

## SUCTION PRESSURE BEHAVIOR IN FUNCTION OF THE HOLES IN THE SUCTION DEVICES OF LUNG SECRETIONS

**Shirley Lima Campos**  
shirleylcampos@uol.com.br

**Fabício Carvalho Soares**  
carvalho@demec.ufmg.br

**José Renato Barbosa de Deus**  
renatodedeus@ig.com.br

**Roberto Márcio de Andrade**  
rma@demec.ufmg.br

**Marcos Pinotti**  
Laboratório de Bioengenharia – Labbio  
Departamento de Engenharia Mecânica  
Universidade Federal de Minas Gerais – UFMG  
Av. Antônio Carlos, 6627 – 31.270-901 – Belo Horizonte, MG - Brasil  
pinotti@demec.ufmg.br

**Abstract.** *Considering that the suction devices possess several formats, varying according to the tip type, length and number of holes, the objective of this study is analyze the influence of the amount of holes in the suction devices on the suction pressure. Measures of the areas of holes and internal diameter were accomplished in devices with 3 holes (one frontal and two laterals). Such measures were as referential for the mathematical modeling of the devices with 1, 2 and 5 holes. Flow and pressure measurements were obtained adapting a flow meter and a vacuum meter to a portable secretion aspirator. The initial suction head pressure was considered constant and equal to -120mmHg. The variation of pressure was analyzed through the Bernoulli's equation. To the models containing 1, 2, 3 and 5 holes were obtained the applied head pressure of -131,17; -120,37; -119,64 and -119,36mmHg, respectively. The light decrease of the vacuous pressure for the devices with 3 and 5 holes is due for the largest available area for the drainage, provoking the effect of a flow diffuser, therefore can be concluded that these are more appropriate for the suctioning procedure, because as the effective pressures stayed inside of the acceptable superior threshold, there is smaller risk of tissue trauma to be caused.*

**Keywords:** suction pressure. suction device, mathematical modeling

### 1. Introduction

The airway suctioning is an invasive procedure, intensely used by the respiratory physiotherapy, in patient unable to expel the lung secretions voluntarily, permitting the maintenance of the bronchial, nasal and oropharynx hygiene through artificial airway (endotracheal and tracheotomy tubes) or the nasal and oral cavities (Costa et al., 1999).

The secretions suctioning can be accomplished in hospital through a negative pressure generator system with wall valve or in clinics and houses through portable aspirator to vacuous. The technique in open system is a procedure accomplished with aseptic rigidity, in that a catheter (suction device) is connected to aspirator pressured negatively and introduced by endotracheal, being removed secretions with soft rotating movements, following by the nasal cavity and oropharynx suctioning (Regan et al, 1994 and Willemen, 2002).

The procedure of suctioning is defined as the movement of fluids of a place for other for pressure gradient. However, the technique of airway suctioning is not exempt of risks, being related some current complications (table. 1).

Table 1. Complications related to the airway suctioning: adapted of Diogo (2001)

Laryngospasms and bronchospasms	Bronchoconstriction
Mucosal lesions	Tracheal wall erosion
Microatelectasis	Hypoxemia (followed or not of cianosis)
Oxygen desaturations	Alterations in the partial pressure of carbonic gas
Bradycardia	Tachycardia
Arrhythmias	Arterial hypertension and increase intracranial pressure
Anxiety	Infections
Heart failure	Sudden death

Complications such as trauma in the tracheal, nasal and oral mucosa generate aspiration of the mucous membrane and provoke ulcerations and bleeding, what it can be related to the absence of metrological standardization. Components as level of negative pressure and ideal size of the suction device are still discussed aspects of the technique (Santos and Zanette, 2001; Pryor and Webber, 2002).

The excessive negative pressure generated during the suctioning can suck the mucous membrane through the holes of the catheter and to displace small fragments of the wall tracheal (Santos and Zanette, 2001).

Although there is not a consensus among authors with relationship at the level of ideal pressure for the procedure, it is recognized that the degree of lung collapse depends on the negative pressure used for the suctioning (Brandstater and Muallem, 1969), and that the tissue trauma is reduced for the use of correct pressures (Copnell and Fergusson, 1995).

