International Journal of Natural and Engineering Sciences 3 (2): 15-17, 2009
ISSN: 1307-1149 www.nobel.gen.tr

Application of Artificial Neural Networks Method in Mucus Clearance in Pulmonary Airways

H. Rıdvan ÖZ[1*] B. KARLIK[2] C.A. EVRENSEL[3]
[1] Department of Genetics and Bioengineering, Fatih University, 34500 B. Çekmece, İstanbul, TÜRKİYE
[2] Department of Computer Engineering, Fatih University, 34500 B. Çekmece, İstanbul, TÜRKİYE
[3] Department of Mechanical Engineering, University of Nevada Reno, Reno, NV, USA

*Corresponding Author
e-mail: hroz@fatih.edu.tr

Received: November 19, 2008
Accepted: December 26, 2008

Abstract:
Clearance of mucus is investigated in this study. Clearance of mucus in the airways by the beating action of cilia inside the serous layer is the primary means of removing inhaled particulates and airway debris from airways in healthy people. One of the major causes of pulmonary airway disease is the weakened clearance mechanism in the airways. In this study, solid and liquid like mucus simulant are used in a tracheal model. Clearance distances of a teardrop shape simulant are measured for different velocities and slope angles. Artificial neural networks method is applied to the data obtained and clearance for intermediate velocity and angle values are determined.

Keywords: mucus simulant, tracheal model, artificial intelligence

INTRODUCTION

Simulation of coughing experiments was performed by using tygon tube [1], endotracheal tube [2] or a rigid channel [3]. Air flow was controlled by a 3-way solenoid valve between a constant pressure source and the test section and the duration of flow was 0.2-0.3 seconds. Two different mixtures were used as mucus simulant (MS). Mucus simulants were prepared by cross-linking locust bean gum with sodium tetra borate, 12% to simulate more gel-like mucus with a low V/E (viscosity/elasticity) ratio [4-6]. Aliquots of 3% simulant is similar to normal lung mucus and the stimulant obtained by mixing higher amount of sodium-tetra-borax can be related with diseases such as cystic fibrosis, chronic bronchitis and asthma [7]. Mucus clearance was investigated mechanically and experimentally (*in vitro*) for different air velocities, coughing angles using different simulants in references before [4-6]. In this study the values obtained previously will be used in artificial neural networks method. Artificial neural networks is an algorithm which simulates neural communication in human brain. It is used in different fields [8-10]. It will be used to obtain the data which is done experimentally previously.

MATERIALS AND METHOD

In this section, *in vitro* experimental procedure for mucus clearance and application of artificial neural networks were discussed.

Experimental Proce dure For I n V itro Muc us Clearance

The experimental setup used İs shown in Figure 1 [6]. The controlled air flow was supplied with constant pressure towards mucus stimulant resting on a removable flat wall inside a half cylindrical pipe. The angle between the tracheal model and the horizontal was changed during the experiment. Mucus clearance was observed for different angles and air velocities. The setup was composed of those parts: tracheal model, laminar flow element to prevent turbulent flow, computer and software which controls air flow, solenoid valve, a close-up high rate imaging system, light source, and a ruler. The stimulant lost its property during long waiting period due to heating of high power light source. That's why the experiments should have been performed rapidly. 1 mm^3 simulant was placed on the tracheal model removable flat wall using a small syringe and allowed settling before sliding it into test section. The air flow was supplied for 0.3 seconds and the clearance was measured by observing the ruler on the video images and/or also was read directly using the ruler. The experiments were performed for different angles, different surface properties (dry, sticky, slippery) and simulants. But here only one type of simulant (12%) and single surface property (dry) was used. The angles are 0, 15, 30, and 45 degrees.

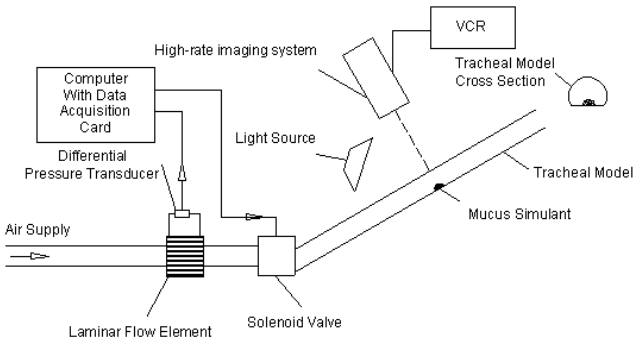


Figure 1. Experimental setup, [6]

The clearance values for 0, 30 and 45 degrees are shown in Figures 2-4. The values for 15 degrees in comparison with ANN method was presented in Section 3. As seen in the figures mucus clearance was difficult in small angles. The clearance increased with increasing angle. Similarly clearance became larger at higher air velocities. From here, it was understood that, the heavy mucus which could be a sign for diseases could be thrown out with difficulty in lie down position. It would be thrown out easily during coughing when someone tried to sit up.

