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Effects of ELTGOL and Flutter VRP1®on the dynamic and static pulmonary volumes and on the secretion clearance of patients with bronchiectasis

Efeitos da ELTGOL e do Flutter® nos volumes pulmonares dinâmicos e estáticos e na remoção de secreção de pacientes com bronquiectasia

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Abstract

Background: Although respiratory physical therapy is considered fundamental in the treatment of hypersecretive patients, there is little evidence of its physiological and therapeutic effects in bronchiectasis patients. **Objective:** To evaluate the acute physiological effects of ELTGOL and Flutter VRP1® in dynamic and static lung volumes in patients with bronchiectasis and, secondarily, to study the effect of these techniques in sputum elimination. **Methods:** Patients with clinical and radiological diagnosis of bronchiectasis were included. Patients underwent three interventions in a randomized order and with a one-week washout interval between them. Before all interventions patients inhaled two *puffs* of 100 μcg of salbutamol. There was a cough period of five minutes before and after the control protocol and the interventions (ELTGOL and Flutter VRP1®). After each cough series patients underwent assessments of dynamic and static lung volumes by spirometry and plethysmography. The expectorated secretions were collected during the interventions and during the second cough series, and quantified by its dry weight. **Results:** We studied 10 patients, two males and eight females (mean age: 55.9±18.1 years). After using Flutter VRP1®and ELTGOL there was a significant decrease in residual volume (RV), functional residual capacity (FRC) and total lung capacity (TLC) ($p<0.05$). There was a higher sputum production during ELTGOL compared with Control and Flutter VRP1® ($p<0.05$). **Conclusion:** The ELTGOL and Flutter VRP1® techniques acutely reduced lung hyperinflation, but only the ELTGOL increased the removal of pulmonary secretions from patients with bronchiectasis.
Trial Registration ClinicalTrials.gov NCT01300403.

Keywords: bronchiectasis; plethysmography; physical therapy; respiratory therapy.

Resumo

Contextualização: Embora a fisioterapia respiratória seja considerada fundamental para o tratamento de pacientes hipersecretivos, há poucas evidências acerca de seus efeitos fisiológicos e terapêuticos em indivíduos com bronquiectasia. **Objetivos:** Avaliar os efeitos fisiológicos imediatos da ELTGOL e do Flutter® nos volumes pulmonares dinâmicos e estáticos em pacientes com bronquiectasia e, secundariamente, determinar o efeito dessas técnicas na remoção de secreção brônquica. **Métodos:** Participaram do estudo pacientes com diagnóstico clínico e radiológico de bronquiectasia. Os pacientes foram submetidos a três intervenções de forma randomizada e com um intervalo (*washout*) de uma semana entre elas. Inicialmente os pacientes inalaram dois jatos de 100µcg de salbutamol. Após 5 minutos de tosse iniciais e após 5 minutos de tosse que sucederam o protocolo controle e as intervenções (ELTGOL e Flutter®), os pacientes realizaram as avaliações dos volumes pulmonares dinâmicos e estáticos por meio da espirometria e pletismografia corporal. A secreção expectorada foi coletada durante as intervenções e durante a segunda série de tosse, sendo quantificada por meio de seu peso seco. **Resultados:** Foram avaliados dez pacientes, dois do sexo masculino e oito do sexo feminino (média de idade de 55,9±18,1 anos). Após a utilização do Flutter® e da ELTGOL, observou-se diminuição significativa do volume residual (VR), da capacidade residual funcional (CRF) e da CPT ($p<0,05$). Foi eliminada maior quantidade de secreção pulmonar durante a ELTGOL em comparação com o Controle e o

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Flutter®. **Conclusão:** O Flutter VRP1® e a técnica ELTGOL reduziram a hiperinsuflação pulmonar a curto prazo, porém apenas o ELTGOL aumentou a eliminação de secreção pulmonar de pacientes com bronquiectasia.

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Palavras-chave: bronquiectasia; pletismografia; fisioterapia; terapia respiratória.

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Introduction

Bronchiectasis is an illness characterized by the abnormal and irreversible dilatation of the bronchus[1]. The destruction of the airway walls occurs due to infections and recurrent inflammations, resulting in impaired clearance, with accumulation of secretions in the affected areas and bacterial colonization[1]. The bronchiectasis is more prevalent in middle-aged women[2] and its main clinical manifestations are the chronic cough often associated to purulent secretions with fetid odor, predominantly in the morning, dyspnea, hemoptysis, fever, fatigue and weight loss[3].

