BRONCHIAL AIRWAY RESISTANCE IN HEALTHY CHILDREN

(UDC 612.215.1:612.66)

L. S. Romanova

Laboratory of Physiology (Head—Prof. L. L. Shik)
A. A. Vishnevsky Memorial Institute of Surgery (Dir.—Active Member AMN SSSR
Prof. A. A. Vishnevsky) AMN SSSR, Moscow
(Presented by Active Member AMN SSSR A. A. Vishnevsky)
Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 60, No. 8,
pp. 17-20, August, 1965
Original article submitted March 24, 1964

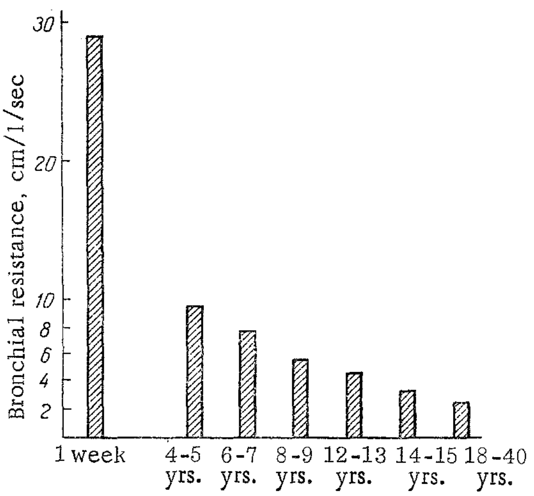
The magnitude of the bronchial resistance determines the conditions for the passage of an air current through the lungs.

The bronchial resistance, that is, the resistance to friction in the tracheo-bronchial tree, is calculated as a ratio between the pressure necessary to drive an air current through the respiratory passages (the difference between the alveolar and atmospheric pressures, which is usually called the alveolar pressure) and the respiratory flow rate of a water column, expressed in centimeters per liter per second.

The bronchial resistance in adults, according to data obtained by different authors, amounts on an average to 1.9-3.6 cm/l/sec with fluctuations of 1.1-6 cm/l/sec [1, 2, 8, 10-14]. It is also known that the bronchial resistance in children between the ages of 8 and 15 years is equal to 5.8-3.3 cm/l/sec, and in the newborn it is 29 cm/l/sec [4, 5].

In order to determine the degree to which the passage of air through the bronchial tree is affected during certain illnesses [1, 11, 12, 16, 17], it is necessary to know the normal values of the bronchial resistance. Since the passages of the bronchial tree change with age, these values must be determined at different ages.

The aim of our work was to ascertain the normal values of the bronchial resistance in children of preschool age (4-7 years).



Magnitude of the bronchial resistance in relation to age.

EXPERIMENTAL METHODS

The examinations were conducted on a universal pneumatachograph of the VNIIMIiO design [3], which combines a device for registering the respiratory flow rate (pneumotachogram) and the alveolar pressure.

The method for recording the respiratory flow rate of the air current during the respiratory cycle (pneumotachograph) was worked out in detail by Fleisch in 1925 [6]. The principle of the method is based on the fact that, in breathing through an obstruction to the air current (in the form of a diaphragm, narrow tube or plate), a difference in pressure is set up on each side of the obstruction. The greater the velocity of the respiratory current the greater the pressure difference. If the obstruction preserves the streamline character of the air current (that is, a linear flow without eddying), then, according to Puazeilya's law, the pressure difference is strictly proportional to the magnitude of the current.

TABLE 1. Bronchial Resistance during Expiration in Relation to Age. (From data of various authors)

Author	Number of examinations	Age	Bronchial resistance cm/l/sec	Mean square errors	Limits of fluctuations
Cook	23	1 week	29	±2.9	
Our data*	39	4-5 years	9.5	±1.8	
" "	41	6-7 years	7.7	±1.8	
		8 years 11 months	5.8	±5.0	
		12 years 5 months	4.7	±3.0	
Cook	85	14 years 11 months	3.3	±3.0	
		21 years	1.9	±1.0	
Our data	20	18-40 years	3.0	±0.8	
Otis	21	18-40 years	3.6		1.6-10.0
Wyss	30	18-40 years	2.2		1.4- 3.2
Jeker	65	18-40 years	2.2		1.1- 3.5
Stettner	21	18-40 years	1.98	±0.82	
Longhini	50	18-40 years	2.4		1.6- 4.0
Pabst	54	18-40 years	1.9	±0.5	
Magazanik *	47	18-40 years	3.3	±1.0	
Mukharlyamov*	?	18-40 years	3.8		3.0- 5.0

* Results obtained in the universal pneumotachograph VNIIMIiO.