Artificial Neural Networks

Neural networks are composed of simple elements operating in parallel. These elements are inspired by biological nervous systems. As in nature, the network function is determined largely by the connections between elements. One can train a neural network to perform a particular function by adjusting the values of the connections (weights) between elements. Commonly neural networks are adjusted, or trained, so that a particular input leads to a specific target output.

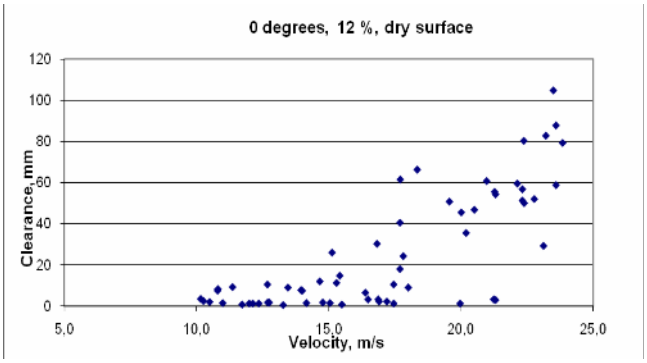


Figure 2. Velocity-clearance values for 0 degree angle

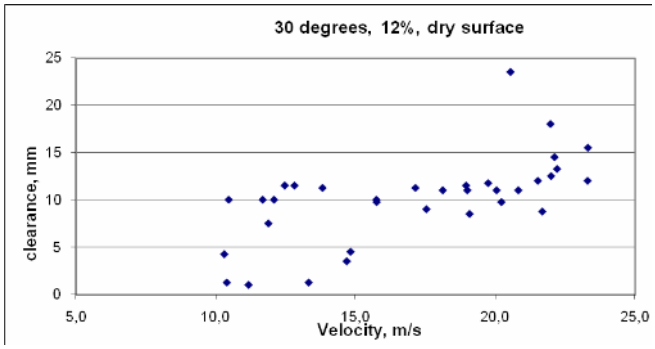


Figure 3. Velocity-clearance values for 30 degree angle

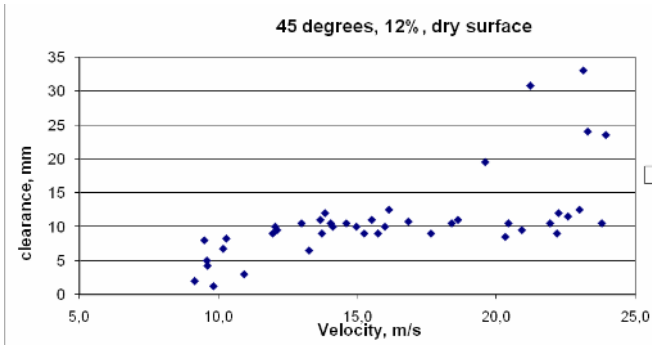


Figure 4. Velocity-clearance values for 45 degree angle

The multi-layer perceptron (MLP) is the most widely used type of neural network. It is both simple and based on solid mathematical grounds. Input quantities are processed through successive layers of ‘‘neurons”. There is always an input layer, with a number of neurons equal to the number of variables of the problem; and an output layer, where the perceptron response is made available, with a number of neurons equal to the desired number of quantities computed from the inputs. The layers in between are called ‘‘hidden” layers. With no hidden layer, the perceptron can only perform linear tasks.

In this study, a feed-forward MLP network architecture which has back-propagation training algorithms, generalized delta rule learning, was used. As it can be seen in Figure 5 the MLP structure consists of 2:15:1 that means it has 2 (air velocity and angle) neurons of input layer, 15 neurons of hidden layer, and 1 neuron (clearance distance) of output layer. The optimum learning rate and momentum coefficient were found as 0.9 and 0.1 respectively.

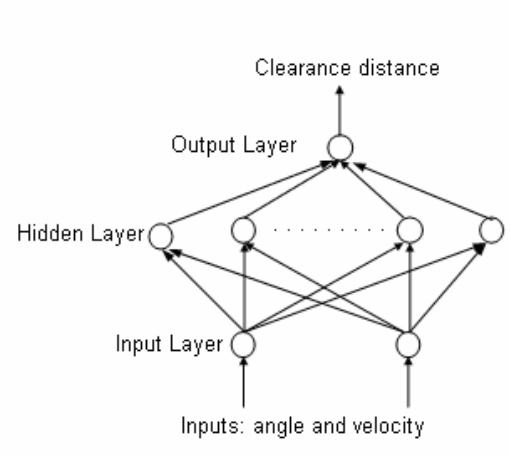


Figure 5. ANN architecture

RESULTS AND DISCUSSION

The output of ANN and experimental results of clearance distance for 0, 30 and 45 degrees were compared as shown in Figure 6. As it can be seen in this figure, the results were able to affirmative. It was also possible to find the other clearance distances using ANN.

