bronchial limb of a double-lumen tube is by routinely performing fiberoptic bronchoscopy after tube placement. This is now our standard practice.

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REFERENCES
2. Benumof JL: Physiology of the open chest and one-lung ventilation, Thoracic Anesthesia, Edited by Kaplan JA. New York, Edin
(Accepted for publication June 4, 1985)

Correction of a Recurrent Error

To the Editor:—We write to call to the attention of your readers a substantive typographic error present in several texts that they may use. The error occurs in the equation giving the pressure drop associated with fully developed turbulent fluid flow (liquids or gases) through straight tubes. The correct formula is

\[ P = \frac{fL \rho \bar{V}^2}{4r^5} \]

where: \( P \) = pressure difference between the ends of the tube; \( f \) = dimensionless friction factor that depends on tube wall roughness and weakly on the Reynolds number, \( L \) = length of the tube; \( \rho \) = fluid density; \( \bar{V} \) = flow rate; and \( r \) = internal radius of the tube. One consistent set of units is: \( P \) in dyn/cm², \( \bar{V} \) in cm/s, \( \rho \) in g/cm³, and \( r \) in cm.

Benumof in Anesthesia and Sykes in Scientific Foundations of Anaesthesia give the formula incorrectly; both texts omit the fluid density term (\( \rho \)) in the numerator on the right side of the equation. Benumof references Sykes for the relationship. Sykes gives no reference. We believe both of these errors have their origins in a mistake in the Handbook of Physiology, which gives the relationship in just the form seen in the other two texts and with the same error.

* Recall that 981 dyn/cm² = 1 cmH₂O pressure.
† The same error, in Sykes, is also present in previous editions.
CORRESPONDENCE

TABLE 1. Definitions and Relationships among Flow Variables as Used by Different Authors

| Source                      | Wall Shear Stress \( (\tau) \) and Definition of Friction Factor \( (f) \)* | Reynolds's Number \( (N_R) \)† | Experimental Value of \( f_r \) | Pressure Drop \( (P) \) Associated with Turbulent Flow through Straight Tubes‡
<table>
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<tbody>
<tr>
<td>Fung</td>
<td>( \tau = \frac{f_g \mu}{2} )</td>
<td>( N_R = \frac{2 \rho u}{\mu} )</td>
<td>( f_r = 0.0779 )</td>
<td>( P = \frac{f_l \rho \nu \sqrt{g}}{2 \pi r^3} )</td>
</tr>
<tr>
<td>Fanning (from Vennard)</td>
<td></td>
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<tr>
<td>Prandtl (Blasius)</td>
<td>( \tau = \frac{f_g \mu}{4} )</td>
<td>( N_R = \frac{f \mu}{\mu} )</td>
<td>( f_0 = 0.133 )</td>
<td>( P = \frac{f_l \rho \nu \sqrt{g}}{2 \pi r^3} )</td>
</tr>
<tr>
<td>Darcy (from Vennard)</td>
<td>( \tau = \frac{f_g \mu}{8} )</td>
<td>( N_R = \frac{2 \rho u}{\mu} )</td>
<td>( f_0 = 0.316 ) ‡‡</td>
<td>( P = \frac{f_l \rho \nu \sqrt{g}}{4 \pi r^3} )</td>
</tr>
<tr>
<td>Giles</td>
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<tr>
<td>Dubois</td>
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</table>

* This column shows the differences in the definition of the friction factor \( (f) \). \( f_g = f_b/2 = f_b/4. u = \text{mean velocity.} \)
† All but Prandtl use diameter in the definition of \( N_R \); Prandtl uses radius. \( \mu = \text{fluid viscosity.} \)
‡ The different numeric factors in these columns reflect the different definitions of \( f \) and \( N_R \). Note that: \( \frac{0.0779}{2^{2/4}} = 0.131 \approx 0.133 \) and \( 0.0779 \cdot 4 = 0.3116 \approx 0.316 \).
§ Derived from Fung and Vennard.
¶ Derived from Prandtl.
** Given by Vennard and Giles (derived from Dubois).
†† Given by Vennard and Giles only.
‡‡ Given by Dubois (with typographic error) derived from Vennard and Giles.

Using dimensional analysis one can see that the equations given in these texts must be incorrect. (A true equality must have the same units or dimensions on both sides of the equal sign. "Dimensional Analysis" is the formal analysis to check that a particular equation meets this requirement.) The correct relationship is given by Prandtl (see e.g., Tietjens) and can be derived from other relationships given by Fung, and others.

Another part of this relationship may be confusing for anyone beginning a study of fluid flow. The value of the natural number in the denominator of the right side of the equation ("4" as presented above) depends upon how one defines the Reynolds number and the friction factor (see table 1). There are two common ways to define each of these parameters. The correct value of the natural number depends on how the above parameters are defined (see table 1).

Table 2 outlines the most important differences between fully developed laminar and fully developed turbulent fluid flow in straight tubes. Note particularly that for these two types of flow the pressure drop is proportional to either the first or second power of the flow rate and inversely proportional to either the fourth or fifth power of the radius.

**TABLE 2. Characteristics of Laminar and Turbulent Flow**

<table>
<thead>
<tr>
<th>Type of Flow</th>
<th>Pressure Drop</th>
<th>Dominant Fluid Characteristic</th>
<th>Velocity Profile</th>
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</thead>
<tbody>
<tr>
<td>Laminar</td>
<td>( P = \frac{8 \rho u V}{\pi r^4} ) (Poiseuille equation)</td>
<td>Viscosity ( (\mu) )</td>
<td>Parabolic</td>
</tr>
<tr>
<td>Turbulent</td>
<td>( P = \frac{1}{4 \pi r^3} )</td>
<td>Density ( (\rho) )</td>
<td>Blunt</td>
</tr>
</tbody>
</table>

REFERENCES


(Accepted for publication June 4, 1983.)