The universal pneumotachograph VNIIMIiO is provided with a wide respiratory tube having a diameter of 37 cm and housing an obstruction in the form of a ceramic plate which ensures that the air current is streamlined. The subject, wearing a clamp sealing the nasal passage, breathes through the tube from which, on each side of the ceramic plate, a small tube leads to a differential manometer (registering up to 15 mm water) recording the difference in the pressures in front of and behind the obstruction. The manometer is provided with a mirror which reflects a ray of light from a quartz lamp onto a self-developing, photographic paper on which the pneumotachogram is recorded and which is used for computing the respiratory flow rate of the respired air. The deflection of the light ray from the null position is converted into the respiratory flow rate in liters per second.

On a similar apparatus, with the help of a differential manometer, recording up to 70 mm water, it is possible to record the alveolar pressure (the difference between the alveolar and atmospheric pressures) by the method of momentarily "overlapping" the respiratory current.

The method of "overlapping" (covering with the palm of the hand is a rough method) was suggested by Neergaard and Wirz in 1927 [9], improved by Fleisch [6] and worked out in detail by Vuilleumier [14]. The principle of the method rests on the instantaneous equalization of the pressures in the oral cavity and the alveolar cavity by overlapping the respiratory current and is produced in the universal pneumotachograph in the following manner. The metallic tube through which the subject breathes is provided with a valve of special construction, operated automatically or by pressing a lever, which closes the opening to the respiratory tube for 0.1-0.2 sec. Vuilleumier calculated that, even at very low air speeds (0.2 l /sec), the transfer of only 1 ml of air into the oral cavity is required for equalizing the pressures, and this takes place in 0.005 sec, that is, almost instantaneously. Since, during the overlapping of the air current, the pressure is instantaneously smoothed out throughout the whole space from the alveoli to the point of overlapping, the pressure changes at that moment and becomes equal to the alveolar pressure. By determining at the same time the respiratory flow rate in the pneumotachogram it is possible to estimate the bronchial resistance as a relationship between the alveolar pressure and the respiratory flow rate of the air current.

The method described is not difficult, even for young children. An examination took 3-5 min.

We examined 80 children (36 boys and 44 girls); 18 at 4 years old, 21 at 5 years, 33 at 6 years and 8 at 7 years.

The bronchial respiration during inspiration and expiration was measured when the subject was breathing quietly.

The manner in which the magnitude of the bronchial resistance depended on sex among children of a given age was not determined.

TABLE 2. Maximal Respiratory Flow Rate of the Respiratory Current in Subjects of Various Ages

	4-5 Years	6-7 Years	Adults
Alveolar pressure at a respiratory flow rate of one liter/sec (bronchial resistance), in cm/l/sec	9.5	7.7	3.0
The same (in %)	317	257	100
Maximal respiratory flow rate during quiet breathing, l/sec	0.47	0.59	0.87
Alveolar pressure at maximal rate, cm/l/sec	4.5	4.5	2.6
The same (in %)	170	170	100

EXPERIMENTAL RESULTS

We carried out 80 determinations of the bronchial resistance in children. The average value of this index in children 4-5 years old (39 examinations) amounted to 9.6 ± 2.0 cm/l/sec (inspiration) and 9.5 ± 1.8 cm/l/sec (expiration), and in children 6-7 years old (41 examinations) the values were 8.7±2.3 cm/l/sec and 7.7 ± 1.8 cm/l/sec respectively.

In order to compare our results with those found in the literature, we determined the bronchial resistance also in healthy adults (Table 1).

As is seen in Table 2, the magnitude of the bronchial resistance in children 4-7 years of age was approximately three times as high as in adults (18-40 years) and approximately one third of that in the newborn child.

In comparing the data obtained from examinations of children of various ages and of adults there appears to be a definite relationship between the changes in bronchial resistance and the age of the subject (see figure).

