PROJECT OF A MECHANICAL DEVICE TO EFFECT THE POSTURAL DRAINAGE

José Renato Barbosa de Deus
University Federal of the Minas Gerais, Department of Mechanical Engineering, 6627 Antônio Carlos Avenue, CEP 31270-901, Belo Horizonte, MG, Brazil
renatodedeus@ig.com.br

Antônio Eustáquio de Melo Pertence
University Federal of the Minas Gerais, Department of Mechanical Engineering, 6627 Antônio Carlos Avenue, CEP 31270-901, Belo Horizonte, MG, Brazil
pertence@ufmg.br

Maria da Glória Rodrigues Machado
University Center of the Belo Horizonte - Uni Bh, Belo Horizonte, Minas Gerais, Brazil
rodrimac@uai.com.br

Shirley Lima Campos
University Federal of the Minas Gerais, Department of Mechanical Engineering, 6627 Antônio Carlos Avenue, CEP 31270-901, Belo Horizonte, MG, Brazil
shirleylcampos@uol.com.br

Francimara Trindade Xavier
University Federal of the Minas Gerais, Department of Mechanical Engineering, 6627 Antônio Carlos Avenue, CEP 31270-901, Belo Horizonte, MG, Brazil
cimarafisio@yahoo.com.br

Luana Souto Barros
University Federal of the Minas Gerais, Department of Mechanical Engineering, 6627 Antônio Carlos Avenue, CEP 31270-901, Belo Horizonte, MG, Brazil
luanasouto@yahoo.com.br

Abstract. *The chest physiotherapy is essential in the treatment of patients with respiratory disorders and difficulties to expectorate the retained secretions. The technique of postural drainage (PD) is one of the resources used to accelerate the displacement of the secretion through the vertical positioning of the bronchial conduits. The use of the gravity force assists in the detachment and transport of secretions in the lung segments, mobilizing mucus to central airways, where will be expelled by the cough or for mechanical aspiration. For the effectiveness of the technique is necessary to know the anatomical position and delimitation of the bronchopulmonary segments. However, as there are controversies in the anatomical determination of the angles of the bronchopulmonary segments to be drained, the present article discusses the conception and development of a device of low cost capable to position the patient in the several known angles. Our results can serve as tool for researches in the optimization of those angles and in the study and determination of news.*

Keywords*: postural drainage, mechanical device, chest physiotherapy*

1. Introduction

Chest Physiotherapy is often used in the treatment of chronic airflow obstruction, especially in patients with excessive production and accumulation of lung secretions (Rubin, 2002).

The bronchial clearance can be facilitated through of techniques of displacement of secretions, from the periphery of the lung to more proximal airways, combined with respiratory patterns that increase and accelerate the expiratory flow, what can improve expectoration (Rubin, 2002).

In healthy individuals, the mucociliary clearance and the cough mechanisms are normally effective. When there is an overload of these systems, as for instance due to lung diseases, the ciliary and/or of the cough dysfunction contributes to the presence of excessive bronchial secretions (Pryor, 1999).

Production of bronchial secretions and continuous transport of these secretions in the direction of the oropharynx is one of the most important defense mechanisms of the airways. The effectiveness of this defense mechanism is probably dependent on the ratio between mucus production and mucus transport (Pryor, 1999).

Respiratory diseases usually evolve with hyper secretion and for times, consequent stasis of tracheobronchial secretion. This retention of secretions predisposes the development of lung infections. In that context, the physiotherapy

acts in the prevention of lung infections to the improve mucus transport. The positioning can also be used to improve lung function and the gas change among the capillary and the alveoli in the different parts of the lung (Van der Schans, 1957).