One of the first studies, testing the effect of different negative pressures in tracheal mucosa of 02 anesthetized dogs, used negative pressure of 100 and 200mmHg and observed that the tracheobronchial trauma was directly related with the magnitude of the applied negative pressure (Kuzenski, 1978).

Czarnik et al. (1991) had found results similar to using the pressure of -200mmHg during suctioning and verified significant tissues lesions in the endotracheal mucous membrane in dogs.

Kerr et al. (1993), had related that the use of vacuous pressure smaller than 120mmHg during the suctioning in individuals with cerebral compromising reduces the risk of increase of the intracranial pressure.

Papa and Trimer (2000) recommend checking of the aspiration equipment and if the suction pressure established is between -80 and -120mmHg with objective to reduce decurrent complications.

Pressures around -100 to -120mmHg for adults, -80 to -100mmHg for children and -60 to -80mmHg for infants are also cited (Scanlan et al. 2000).

The factors that interfere in the attendance to the patients should be investigated and request identification, partly to define the approaches in that are necessary researches and also for comparison and prevision so that the attendance to the individual patient and the therapeutic planning can be made on a firm scientific base.

The suction devices available commercially possess several formats, varying according to the tip type, length and holes, seeking to minimize lesions in mucous membranes (Scanlan et al. 2000).

However, standardizations do not exist with regard to the ideal number of holes for a same length and diameter of a suction device, so that the effect of the amount of holes in the suction pressure is not still objectively determined.

In this context, the mathematical modeling and computational simulation, inserted in the studies of Bioengineering, have been presenting important paper in the evolution of the Medicine, being constituted efficient tools in the investigation of complex biophysical phenomena. The simulation of vital phenomena demands the elaboration of models capable to describe the behavior of the biological systems, what involves experimental and analytic studies (Wood, 1998; Savi and Pacheco, 1999).

Such models are of great importance in projects of medical equipments, study of pathologies and establishment of diagnostic hypotheses, as for instance, the use of mathematical models of the several human physiologic systems to project breathers, anesthesia machines, infusion bombs for automatic administration of medication and heart monitors (Wood, 1998; Savi and Pacheco, 1999; Oh and Seo, 2003).

Therefore, the objective of this study is to analyze the influence of the amount of holes in the suction devices on the suction pressure. Thus, this experiment can bring benefits to the physicians, since these information can allow the analysis of the appropriate handling to the patients that need the accomplishment of the suctioning procedure for a better lung ventilation.

## 2. Methodology

The mathematical modeling was performed starting from the standard measurements of the suction devices available commercially and of measured parameters with the assembly of the measurement system.

A survey of the types of suction devices existents was accomplished in several representations of hospital equipments, being selected some samples of these devices of several marks.

It was verified that, for a same caliber, there were devices with 1 hole (frontal), 2 holes (one frontal and one lateral), 3 holes (one frontal and two laterals) and 5 holes (one frontal and four laterals).

Measurements of the areas of the front hole and lateral holes and of the internal diameter were executed with the use of a calliper rule in a sample of siliconized catheters, of polyvinyl chloride (PVC), of calibers 12 French (3,96.10<sup>-4</sup>m), length 0,5m, containing intermittent valve for negative pressure (Embramed, 3 holes).

The measures obtained for the area of the front hole and for each area of the lateral holes were of 1.10<sup>-6</sup> m<sup>2</sup> and 3. 10<sup>-6</sup> m<sup>2</sup>, respectively.

Flow and pressure gradient measurements were obtained joining a flow meter (Unitec) and a vacuum meter (Famabras) in series to a portable secretions aspirator (Microaspirador MA 520 manufactured by ASPIRAmox -NS).

The flow measurements made by two appraisers, that altered in the reading and annotation of the measured values were uniform and equivalent to 10L/min (1,67.10<sup>-4</sup> m<sup>3</sup>.s<sup>-1</sup>).

The Bernoulli's equation relates the potential and kinetics energies and of pressure of the fluid during the drainage in points of a same average line (Scanlan et al. 2000; Figliola and Beasley, 1995; Schiozer, 1996).

