A NOTE ON THE OPTIMAL SIZE OF ENDOTRACHEAL TUBES BASED UPON STUDIES OF BLOOD GASES *

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THE question of the correct bore of tube for endotracheal anesthesia has been discussed for many years. This has led to the use of increasingly great diameters, in many places up to 14 mm., and in some places even larger. Gillespie has rightly called this a vexed question. Perhaps the choice may be put on an objective basis by considering the function required.

The function of an endotracheal tube is to facilitate ventilation of the lungs, and the measure of the effectiveness of this ventilation can under usual circumstances be judged by the oxygen saturation of the hemoglobin and the carbon dioxide tension of the arterial blood. These values should remain normal throughout prolonged anesthesia. As a generalization, it may be said that the tube of smallest bore that will ensure this ventilation is the optimal size.

Data obtained in connection with two other studies, when considered together, are relevant to this problem. In the first paper (1) 43 patients who were undergoing thoracic surgery were studied; among other things, arterial oxygen content and saturation of hemoglobin were measured. In the second paper (2) a careful study (uncomplicated conditions) of carbon dioxide content and tension and hydrogen ion concentration of the arterial blood were determined in 20 patients. Half of these patients were anesthetized by the open drop technic and breathed room air; half, as indicated, were anesthetized with the closed technic and inspired approximately 96 per cent oxygen. Both studies were made using ether anesthesia. The findings appear in tables 1 and 2.

The endotracheal tubes used to obtain the data in table 1 were Flagg or Flagg-Woodbridge, number 7 or 9, or Magill, 32 French. Their maximum outside diameters are 11 mm., shown in table 3. When the steel spring tubes were used, they were connected directly with the anesthesia machine through a Bradshaw rubber diaphragm mask, with no ventilation around the tube. When the Magill tubes were used, they lay free under the face mask, without inflatable cuff or throat pack. In

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TABLE 1

OXYGEN IN ARTERIAL BLOOD

Number of Patients	Operations (Lateral Position)	Duration of Anesthesia (minutes)	Before Anesthesia		Near Operation's End	
			O_2 Content (vol. %)	Saturation %	O_2 Content (vol. %)	Saturation %
16	Pneumonectomy	199	15.7	95	15.2	94
20	Lobectomy	174	16.7	95	16.3	97
7	Miscellaneous open thorax	126	17.5	95	17.5	97

this instance some ventilation doubtless occurs around the tube. Oxygenation was satisfactory when either types of tube was employed.

The data in table 2 were obtained using Magill tubes, 32 French. These lay free under the face mask and were used without cuff or throat pack, which permits some exchange around the tube. It is evident (table 2) that there is no important difference in hydrogen ion concentration, carbon dioxide content, or carbon dioxide tension between the data obtained during anesthesia with open drop ether with-

TABLE 2

CARBON DIOXIDE IN ARTERIAL BLOOD SERUM

Number of Patients	Operations	Duration of Anesthesia		Before Anesthesia			Near Operation's End		
		Open Drop, No Endotracheal Tube (minutes)	Closed, with Endotracheal Tube (minutes)	pH	CO_2 (vol. %)	CO_2 Tension (mm. Hg)	pH	CO_2 (vol. %)	CO_2 Tension (mm. Hg)
10	Miscellaneous patient supine	106	—	7.40	58.5	44.0±0.7	7.38	54.8	41.5±1.1
10	Miscellaneous patient supine	—	124	7.40	60.0	42.7±0.7	7.40	54.5	38.6±1.0

out an endotracheal tube and data obtained when a closed machine (Foregger, circle filter) with endotracheal tube (Magill, 32 French) was used. An examination of each case record as well as of the average data shown here supports this statement. Individual case records and details of the technic of measuring the gases in the blood and the hydrogen ion concentration may be found in the papers to which reference is made. Carbon dioxide tension would not have remained normal in the

TABLE 3

Type Tube	Size	Outside Diameters in mm.	
		Shaft	Tip
Flagg-Woodbridge (Steel spring)	7	8.7	9.7
Flagg-Woodbridge (Steel spring)	9	10.0	11.0
Magill	32 F	10.7	10.7

presence of harmful resistance to breathing, nor would it have remained normal if anoxia had been present.

When the patient is very large and the tube is to be connected directly to the anesthesia machine, a pharyngeal pack or inflatable cuff being employed, it may be desirable to use a Magill tube, size 34 French, but not larger.

The 63 patients used in this study were adults chosen at random; they exhibited all the variations in size found in any hospital.

As already mentioned, one often meets the point of view that as large an endotracheal tube should be used as will slip through the cords. The skilled anesthetist can usually insert large tubes without trauma, but however great the skill of the anesthetist, it is never great enough to prevent the trauma caused by the rubbing of the needlessly large tube against the tracheal mucosa with every breath the patient takes, nor to prevent the trauma that results from movement of the trachea by the surgeon during operations in the neck. Furthermore, the curve of the tube must fit the patient more precisely with large than with small tubes if trauma is to be avoided.

The trauma on insertion increases directly as the skill of the anesthetist is deficient. Less damage is caused by smaller tubes, provided a tube is used whose bore is adequate to provide for normal levels of oxygen and carbon dioxide in the arterial blood. As shown here, smaller tubes than generally supposed will provide these essentials.

SUMMARY

It has been shown that smaller, free-lying endotracheal tubes than generally supposed are entirely satisfactory, size 32 French, Magill, for example. Judgment of effectiveness is based upon the normal levels of arterial oxygen and carbon dioxide maintained throughout prolonged anesthesia by such tubes.

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