CLINICAL WORKSHOP
Anesthesiology
May-June 1968

588

nique. All five cases showed a statistically significant increase in the blood levels of meperi-
vacaine with each refill dose. Mepivacaine crossed the placental barrier but did not de-
press the neonate.

The help of B. M. Bennett, Ph.D., Associate Professor, Preventive Medicine, University of
Washington School of Medicine, Seattle, Washington, in performing the statistical analyses is
acknowledged.

REFERENCES
1. Frahm, M.: Beitrage zur pharmakologischen
answertung neuer Lokalanalgetika. Der Ana-
2. Truax, A. P., and Wiedig, S.: Contribution
to pharmacological and toxicological evalua-
tion of new local anaesthetic, d,l-methyl-
pipecolyl-2, 4-xyldide, Acta Chir. Scand.
3. Henn, F.: Determination of toxicological and
pharmacological properties of carboxaine,
lidocaine and procaine by means of simul-
Springfield, Ill., Charles C Thomas, 1964,
page 23.
5. Pratt, E. L., Warrington, H. P., and Grego, J.:
The gas chromatographic determination of
7. Marushima, H. O., Daniel, S. S., Finster, M.,
Poppers, P. J., and James, L. S.: Transmission
of mepivacaine hydrochloride (carbocaine)
across the human placenta, ANESTHESIOLOGY

Resistance of Nasotracheal Tubes Used in Infants

PENELLOPE CAVE, M.B.B.S., LONDON,* AND GRANT FLETCHER, M.D.†

Currently, nasotracheal intubation is pre-
ferred to tracheostomy for prolonged main-
tenance of the airway in the newborn infant.1, 2
Management of the airway is simpler and
there appear to be fewer post-extubation com-
pliations.3

An endotracheal tube has a smaller internal
diameter than an infant's glottis, and may pro-
duce a significantly greater airway resistance
than that of the infant's upper airway. Me-
chanical ventilation can be used to overcome
such an increase in resistance, but during spon-
taneous ventilation the increase in total airway
resistance would increase the work of breath-
ing. This situation arises during the period of
weaning from a ventilator, when it is desirable
to leave the tube in place and avoid frequent
reintubation.

* Instructo, Department of Anesthesia and
Pediatrics, Stanford University School of Medi-
cine, Palo Alto, California.
† Assistant Professor, Department of Anesthesia,
Stanford University School of Medicine, Palo Alto,
California.
Supported by a Grant from the John H. Hart-
ford Foundation.

The purpose of this investigation was to
study the airway resistance of nasotracheal
tubes of sizes commonly used for prolonged
intubation of infants4, 5 and to make a com-
parison with the reported upper airway re-
stance of the newborn.6

METHOD AND MATERIALS

Three sizes of plastic tubes were chosen for
study (table 1). They were cut to lengths
usually required to maintain the tip of the
tube in the trachea, midway between the car-
rina and the glottis. Connectors (Bennett †)

† Puritan Bennett, subsidiary of Puritan Com-
pressed Gas Corporation, Kansas City, Missouri.

<table>
<thead>
<tr>
<th>French Scale</th>
<th>Magill No.</th>
<th>Int. Dist. in mm.</th>
<th>Hub No.</th>
<th>Length in cm.</th>
<th>Connector Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>&lt;00</td>
<td>2.5</td>
<td>0</td>
<td>10</td>
<td>2L</td>
</tr>
<tr>
<td>14</td>
<td>00-0</td>
<td>3.0</td>
<td>&lt;1</td>
<td>11</td>
<td>3S</td>
</tr>
<tr>
<td>16</td>
<td>0</td>
<td>3.5</td>
<td>&gt;1</td>
<td>12</td>
<td>4S</td>
</tr>
</tbody>
</table>

Table 1. Dimensions of Tubes Studied
Table 2. Measured Drop in Pressure (cm. H₂O) Across Nasotracheal Tubes