The potential energy is determined for the position of the fluid in relation to a reference plan, being proportional to the difference among the height of the entrance and of the exit of the tube. The kinetic energy is the amount of work accomplished by the matter in movement, being directly proportional to your speed and your mass. The pressure energy of the fluid or pressure potential links to the pressure exercised by the fluid in movement (Scanlan et al. 2000; Präss, 2005; Fox and McDonald, 2001).

The theorem (Eq. 1) expresses the conservation of the mechanical energy in the ideals fluids, according to the first law of the thermodynamics, the energy in a certain point of a fluid current should be the same along the tube, affirming that, in any point of the fluid, there is a constant relationship among speed, pressure and potential energy of the fluid, described for:

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + h_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + h_2, \quad (\text{Eq. 1}), \quad \text{where:}$$

$P$  is the pressure exercised by the fluid in the sections  $[\text{N/m}^2]$ ;

$\gamma$  is the specific weight. Equal the relation among the weight of the fluid (the mass under the influence of the gravity) and the volume occupied for the same  $[\text{N/m}^3]$ ;

$V$  is the speed of drainage of the fluid. Gived by the reason between the flow volume and the unit of area  $[\text{m/s}]$ ;

$g$  is the acceleration gravitational  $[\text{m/s}^2]$ ;

$h$  is the height in relation to the reference line  $[\text{m}]$ .

For the application of the Bernoulli's equation to the fluid drainage in devices with 1, 2, 3, and 5 holes, in other words, presenting differentiated areas, were made the following considerations:

a) Once the pressures  $P_1$  and  $P_2$  are considerably higher than the due pressure to the height difference between  $h_1$  and  $h_2$ , the influence of those heights can be despised and, therefore, to simplify the equation for:

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} = \frac{P_2}{\gamma} + \frac{V_2^2}{2g}, \quad (\text{Eq. 2}),$$

b) The initial suction head pressure ( $P_1$ ) was considered constant and equal to -120mmHg (-16KN/m<sup>2</sup>).

c) The speed of drainage of the fluid was obtained using the Continuity Equation:

$$\text{Considering that } V = \frac{Q}{A} \text{ and that } Q_1 = Q_2 \Rightarrow A_1 \cdot V_1 = A_2 \cdot V_2, \quad (\text{Eq. 3}) \quad \text{where:}$$

$V$  is the drainage speed  $[\text{m/s}]$ ;

$Q$  is the flow volume  $[\text{m}^3/\text{s}]$ ;

$A$  is the area of traverse section  $[\text{m}^2]$ ;

d) The areas of the devices of 3 holes were used (Fig. 1) as reference values to esteem the areas of the devices with 1 hole (frontal), 2 holes (a frontal and a lateral one) and 5 holes (a frontal and four lateral).

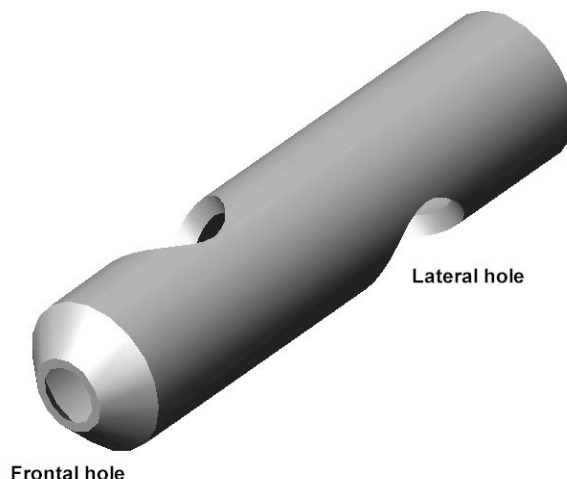


Figure 1. Schematic Illustration of suction device containing 3 holes

e) In this first approach the loss of energy due to the attrition was despised, therefore, it was considered that the pressure inside the device was constant in all your length.

### 3. Results and Discussion

The figure 2 presents the results of the mathematical calculations, considering that the flow volume measured in the aspiration system was constant and equivalent to  $1,67 \cdot 10^{-4} \text{ m}^3/\text{s}$  and that the density of the air to the temperature of  $35^\circ\text{C}$  was of  $1,131 \text{ Kg/m}^3$ .