In patients with bronchiectasis, respiratory physical therapy aims to prevent or reduce the consequences of retained secretions and reduce the recurrence of infections[4]. Several techniques can be used to assist mucociliary clearance, remove the excess of secretions with the lower possible effort, promote greater ventilation and improve the quality of life of these patients[5,6]. A physical therapeutic resource used for removal of bronchial secretion of patients with bronchiectasis is the Flutter® (Scandipharm, Birmingham, AL, USA), which combines high-frequency oscillation and positive expiratory pressure, resulting in decreased viscosity of secretions and easier transportation[7]. A technique called ELTGOL (*L'expiration Lente Totale Glotte Ouverte en Decubitus Lateral*) has also been proposed to promote the removal of secretion in hypersecretive patients[8]. Among the potential benefits of this technique are the improvement of peripheral airway clearance[9] and dyspnea, and the reduction in disease exacerbations[10]. The ELTGOL consists of performing slow expirations with the glottis opened, from the functional residual capacity (FRC) to the residual volume (RV), with the individual in the lateral *decubitus* position with the affected lung in the dependent position[11]. Despite this is a simple and low-cost resource, there is little evidence about its efficacy and physiological effects in hypersecretive patients. To our knowledge, there are no studies examining the effects of ELTGOL in subjects with bronchiectasis.

Several methods are proposed to evaluate the effects of airway clearance techniques, including the measurement of lung volumes. The use of this method is based on the premise that the bronchial secretions removal and the consequent airway resistance reduction could diminish the lung hyperinflation[12].

Thus, the objectives of this study were to assess the immediate physiological effects of ELTGOL and Flutter® in the pulmonary function of patients with bronchiectasis through spirometry and whole body plethysmography, and to determine the effect of these techniques in the removal of pulmonary secretions.

Methods

This was a crossover (6 x 3) randomized trial. Participants were recruited from the Ambulatory of Bronchiectasis of the Pedro Ernesto University Hospital (HUPE) of the Universidade do Estado do Rio de Janeiro (UERJ), Rio de Janeiro, RJ, Brazil. Participants with clinical and radiological diagnosis of bronchiectasis and with pulmonary hypersecretion (persistent productive cough) were included. Patients were excluded if they were undergoing regular physical therapy treatment or had current acute chest pain, recent history of hemoptysis, respiratory infection in the four weeks preceding the study, pneumothorax for at least one year and with confirmed diagnosis of asthma or cystic fibrosis.

The sample size was calculated using the program SigmaStat 3.1 (SYSTAT Software Inc., Point Richmond, CA, USA) and considering the production of secretion as the primary outcome. According to the results of the study of Bellone et al.[8], considering an average difference of 65%, standard deviation of 41%, power of 80% and α=5%, the sample size estimated was nine individuals.

The present study was approved (nº 02/2009) by the Ethics in Research Committee of the Centro Universitário Augusto Motta (UNISUAM), Rio de Janeiro, RJ, Brazil, and all participants signed a free and informed consent.

Data collection was performed at the Laboratory of Pulmonary Function of the Pneumology Service of the HUPE/UERJ, always in the mornings. Patients were submitted to the control protocol and to two interventions in a random order and with a one week washout interval between procedures. Block randomization sequences were created by a researcher not involved with recruitment, selection and assessments. Sealed opaque envelopes containing patients' assignments were opened at the time of first treatment.

Before the control protocol and the interventions, two jets of 100 mcg of Salbutamol, followed by a series of 5 minute of voluntary cough were administered.

In the control protocol (CTRL), patients remained seated comfortably without performing any maneuver for 15 minutes. In the intervention with ELTGOL (ELTGOL), individuals remained in lateral *decubitus* and performed slow expirations with the glottis opened through a mouthpiece to the RV, starting from FRC. Although in the ELTGOL the therapist can support the exhalation by a manual compression, in this study, the patients performed free (unattended) exhalations during this technique. This intervention was designed so that the runtime was similar to the Flutter® intervention. Thus, it consisted of three series of ten repetitions with a 2-minute interval between them (bilaterally), totalizing approximately 7 minutes and 30 seconds in each *decubitus* (total time of intervention = 15 minutes).

The intervention with the Flutter® (FLUTTER) was performed with the patient seated comfortably, performing expirations in the equipment, from the total lung capacity (TLC) until cough occurred, in a total time of 15 minutes[13]. Each exhalation in the equipment was alternated with a normal breathing. The angulation of the Flutter® was determined by each patient, according to their adaptation, perception and effectiveness of bronchial secretions removal[14]. During the control and during the interventions, participants were free to cough and expectorate. After each intervention and after the CTRL, a series of 5 minutes of cough was performed. During this period, patients were verbally encouraged to cough every 30 seconds, and short intervals of rest were allowed, according to the patients' tolerance. The functional characteristic of patients was determined by spirometry, and the equations of Pereira, Sato and Rodrigues[15] (spirometry) and Neder et al.[16] (static lung volumes) were used for the interpretation of the functional parameters.