<table>
<thead>
<tr>
<th>Flow</th>
<th>Tube Size (mm, I.D.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0 l/min.</td>
<td>2.5  3.0  3.5</td>
</tr>
<tr>
<td>83 ml/sec.</td>
<td>2.7  1.5  1.0</td>
</tr>
<tr>
<td>10.0 l/min.</td>
<td>14.0 4.5  2.5</td>
</tr>
<tr>
<td>166 ml/sec.</td>
<td></td>
</tr>
</tbody>
</table>

for attaching the tubes to an infant ventilator circle were inserted into the tubes. Slight variations in length of the tubes for different infants would not make a significant difference in total resistance, for at a constant driving pressure flow in a tube is proportional to the fourth power of the diameter, assuming laminar flow.⁷

Pressure differences were measured with a water manometer (Table 2) and air flow rates with a precision flowmeter (Fisher-Porter). The resistance of the tube was calculated from the pressure differences across the connector and tube at different rates of flow. The range of 5 to 15 l/min. was used (83 to 250 ml/sec.). These flows include the maximum flow rates seen in infants.⁸ The range for premature and newborn infants is 48 ml/sec. to 161 ml/sec.⁹ ¹⁰

RESULTS

Figure 1 shows pressure difference in cm. H₂O plotted against air flow rates in l/min. and ml/sec. At the lowest flows the differences between the tubes were small. Resistance increased disproportionately to flow rate with the smallest tubes 2.5 mm. in internal diameter (I.D.), above 50 ml/sec., indicating the development of turbulent flow. The 3.5 mm. I.D. tube appeared to have essentially laminar flow throughout the range studied.

DISCUSSION

The total airway resistance of newborn infants has been found to average between 18 and 29 cm. H₂O/L/sec.¹⁰ ¹¹ ¹² The mean nasal airway resistance is reported to be 12.1 cm. H₂O/L/sec. (range 5.6–19.9) or 40 percent of the total airway resistance. Nasal airway resistance constitutes approximately two-thirds of the upper airway resistance, whereas the glottis and larynx appear to constitute only a small amount (less than 10 percent).¹³ It seemed reasonable to compare the resistance of the endotracheal tubes studied with the upper airway resistance of the newborn to estimate whether they would increase the work of breathing if left in place in spontaneously-breathing infants.

At 100 ml/sec. the resistances of the 3.0 mm. I.D. and 3.5 mm. I.D. nasotracheal tubes studied (with connectors) were equal to or less than the upper airway resistance. On the other hand the 2.5 mm. I.D. tube had a resistance equal to or greater than either the upper or the total airway resistance of infants. During spontaneous breathing it is unlikely that there will be an increase in work of breathing if the 3.0 mm. I.D. or the 3.5 mm. I.D. tubes are used. The increase in work would be significant if the 2.5 mm. I.D. tube is used (Table 3).

FIG. 1. Relationship between pressure difference (cm. H₂O) and air flow rate (l/min. and ml/sec.) in three sizes of nasotracheal tube.
TABLE 3. Resistances of Tubes as Percentages of Reported Total Airway Resistance

<table>
<thead>
<tr>
<th>Tube Diameter (mm)</th>
<th>Resistance (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>100</td>
</tr>
<tr>
<td>3.0</td>
<td>60</td>
</tr>
<tr>
<td>3.5</td>
<td>41</td>
</tr>
</tbody>
</table>

CONCLUSION

The resistances to air flow in three sizes of endotracheal tubes and connectors were measured and compared with the reported upper airway resistance of the infant. 3.0 and 3.5 mm. I.D. tubes of the usual length appeared to impose little chance of increasing the work of breathing in the spontaneously-breathing newborn infant. 2.5 mm. I.D. tubes had a high resistance, compared with the infant's airway resistance, and should be used only in association with artificial ventilation.

REFERENCES


Surgery

DELIRIUM IN THE CCU

Eleven patients experienced varying degrees of delirium during the treatment of myocardial infarction in a coronary care unit. Sensory monotony and sleep deprivation seem to be of importance in the etiology of this state. Early signs of impaired thinking, confusion, or inappropriate behavior should alert the physician to impending delirium. The patient should be moved promptly to an environment of more nearly normal surroundings where family members may stay with him for long periods. Use of oxygen tents and monitoring equipment usually must be discontinued temporarily. Restraints should be avoided whenever possible. Sedation is almost always necessary, and one of the phenothiazines should be used in preference to barbiturates, which frequently accentuate the delirium. (Parker, D. L., and Hodge, J. R.: Delirium in a Coronary Care Unit, J.A.M.A. 201: 702 (Aug.) 1967.)