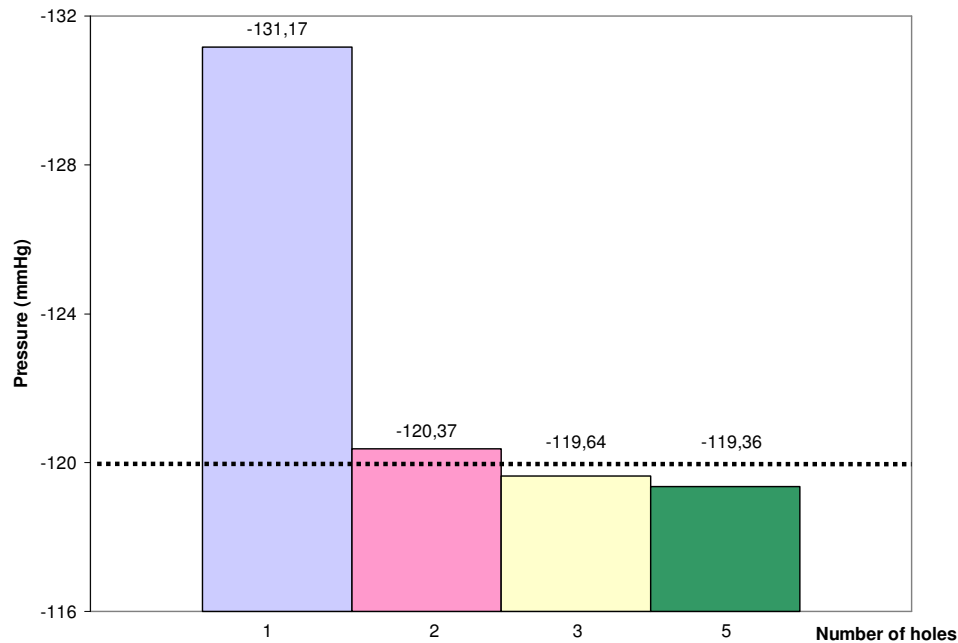


Figure 2. Final head pressures (tip of the catheter) in the suction devices with 1, 2, 3 and 5 holes.

The models of devices containing 1, 2, 3 and 5 holes had as results, respectively, an effective suction head pressure of 131,17mmHg; 120,37mmHg; 119,64mmHg and 119,36mmHg. The correlations between the areas of the holes of the suction devices and the generated pressures are observed in the Fig. 3.

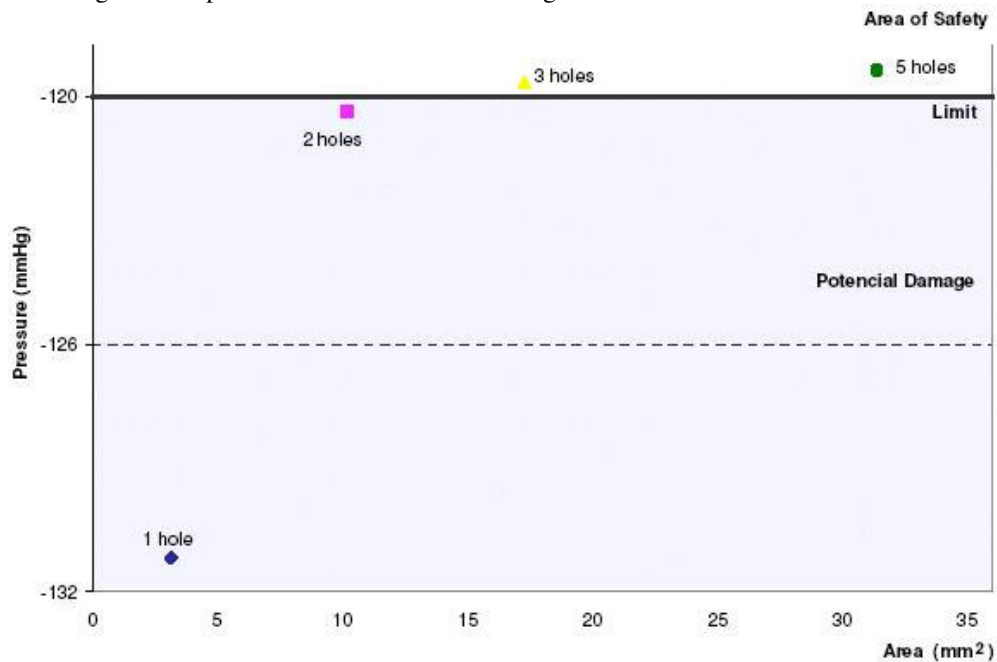


Figure 3. Correlation between the total area of the holes of the devices and the suction head pressures