The postural draining (DP) is a technique which consists in positioning of the patient to drain secretions of lung origin of the bronchial tree, in such a way that the corresponding bronchi of the bronchopulmonary segment that it will be drained remains most vertical possible (Postiaux, 2004)

The physical principle of the gravity force to accelerates the displacement of the secretion to the most superior regions of the bronchial tree, helping its elimination. Technique effectiveness depends on the knowledge of the anatomical position and delimitation of the bronchopulmonary segments. (Postiaux, 2004)

Anatomically the respiratory system is constituted of superior (nose and mouth, pharynx and larynx) and inferior airway. The inferior airway includes the trachea, which is divided in right main bronchus and left main bronchus. The bronchi have similar structural disposal to a tree in inverted position and when penetrating in the lungs, they continue subdividing in 16 generations (Dangelo and Fattini, 2000) (Fig. 1)

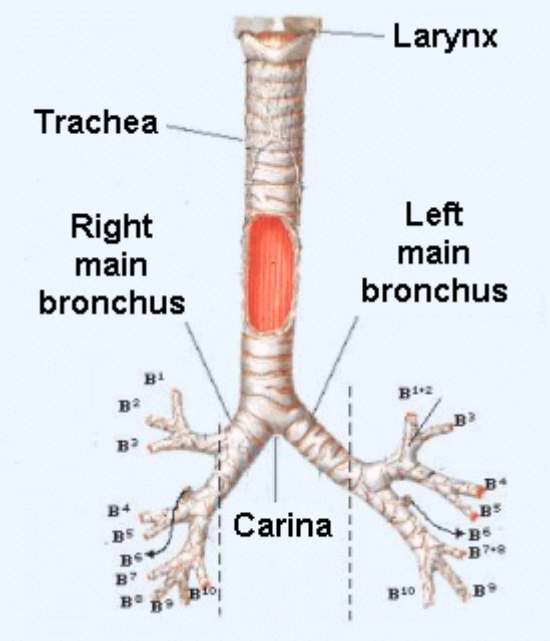

Fig 1. Simplified drawing of the bifurcation of the bronchi until the third generation
(Adapted from Netter, 1996)

The postural drainage positions for the lung segments recommended by Kacmareck et al. (1990) are:

a) Apical segments of right and left upper lobes: Patients in semi-Fowler's position with head of the bed raised 45°;

b) Anterior segments of both upper lobes: Patient in supine with the bed flat;

c) Posterior segments of right upper lobe: Patient one-quarter turns from prone with the right side up, supported by pillows, with head of the bed flat;

d) Apical-posterior segment of left upper lobe: Patient one-quarter turn from prone with the left side up, supported by pillows, and with head of the bed elevated 30°;

e) Medial and lateral segments of right middle lobe: Patient one-quarter turn from supine with right side up and foot of the bed elevated 0,305m;

f) Superior and inferior segments of lingual: Patient one-quarter turns from supine with left side up and foot of the bed elevated 0,305m;

g) Superior segments of both lower lobes: Patient prone with head of the bed flat and pillow under abdominal area;

h) Anteromedial segment of left lower lobe and anterior segment of right lower lobe: Patient supine, with foot of the bed elevated 0,508m;

i) Lateral segment of right lower lobe: Patient directly on left side with right side up and foot of the bed elevated 0.508m;

j) Lateral segment of left lower lobe and medial (cardiac) segment f right lower lobe: Patient directly on right side, with left side up and foot of the bed elevated 0,508m;

k) Posterior segment of both lower lobes: Patients prone with foot of the bed elevated 0,508m.

There are many drainage positions, but due to the high cost, in Brazilian reality are used pillows and cushions to reach the diverse necessary positioning angles.

It must be considered that the measurements published for bronchopulmonary segments angles present high uncertainty. This will require researches and adequate statistics treatments to find acceptable measures for them.

In this article we intended to discuss the conception and development of a device of low cost capable to position the patient in the several known angles, favorable the drainage postural, as well as, to serve as tool for new researches, seeking not only the optimization of those angles as well as the determination of news.