The sharpest drop in the bronchial resistance occurs, evidently, in the first year of life. There is a morphological reason for this—an increase in the lumen of the tracheobronchial tree.

As indicated above, the bronchial resistance is expressed by the alveolar pressure in centimeters of water at an air current speed of one liter per second. The actual respiratory flow rate is different at different ages and, thus, the alveolar pressure (and the work performed by the respiratory muscles in ensuring it) depends on both the bronchial resistance and the respiratory flow rate. Consequently, in all the experiments made on children and adults we determined the maximal respiratory flow rate during quiet respiration. It was found that the maximal flow rate during quiet respiration was equal to 0.47 l/sec at ages of 4-5 years, 0.59 l/sec at 6-7 years and 0.87 l/sec in adults (see Table 2).

In Table 2 a comparison is made between the average values of the alveolar pressure at a speed of one liter//sec (that is, the bronchial resistance), the maximal respiratory flow rate during quiet respiration and the alveolar pressure at this rate.

From Table 2 it is seen that, in reality, the alveolar pressure necessary for overcoming the bronchial resistance in children 4-7 years old is constant and only 70% higher than that in adults.

Thus, the rise in the bronchial resistance of children, dependent on the narrowness of the respiratory passage, is to a considerable degree compensated for by a lower air current speed linked with a smaller air flow rate. In spite of all that, the alveolar pressure and, consequently, the work of the respiratory muscles necessary for overcoming the bronchial resistance of the respiratory passages appear to be increased. This fact is confirmed by data which we obtained with the aid of electromyography on the large electrical activity of the respiratory musculature (intercostal) in children compared with that in adults.

SUMMARY

A universal pneumotachograph was used to determine the alveolar pressure, the respiratory flow rate and the bronchial airway resistance. In children aged 4-5 years the latter was found to be equal to 9.6±2.0 in inspiration and to 9.5±1.8 cm/l/sec in expiration; in children aged 6-7 years the values were 8.7±2.3 and 7.7±2.3 cm/l/sec respectively, i.e., 3-2.5 times higher than in adults. The maximum respiratory flow rate in quiet breathing in children proved to be lower than in adults. Therefore, the increased bronchial airway resistance in children, due to their narrow air passages, is partly compensated for by slower air flow rates. Nevertheless, the alveolar pressure and, consequently, the exertion of the respiratory muscles required to overcome the bronchial airway resistance are higher in children than in adults.

LITERATURE CITED

1. N. A. Magazanik, Changes in the Mechanics of Respiration during Shortness of Breath in Patients with Lung Diseases [in Russian], Candidates Dissertation, Moscow (1962).
2. N. M. Mukharlyamov, Trudy Vsesoyuzn. nauchno-issled. inst. med. instrumentov i oborudovaniya, No. 1, p. 108 (1963).
3. A. S. Perel'mutr, M. N. Katsuba, and S. E. Ksandrova, Novesti med. tekhniki, No. 1 (1961), p. 18.
4. C. Cook et al., J. clin. Invest., 36 (1957), p. 440.
5. C. Cook et al., J. appl. Physiol., 13 (1958), p. 349.
6. A. Fleisch, Helv. physiol. pharmacol. Acta, 14 (1956), p. 363.
7. K. Jeker and F. Wyss, Helv. med. Acta, 19 (1952), p. 383.
8. E. Longhini, A. Randazzo, and O. Mantero, Minerva med., 51 (1960), p. 3705.
9. K. Neergaard and K. Wirz, Z. klin. Med., 105, 51 (1927).
10. A. Otis and D. Proctor, Am. J. Physiol., 152 (1948), p. 106.
11. H. Pabst, Helv. med. Acta, 27 (1960), p. 759.
12. A. Randazzo, E. Longhini, and O. Mantero, Minerva med., 51 (1960), p. 4224.
13. H. Stettner-Grabenhofen, Normalwerte der Atemwiderstandsmessungen und deren Schwankungsbereite. Diss. Dokt. München (1957).
14. P. Vuilleumier, Z. klin. Med., 143, 698 (1944).
15. F. Wyss and F. Schmid, Schweiz. med. Wschr., 81, 916 (1951).
16. F. Wyss, Asthma bronchiale. . .Stuttgart (1955).
17. R. Zeilhofer and C. Bar, Arztl. Wschr., 11, 586 (1956).

All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.