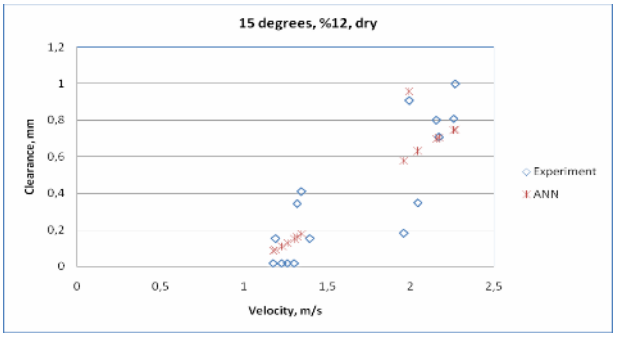


Figure 6. Comparison of experimental and ANN results

Figure 7 shows that the mean square error (MSE) according to iteration of ANN. Naturally, the MSE decreased while increasing the number of iteration. Total MSE error was found as %e=1.2086 after 2000 iterations. This error were found as %e=1.1745 and %e=1.1594 for 5000 and 10000 iterations respectively.

CONCLUSION

Mucus clearance is investigated in pulmonary airways using artificial neural networks method. Clearance values obtained experimentally for different angles (0, 30, and 45 degrees) and for different air velocities is used in the training phase of ANN method, Then it is tested for the 15 degree angle which is not used in the training phase. The results obtained in the test phase and experimental values are

compared. For both training and testing, a MLP architecture which has back-propagation algorithm were used. We can say that proposed ANN model is a very useful model after comparing experimental and neural networks results. In this study we used a well-known neural networks algorithm. In the future the other neural networks algorithms can be used and compared with this study to find the best ANN algorithms for this problem.

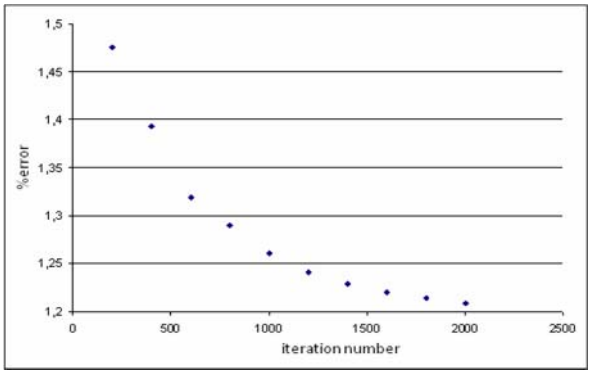


Figure 7. Variation of percentile error with number of iterations

REFERENCES

[1] Scherer PW, Burtz L. 1978. Fluid mechanics experiments relevant to coughing. J. Biomechanics. 11:183-187.

[2] Hassan AA, Evrensel CA, Krumpe PE. 2000. Interaction of airflow with viscoelastic gel in endotracheal tubes. Advances in Bioengineering, Ed. T.A. Conway, ASME BED- 48:231-232.

[3] King M. 1987. The role of mucus viscoelasticity in cough clearance. Biorheology. 6:589-597.

[4] Evrensel CA, Krumpe PE, Hassan AA, Öz HR. 2002. Effect of slope and viscoelastic behavior on the clearance of mucus simulant in tracheal models. ASME Proceedings of ESDA2002: 6th Biennial Conference on Engineering Systems Design and Analysis, ESDA2002/ BIO-012, July 8-11, Istanbul, TURKEY.

[5] Krumpe PE, Öz HR, Evrensel CA, HassanAA. 2001. Why do we sit up to cough? The benefits of vertical posture during cough clearance, Chest 2001 Annual Meeting, 120: 236-237A, November 4-8, Pennsylvania Convention Center Philadelphia, Pennsylvania, USA.

[6] Evrensel CA, Öz, HR, Krumpe PE, Hassan AA. 2001. Simulated mucus clearance in horizontal vs. vertically inclined rigid tracheal model, Proceedings of 2001 ASME International Mechanical Engineering Congress and Exposition, IMECE2001/BED-23107, November 11-16, New York, NY, USA.

[7] King M, Macklem PT. 1977. Rheological properties of microliter quantities of normal mucus. J. Appl. Physiol.: Respirat. Environ. Exercise Physiol. 42:797-802.

[8] Ozbay Y, Ceylan R, Karlık B. 2006. A fuzzy clustering neural network architecture for classification of ECG arrhythmias. Comp. in Bio. and Med. Feb. 36(4):376–388.

[9] Karlık B, Ünlü S. 2008. Practical artificial neural networks software for breast cancer diagnosis. Ukrainian Journal of Telemedicine and Medical Telematics. Mar. 6(2):63-68.

[10] Ceylan R, Özbay Y, Karlık B. 2008. A novel approach for classification of ECG arrhythmias: Type-2 fuzzy clustering neural network expert systems with applications. Expert Systems with Applications. Sep. 44(1), Sep.