2. Methodology

For the conception of the device, preliminarily, it was verified necessity to develop a method of correlation between the angles of the bronchial tree and the angles of the device of postural draining, so that the axis of each lobar bronchus to be drained could be guided through the angular motions of the device of postural draining of such form that these axis always are in the same direction of the gravitational force or, of coordinate axis Z. The figure 2 illustrates the positioning of the bronchial tree during the accomplishment of a specific position of bronchial draining.

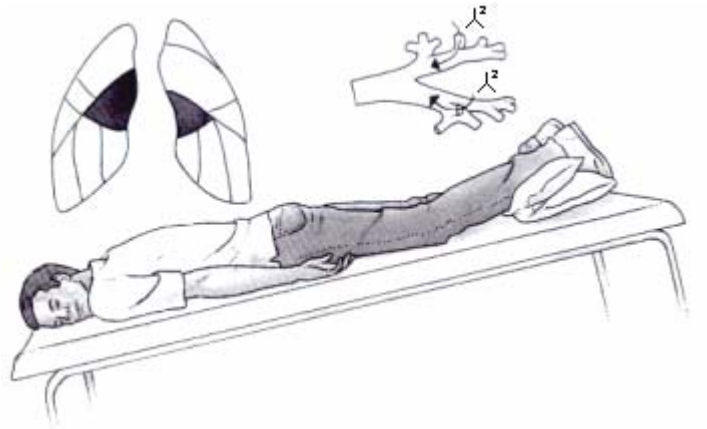

Fig 2. Posture of drainage of the segment superior broncopulmonary of the inferior lobe of both lungs (Adapted from Costa, 1999)

2.1. Conventions and adopted simplifications

For the development of the method of correlation between the angles of the bronchial tree and the angles of the device of postural draining had been considered the following procedures:

a) Definition of a system of global coordinates, localized in the table of the device with origin above the intersection of the axes of turn of the same and, also, that your coordinated axes contained in the plan of the table (XY) are in the same direction of the axes of turn of the device, as is illustrated in Fig. 3.

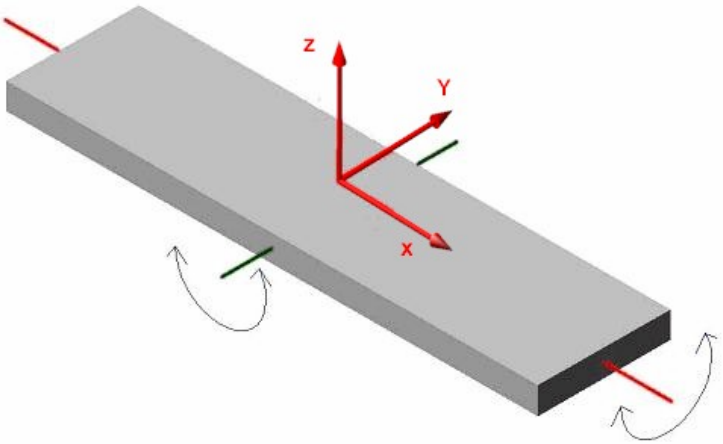

Fig 3. System of global coordinate on the mechanical device

b) Definition of a local system of coordinates, for each one of the lobar bronchus, parallels to the global system and with its origin localized in the junction of the lobar bronchus with its respective main bronchus, as indicated in Fig. 4.

