MODELLING OF THE RESPIRATORY SYSTEM IN MATLAB

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Abstract

The design of the mathematical model of the respiratory system is described in the study. The model has been designed using an electro-acoustic analogy and geometrical dimensions of the morphological models of the respiratory system. The dependence of the geometrical dimension of the airways upon the total lung impedance is studied. Geometrical dimensions of adult respiratory system and neonate respiratory system are taken to compare the effect of the respiratory system dimensions upon the total lung impedance.

1 Methods

The aim of this study is to observe the effect of the geometrical dimensions of the respiratory system upon the total lung impedance. A special model is designed to study the respiratory system of neonates, children and adult people also. The model is implemented in MATLAB.

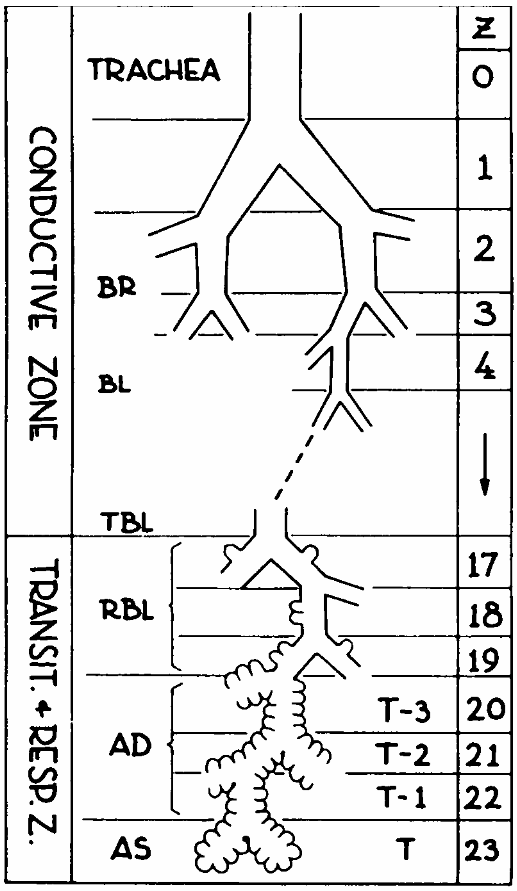

Figure 1: The schematic representation of the airways [1, 2] (z – generation, BR – bronchi, BL – bronchiole, TBL – terminal bronchiole, RBL – respiratory bronchiole, AD – alveolar duct, AS – alveolar sac). Generations 0–16 create convection zone, respiratory zone is determined by the generations 17–23.

The respiratory system has relatively complex anatomical structure. The elementary airways branch by the mean of irregular dichotomy. It means that airways in the same generation of the bronchial tree have various length and diameter. Therefore, it is difficult to describe the structure mathematically. We have used a morphological model of the respiratory system, where the irregular dichotomy is neglected. Then, the geometrical dimensions of the airways in the same generations are uniform. This approach allows describe the structure of the respiratory system and design the model that respects anatomical structure of the respiratory system. The geometrical dimensions of the morphological model are shown in Table 1. Acoustic elements are computed from the known dimensions. The electro-acoustic analogy [3] is used to model the elementary airways and electric laws can be used to solve the model.

Table 1: GEOMETRICAL DIMENSIONS OF THE MORPHOLOGICAL MODEL OF THE RESPIRATORY SYSTEM (AVERAGE ADULT HUMAN LUNG WITH THE LUNG VOLUME OF 4800 ML, 3/4 OF THE TOTAL LUNG CAPACITY APPROXIMATELY) AND NEONATAL LUNG: GENERATION IS DENOTED AS Z, AIRWAY NUMBER IN GENERATION N(Z), AIRWAY DIAMETER D(Z), AIRWAY LENGTH L(Z) [4, 5]