The mathematical modeling of the relationship between the number of holes of the suction devices and the suction pressure generated showed that for an initial head pressure of aspirator of  $-120 \text{ mmHg}$ , at temperature of  $35^\circ\text{C}$  and density of the air of  $1,131 \text{ kg/m}^3$ , there is a light decrease of the vacuous pressure for the devices with 3 and 5 holes.

This happens for the fact of the increase of the number of holes to generate a larger available area for the drainage, so that, the increase of the traverse section of the tip in relation to the body of the probe, provokes the effect of a flow diffuser (Fig. 4).

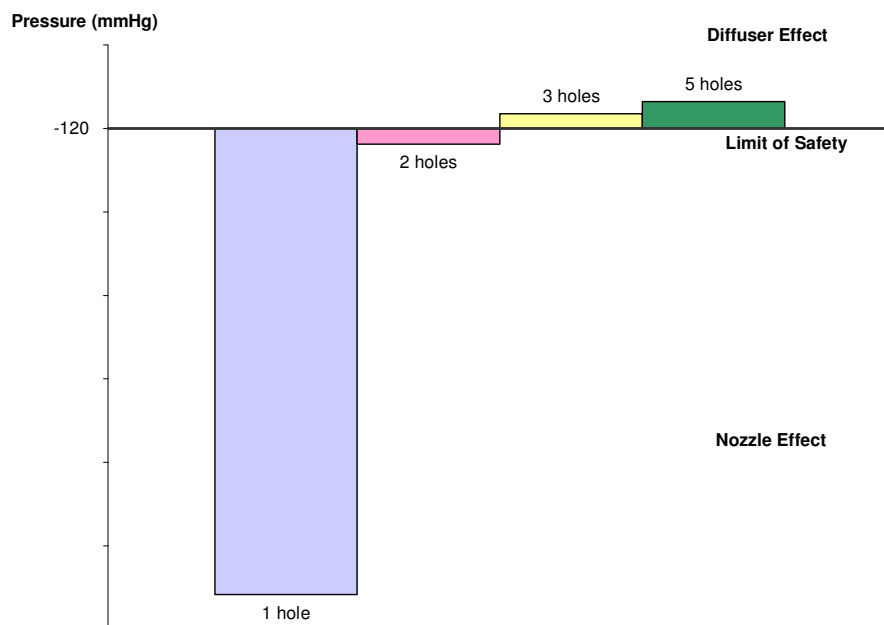


Figure 4. Effect mouthpiece and effect flow diffuser in the suction devices

For the devices with 1 and 2 holes, there is an increase in the module of the effective pressure, due to an effect contrary to the of flow diffuser, known as effect mouthpiece, being the vacuums pressures higher than the recommended by the physiologic studies.

The results lead to the hypothesis that, in situations of obstruction of a hole, the vacuum pressure applied will become larger than the expected for a certain device.

However, the calculations were accomplished considering approaches to a control situation and that, for the pioneer study, weren't found in the literature analytic studies and / or experimental with reference this analysis approach.

The modeling of the suction devices for a certain caliber showed that the kinetic energy is influenced by the area of the devices, and that therefore, depends on the number of your holes.

#### 4. Conclusion

The mathematical modeling of the suction pressure for a certain caliber of suction probe, presents a line of research of great relevance for the care and treatment of individuals with breathing disturbances.

According to the results, could be concluded that the devices with 3 and 5 holes are more appropriate for the accomplishment of the suctioning procedure, because the observed pressures stayed inside of the acceptable superior threshold.

This study offers to the professionals of health, an auxiliary tool for the selection of more reliable suction devices, what can contribute to the reduction of the high traumas index in the tracheal, nasal and oropharynx mucosa, for use of excessive levels of suction pressure during the suctioning procedure.

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