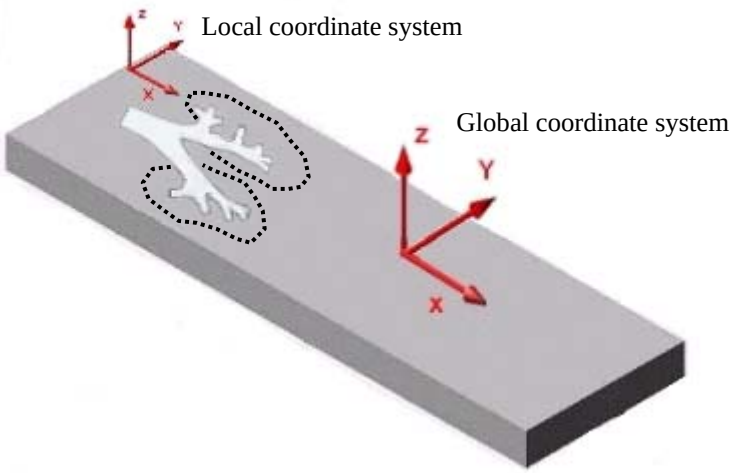

Fig 4. Local and global coordinate systems

c) For the postural drainage only the orientation is important, therefore, the space location of the lobar bronchi will not be considered in the present study.

d) The system of spherical coordinates was used to be located the orientation of each axis of bronchial segment and thus to determine the values of the angles of rotation of the device to process the postural drainage. The figure 5 illustrates the system of spherical coordinates.

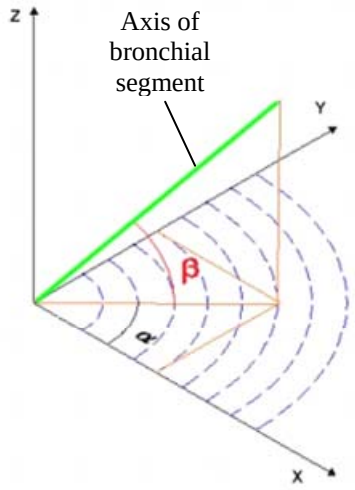

Fig 5. System of spherical coordinates

2.2. Procedures

Once known the spherical coordinates of the bronchial tree, beginning from trachea until that is reached the lobar bronchi, is possible to define schematically the axes of each segment so that can get the angles of turn of the mechanical device, that would represent the ideal angles to effect the postural drainage. As the systems of local and global coordinates were defined parallel between itself, the projections of the lobar bronchi, in the same ones, are identical. The figure 6 indicates the angles of the used projections.

The value of β corresponds to the angle between the axis of the bronchial segment and its projection in the perpendicular plan to XY, the value of ω indicates the angle between the axis of the bronchial segment and the axis coordinate Y. The angles α e λ are respectively, the angles of the projections of the axis of the bronchial segment in plans XY and XZ.

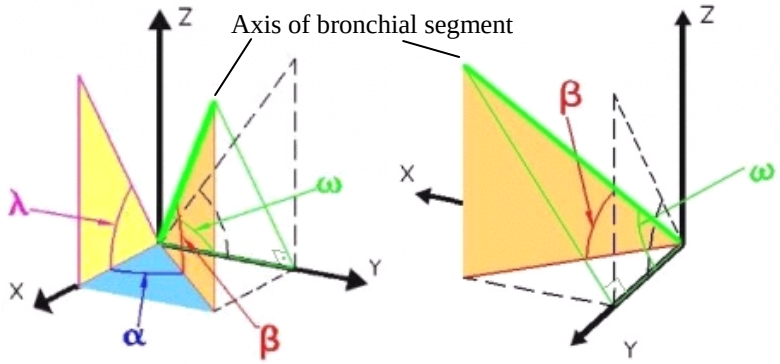

Fig 6. Angles of the projections.

Analyzing the rectangular triangles formed by the projections, the following relations can be obtained:
a) The dimension of the opposite cathetus to the angle β is equal to the opposite cathetus to the angle λ.
b) The adjacent cathetus to the angle β corresponds hypotenuse of the triangles that contain the angle α and the angle (90^o-α).
c) The adjacent cathetus to the angle α is equal to the adjacent cathetus to the angle λ.
d) The hypotenuse of the triangle that contains the angle β is equal to hypotenuse of the triangle that contains the angle ω.
e) The adjacent cathetus of the triangle that contain the angle ω is equal to the adjacent cathetus of the triangle that contain the angle (90^o-α).