lung dimensions		adult lung		neonatal lung	
z	n(z)	d(z) [cm]	l(z) [cm]	d(z) [cm]	l(z) [cm]
0	1	1,8	12	0,539	3,594
1	2	1,22	4,76	0,365	1,426
2	4	0,83	1,9	0,249	0,569
3	8	0,56	2,76	0,143	0,195
4	16	0,45	1,27	0,115	0,325
5	32	0,35	1,07	0,09	0,274
6	64	0,28	0,9	0,072	0,23
7	128	0,23	0,76	0,059	0,195
8	256	0,186	0,64	0,048	0,164
9	512	0,154	0,54	0,039	0,138
10	1024	0,13	0,46	0,033	0,118
11	2048	0,109	0,39	0,028	0,1
12	4096	0,095	0,33	0,024	0,084
13	8192	0,082	0,27	0,021	0,069
14	16384	0,074	0,23	0,019	0,059
15	32768	0,066	0,2	0,017	0,051
16	65536	0,06	0,165	0,015	0,042
17	131072	0,054	0,141	0,014	0,036
18	262144	0,05	0,117	0,013	0,03
19	524288	0,047	0,099	0,012	0,025
20	1048576	0,045	0,083	0,012	0,021
21	2097152	0,043	0,07	0,011	0,018
22	4194304	0,041	0,059	0,01	0,015
23	8388608	0,041	0,05	0,01	0,013

2 Results

The total lung impedance is computed for the adult lung and the impedance is shown in Figure 2. The resonant frequency for adult lung is approximately f_r= 3Hz. This result is consistent with literature [6]. The frequencies used during high frequency ventilation (HFV) are close to f_r. The impedance is higher for the frequencies that correspond to the use of convention ventilation (CV). This result suggests that HFV is gentler to the respiratory system, because it is possible to maintain the tidal volume with lower pressure. The dependence of the total lung impedance of the neonatal lung upon the frequency has a different character contrary to adult lung. The chart is shown in Figure 3. The impedance is higher according to smaller proportions of the lung and it is difficult to determine f_r.

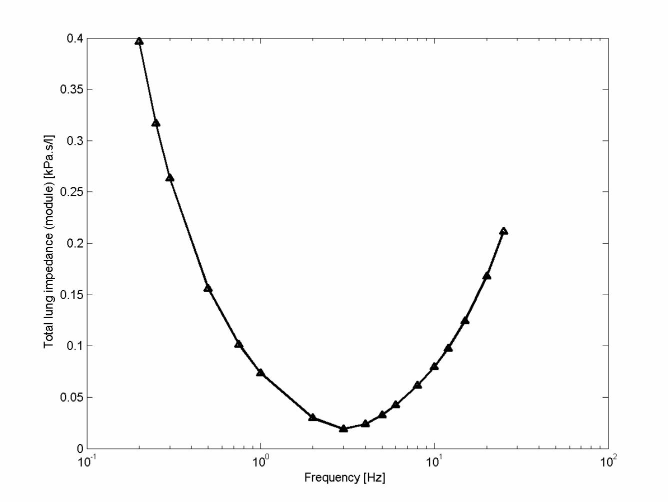

Figure 2: Total impedance of the respiratory system for adult lung dimensions.

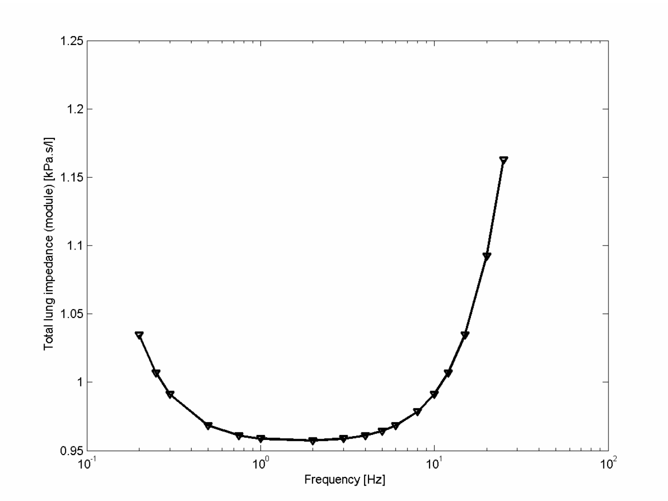

Figure 3: Total impedance of the respiratory system for neonatal lung dimensions.

Discussion

The unique model according to the anatomic structure of the respiratory system is designed. The total lung impedance of the respiratory system is studied. The simulations that were conducted on the model are described.

The presented results suggest that total lung impedance is strongly dependent upon the geometrical dimensions of the respiratory system. It is necessary to change the ventilatory parameters when the geometrical dimensions of the airways are changed. The change can be caused for example by obstruction of the airways.

References

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