Measurements of static lung volumes were conducted before the spirometry to avoid any residual effect of dynamic compression of the airways in the plethysmography results. These examinations were conducted after the initial 5 minutes cough series and after the 5 minutes cough series that succeeded the interventions and the CTRL, through spirometry and whole body plethysmography (Collins Plus Pulmonary Function Testing Systems, Warren E. Collins, Inc., Braintree, MA, USA) in accordance with the recommendations of the Brazilian Society of Pneumology and Tisiology (Sociedade Brasileira de Pneumologia e Tisiologia)[17]. The following variables were evaluated: forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), FEV_1/FVC, forced expiratory flow between 25 and 75% of the FVC ($FEF_{25-75\%}$), inspiratory capacity (IC), vital capacity (VC), TLC and RV.

The secretions expectorated during the initial 5 minutes of cough were discarded. Secretions eliminated during the interventions and in the later 5 minute cough period were collected and analyzed. After being in a stoveat 60ºC during 48 hours, the material was weighted in a precision scale for quantification of dry weight[18].

Statistical analysis was conducted by comparing the percentage variations pre and post of ELTGOL, FLUTTER and CTRL. Since data was not normally distributed (Shapiro-Wilk Test), the Friedman's Test for repeated measures was chosen, followed by the Dunn's Test for multiple comparisons. The comparison between the values pre control and pre intervention was performed by means of the Repeated Measures Analysis of Variance or Friedman's Test, followed by the Tukey or Dunn's test, whenever appropriate. Differences were considered significant at $p<0.05$.

Results

From April 2010 to November 2010, ten patients were recruited and evaluated. All individuals tolerated and completed the steps in this study. Their demographic and functional characteristics are presented in Table 1.

There were no statistically significant differences between the results of spirometry and plethysmography at baseline between control and interventions (Table 2).

Table 1. Functional and demographic characteristics of patients with bronchiectasis.

Characteristic	N=10
Age (yrs)	55.9±18.1
Gender (M/F)	2/8
Weight (kg)	54.7±10.5
Height (cm)	154.8±6
BMI (kg/m²)	22.8±4.2
FEV_1 (% pred)	53.4±18.9
FVC (% pred)	68.4±20.1
FEV_1/FVC	64.1±14.5
$FEF_{25-75\%}$ (% pred)	38.9±38.6

FEV_1=forced expiratory volume in 1 second; FVC=forced vital capacity; FEF_{25-75}=forced expiratory flow between 25% and 75% of the forced vital capacity; BMI=body mass index.

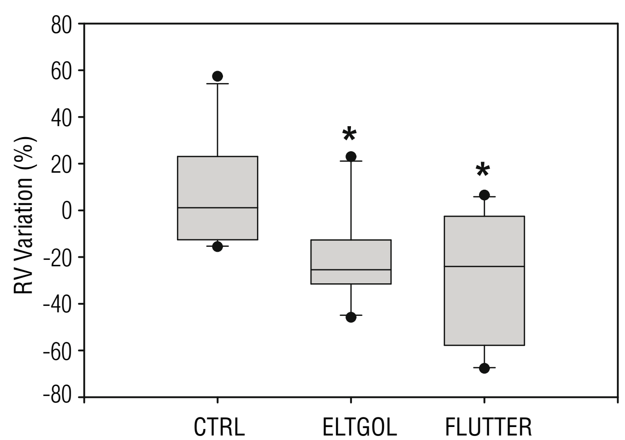
Table 2. Baseline conditions.

	CTRL	ELTGOL	FLUTTER	p
FVC (L)	2±0.73	1.9±0.77	1.87±0.64	0.527
FEV_1 (L)	1.24±0.55	1.25±0.62	1.19±0.47	0.452
FEV_1/FVC	64±14.2	63.6±12.45	63.5±14.47	0.926
$FEF_{25-75\%}$ (L/s)	1±1.06	0.92±1.05	0.85±1.04	0.358
IC (L)	1.23±0.44	1.29±0.54	1.32±0.52	0.171
VC (L)	1.84±0.73	1.81±0.82	1.79±0.73	0.838
TLC (L)	4.09±1.04	4.55±1.38	4.14±1.09	0.104
FRC (L)	2.94±0.96	3.25±0.96	3.09±1.35	0.273
RV (L)	2.25±0.85	2.11±0.61	2.41±0.76	0.298
RV/TLC (%)	54.4±13	56.8±15.05	56.2±14.04	0.273
IC/TLC	0.31±0.09	0.32±0.07	0.29±0.15	0.651

FEV_1=forced expiratory volume in 1 second; FVC=forced vital capacity; FEF_{25-75}=forced expiratory flow between 25% and 75% of the vital capacity; IC=inspiratory capacity; VC=vital capacity; TLC=total lung capacity; FRC=functional residual capacity; RV=residual volume.