2.3. Mathematical equations

Considering the trigonometrically properties and the indicated relations above is possible to develop a correlation among the angles through Eq. (1) and Eq. (2).

$$\lambda = arcTang\ [\frac{Tang\ (\beta)}{Cos\ (\alpha)}] \tag{1}$$

$$\omega = arcCos\ [Cos\ (90^o - \alpha) Cos\ (\beta)] \tag{2}$$

Where λ is the angle of the projection of the axis of the bronchial segment that is being drained, in the plan XZ. For this projection to be parallel to the axis Z is necessary that the same is rotated in relation to the axis Y of (90^o-λ) in the counterclockwise sense (Fig 7(a)). After this operation it remains to rotate, in the hourly sense in relation to the axis X, of the angle of (90^o-ω), once after the turn in relation to the axis Y (Fig. (7b)), ω will be the angle of the projection in the plan YZ (Fig. (7c)).

Like this both projections, so much in the plan XZ as YZ, will be parallel to the axis Z and consequently the bronchial segment will also be. Using these angles to turn the projections of the bronchial tree, for the origin of the system of global coordinates, the lobar bronchi will be, each one your time, positioned parallel to the axis Z.

As the global system was placed conveniently, those will also be the values of the angles of turn of the device.

2.4. Development of the mechanical device of postural draining

Known the rotation angles are possible to project, at a low cost, a device, as indicated in Fig. 8. For in such a way a maximum inclination of the table of rotation of 120^o (60^o for each direction of turn) for the longitudinal system and 90^o (45^o for each side of turn) for the lateral system was considered respectively. The sizing was made considering a useful load of 1500N and a estimate weight of 700N for the mechanical device.

One used the manual systems of movement of the table of rotation, with continuous regulation and system of reduction in the direction to propitiate necessary and soft movements to the patients, beyond and low level efforts and good sensitivity in the adjustment of the position for the physiotherapist.

One also used mechanisms of setting for to fix the rotation table in accordance with the specified conditions of draining.

Moreover it was looked to use easy manufacture materials such as plates and profiles of the wood and aluminum that basically demanded manual operations of cut, drilling and finishing.

In the current phase of the research, we are considering the use, to make the positioning of the device in the drainage angles and the following possibilities: groups of gears; chains; belts and cables.