There were no differences between the percentage variations of FVC, FEV_1, FEV_1/FVC, $FEF_{25-75\%}$, VC, IC and RV/TLC between ELTGOL, FLUTTER and CTRL. The variables RV (Figure 1), FRC and TLC showed reduction in ELTGOL and FLUTTER when compared to CTRL (Table 3). There was a reduction in IC/TLC only in FLUTTER (Table 3).

Expectorated secretions were obtained from eight patients. The dry weight of secretions was higher ($p<0.05$) for ELTGOL compared to FLUTTER and CTRL (median; min-max): [0.38; 2.63-0.06 g] vs [0.15; 1.3-0.05 g] vs [0.14; 0.65-0.02 g], respectively.



* significantly different from control (p<0.05).

Figure 1. Residual volume (RV) percentage variation in control (CTRL), ELTGOL and FLUTTER, considering the pre and post-intervention values. The superior and inferior borders represent the quartiles (percentile 25 and 75, respectively). The internal line is the median, whilst the vertical lines represents the data amplitude/variation.

Discussion

This study showed that both ELTGOL and FLUTTER acutely reduced pulmonary hyperinflation, although ELTGOL was more effective in removing pulmonary secretions of patients with bronchiectasis.

Bronchiectasis evolves with a pulmonary obstructive syndrome in which the RV is typically elevated by airway obstruction and loss of elastic retraction[19]. This elevation of the RV promotes an increased relationship RV/TLC[19] that, in healthy young individuals, is between 0.20-0.25, with values increasing with age but not reaching a maximum of 0.4 in ages above 60 years[20].

In our study, patients showed RV/TLC and FRC beyond the normally accepted upper limit, probably due to airway obstruction, with consequent air retention and lung hyperinflation[21,21]. After the application of the FLUTTER, there was a reduction in FRC, RV and TLC, suggesting that the airway clearance was sufficient to reduce pulmonary hyperinflation. This reduction is remarkable as the positive expiratory pressure performed during the evaluated protocols could increase the FRC, as noted by Jones et al.[21]. It is likely that the positive pressure performed during the Flutter intervention stabilized the airways during expiration, avoiding the dynamic collapse and favoring pulmonary deflation[23].

During the intervention with Flutter, there was no increase in the airway secretions removal when compared to CTRL. Perhaps the time required for the displacement of secretions with FLUTTER is higher than that observed with ELTGOL, causing movement of secretions, but without reaching central airways from where they could be eliminated through coughing. This hypothesis is reinforced by the fact the ELTGOL

Table 3. Spirometric and plethysmographic percentual variations in the different interventions.

	CTRL	ELTGOL	FLUTTER
ΔFEV_1	1.4 [(-6.3) - (13.3)]	2.2 [(-20.2) - (20.9)]	1.6 [(-6.8) - (21.4)]
ΔFVC	0.2 [(-35.3) - (7.5)]	0.96 [(-11.8) - (22.1)]	2.44 [(-3.9) - (8.1)]
ΔFEV_1/FVC	0.8 [(-4) - (5.9)]	0 [(-8.6) - (10.6)]	0.7 [(-11.3) - (19.6)]
ΔFEF_{25-75}	0.43 [(-36.9) - (40.4)]	6 [(-90.51) - (236)]	4.5 [(-21.4) - (160)]
ΔIC	5.70 [(-8.46) - (23.68)]	2.65 [(-15.65) - (27.66)]	-3.49 [(-28.47) - (33.78)]
ΔVC	-2.35 [(-8.12) - (18.42)]	5.01 [(-8.56) - (22.22)]	-2.44 [(-20.76) - (7.33)]
ΔTLC	4.63 [(-7.45) - (12.63)]	-9.66 [(-40.03) - (-1.96)]*	-18.27 [(-42.83) - (-6.43)]*
ΔFRC	4.26 [(-18.87) - (22.43)]	-14.48 [(-55.65) - (-3.60)]*	-25.81 [(-52.02) - (-5.14)]*
ΔRV	2.89 [(-8.02) - (35.14)]	-18.72 [(-71.85) - (-10.73)]*	-29.55 [(-54.66) - (-8.86)]*
ΔRV/TLC	0.81 [(-6.00) - (20.69)]	-8.48 [(-25.46) - (113.04)]	-5.21 [(-22.81) - (27.59)]
ΔIC/TLC	6.73 [(-17.3) - (21.3)]	17.9 [(-10.2) - (57.8)]	22.8 [(-3.64) - (82.5)]*