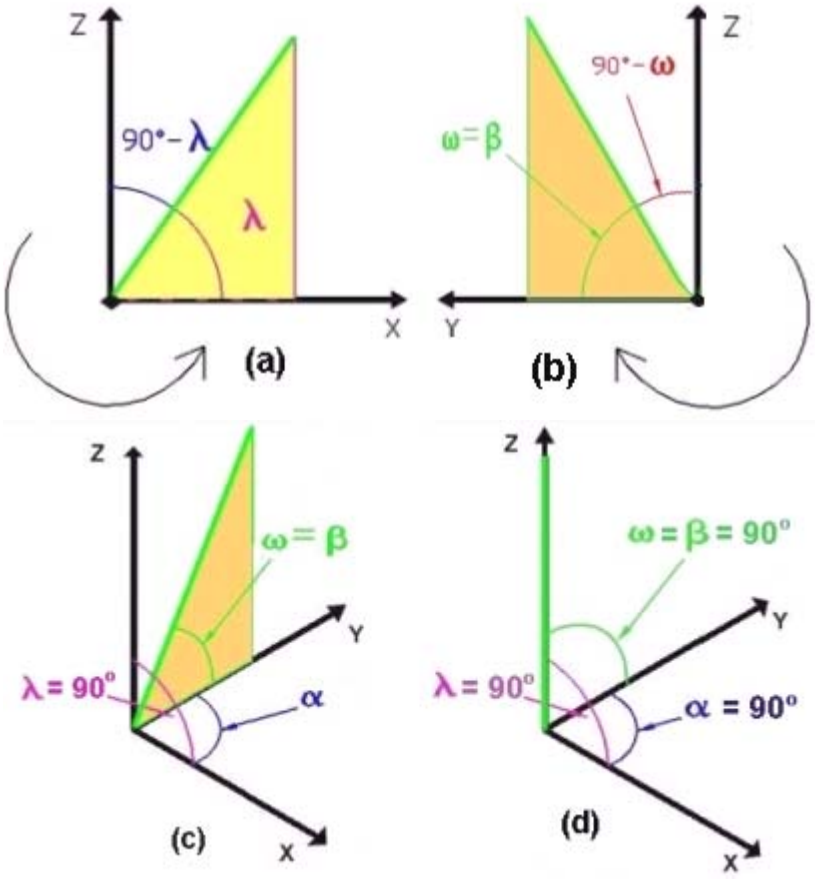

Fig 7. Rotations of the angles λ e ω

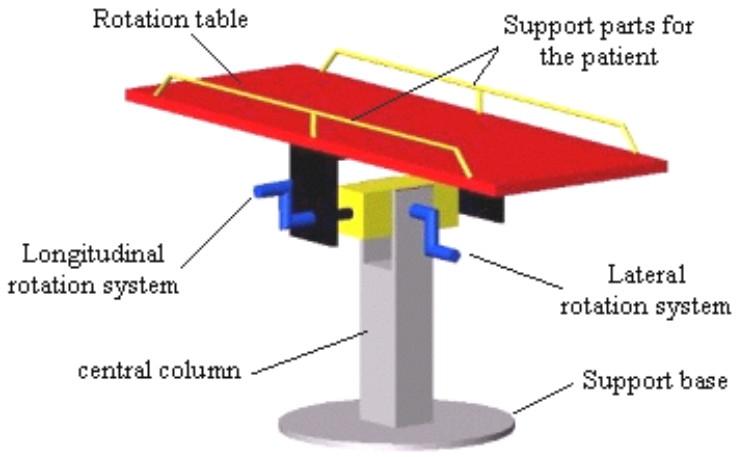

Fig 8. Schematic drawing of the mechanical device for postural draining.

3. Conclusions

The uncertainties of the measures of the angles of the bronchial tree are still high, however many researchers have been working to reduce them. In this phase of the research, the equipment can be used, in an empiric alternative, in the optimization of the angles for postural drainage described in the literature.

Once reliable values for the angles of the bronchial tree are found, easily, with the application of the described methodology, they can be related to the angles of turn of a device for postural drainage.

The low cost foreseen in the conception of the proposed device it can be a decisive factor to turn possible an expressive number of new researches.

4. Acknowledgements

Gratefulness to the CAPES for the financial support for development of the present study.

5. References

Costa, D. *Fisioterapia Respiratória Básica*. São Paulo: Atheneu, 1999. p. 01-0 9.
Fattini, C. A.; Dangelo, J. G. *Anatomia Humana Sistêmica e Segmentar*. São Paulo: Atheneu, 2002.
Kacmarek, R. M.; Mack, C.; Dimas S. *Essentials of Respiratory Care*, 3rd ed. Chicago: Year Book Med, 1990.
Netter, F. H. *Atlas de Anatomia Humana*. Porto Alegre: Artes Médicas, 1996. p. 190.
Postiaux, G. *Fisioterapia Respiratória Pediátrica*, São Paulo: Artmed, 2004.
Pryor, J. A. 1999, Physiotherapy for airway clearance in adults, *Eur Respir J*, vol.14, p. 1418/1424.
Rubin, B. K. 2002, Physiology of Aiway Mucus Clearence, *Respiratory Care*, vol.47, No 7,761-768 pp.
Van der Schans, C.P. 1957, Physiotherapy and Bronchial mucus transport, *Procedings of thesis*. p. 45 and 63.

6. Responsibility notice

The authors are the only responsible for the printed material included in this paper.