Δ=percentage difference between post and pre-intervention; FEV_1=forced expiratory volume in 1 second; FVC=forced vital capacity; FEF_{25-75}=forced expiratory flow between 25% and 75% of the vital capacity; IC=inspiratory capacity; VC=vital capacity; TLC=total lung capacity; FRC=functional residual capacity; RV=residual volume; *=different from CTRL (p<0.05). Values are median [min – max]. CTRL=control protocol; ELTGOL=ELTGOL intervention; FLUTTER=Flutter VRP1® intervention.

promotes the narrowing of the airways and, consequently, the increase of gas-liquid interaction, favoring the dynamic drag of the secretions toward central airways[7], while the Flutter has as main mechanism the change in secretions rheology, favoring the mucociliary clearance[7]. Since patients with bronchiectasis present deficiency in mucociliary system, it is possible that the secretions moved slower, even with a change in the rheological properties[8]. In addition to these factors, during the FLUTTER, bronchial secretions had to move against gravity, while, during the ELTGOL, the patient experienced the two lateral *decubitus*, which, in theory, could accelerate the mucociliary clearance, with more expressive results in the amount of secretion expectorated immediately after the application of the technique.

Considering the physiological repercussions compatible with bronchial secretions removal observed in our study, it is likely that a larger sample size and the secretion collection at 30 and 60 min after the interventions would provide statistically significant results for the secretion elimination with FLUTTER.

As for spirometry, our findings are consistent with previous studies in which they noted improvement in spirometric values after airway clearance techniques[18,24,25]. Similarly to our study, Bellone et al.[8] did not find significant differences in FEV_1 between Flutter® and ELTGOL in patients with acute exacerbation of chronic bronchitis.[8] According to van der Schans[6], the use of pulmonary function tests in the short term is a limited method for assessing airway clearance techniques. The compressive effect of the forced maneuver, in addition to the possible presence of secretions in the intermediate airways[26], can justify the absence of significant differences in the spirometric variables observed in several studies. In contrast, the results of the study of Figueiredo, Zin and Guimarães[27] demonstrated a reduction in total and peripheral respiratory system resistance after applying the Flutter®[27] in patients with bronchiectasis. Additionally, Martins et al.[9], found an increase in the peripheral airway clearance following the use of ELTGOL in patients with chronic bronchitis. These results could help explain the changes in static lung volumes observed in our study. Corroborating this hypothesis, Regnis et al.[12] found a positive association between mucociliary clearance assessed by radioactive marker and RV/TLC in patients with cystic fibrosis.

Regarding the lung volumes changes in FLUTTER, the decrease in TLC was mainly influenced by a reduction in FRC, with small reduction in IC. This combination promoted a significant reduction in the inspiratory fraction (IC/TLC), since there was a higher reduction in TLC than in IC (-18.27 vs -3.49%). When compared to ELTGOL, this result represents a superiority of the FLUTTER in reducing pulmonary hyperinflation and improving the respiratory mechanics. After ELTGOL an increase in the inspiratory fraction (17.9%) was also noted, however, probably due to the small sample size, these results were not statistically significant.

The main limitations of the present study are: the small sample size, the collection of secretion in only eight of the ten patients and the lack of evaluation of the long term effects of the interventions. Nevertheless, considering the scarcity of studies related to the ELTGOL in the literature, it is believed that our results signalize a possible application of this technique for the treatment of patients with bronchiectasis. The ELTGOL promoted greater secretion removal than the FLUTTER, in addition of being a technique of easy administration and low cost. Thus, although the Flutter is largely described and cited in the literature[24,28,29], the ELTGOL might be an interesting alternative for the treatment of chronic patients requiring therapeutic procedures to increase the removal of lung secretions. However, further studies are needed in order to evaluate other clinically relevant outcomes such as the reduction of exacerbations and the improvement of lung function in the long term to validate the benefits of ELTGOL in treating hypersecretive patients[30].

In conclusion, ELTGOL and Flutter VRP1® techniques acutely reduced lung hyperinflation, but only the ELTGOL increased the removal of pulmonary secretions from patients with bronchiectasis..

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