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Influence of change in lateral decubitus on pulmonary aerosol deposition

Influência da variação dos decúbitos laterais na deposição pulmonar de aerossol

Luciana Alcoforado[1], Luiz C. Pessôa Filho[1†], Daniella C. Brandão[1], André M. Galvão[1], Cyda M. A. Reinaux[1], Armèle Dornelas de Andrade[2]

Abstract

Background: The lateral decubitus position leads to the greatest changes in regional pulmonary ventilation and is used in respiratory physical therapy routines. **Objectives:** To evaluate the influence of the lateral decubitus position on the pulmonary deposition of inhaled radioaerosol particles in young people and report the effects of the decubitus position on routine therapy. **Methods:** Eight healthy male volunteers, mean age 23.6±2.5 years, were included in a randomized study in two phases. In the first phase, aerosol was inhaled for nine minutes in a randomly-selected lateral decubitus position and after an interval of 5 to 7 days, the second phase was conducted. Pulmonary scintigraphy was carried out by inhalation of 25 mCi of 99mTc-DTPA. Following inhalation, images were acquired with scintillation cameras and regions of interest (ROI) were investigated in the longitudinal and cross-sectional divisions of the lungs. Statistical analysis included a paired Student's *t*-test with a significance level of $p \leq 0.05$. **Results:** Inhalation in the right lateral decubitus position presented higher counts ($p \leq 0.04$) in posterior ROI of the right lung than in the posterior ROI of the left lung. In the left lateral decubitus position, the count was higher in the left lung ($p \leq 0.02$) than in the posterior ROI of the right lung. **Conclusions:** The deposition of aerosol particles during inhalation was position-dependent in the two phases of the study, which confirms the validity of technical and therapeutic resources based on the physiology of position-dependent ventilation and suggests that body positioning can be used to advantage in routine therapy.

Keywords: pulmonary ventilation; posture; scintigraphy; physical therapy.

Resumo

Contextualização: O decúbito lateral apresenta as maiores mudanças em relação à ventilação pulmonar regional e é utilizado na rotina da fisioterapia respiratória. **Objetivos:** Avaliar a influência do decúbito lateral na deposição pulmonar de radioaerossol durante a inalação em indivíduos jovens e relacionar os efeitos desse decúbito na rotina terapêutica. **Métodos:** Em estudo randomizado em duas fases, foram incluídos oito homens voluntários saudáveis, com média de idade de 23,6±2,5 anos. Na primeira fase, inalou-se aerossol durante nove minutos no decúbito lateral sorteado e, após intervalo de cinco a sete dias, realizou-se a segunda fase. Para a cintilografia, inalou-se uma dose média de ácido dietilnotriaminopentacético marcado com tecnécio (DTPA – TC^{99m}), com uma atividade radioativa em média de 25 milicuries (mCi). Ao final da inalação, as imagens foram adquiridas em câmaras de cintilação e analisadas por meio da divisão longitudinal e transversal dos pulmões em regiões de interesse (ROI). Para análise estatística, utilizou-se o teste *t* de *Student* pareado, considerando significativo $p \leq 0{,}05$. **Resultados:** A inalação em decúbito lateral direito apresentou, na ROI posterior do pulmão direito, um maior número de contagem ($p \leq 0{,}04$) quando comparada à ROI posterior do pulmão esquerdo. No decúbito lateral esquerdo, observou-se um maior número de contagem no pulmão esquerdo ($p \leq 0{,}02$) do que na ROI posterior do pulmão direito. **Conclusões:** A deposição das partículas de aerossol durante inalação apresentou um comportamento decúbito dependente nas duas fases do estudo, ratificando técnicas e recursos terapêuticos baseados na fisiologia da ventilação decúbito dependente e sugere a utilização do posicionamento corporal na rotina terapêutica.

Palavras-chave: ventilação pulmonar; postura; cintilografia; fisioterapia.

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[1]Laboratory of Cardiorespiratory Physical Therapy, Physical Therapy Department, Universidade Federal de Pernambuco (UFPE), Recife, PE, Brasil
[2]Postgraduate Program in Physical Therapy, Physical Therapy Department, UFPE
[†]In memorian
Correspondence to: Luciana Alcoforado, Departamento de Fisioterapia, Av. Moraes Rego, S/N, Cidade Universitária, CEP 50670-091, Recife, PE, Brasil, e-mail: lucalcoforado@yahoo.com.br

Introduction

In clinical practice, corporal positioning may be used to optimize oxygen transport, improve the ventilation-perfusion relationship, increase lung volume and capacity and help increase mucociliary clearance, as well as reduce the work of breathing and cardiac work[1-4].

Lateral decubitus is the corporal position that results in the greatest changes regarding static volume, regional ventilation, perfusion and pulmonary diffusion capacity[5-8]. This occurs due to the craniocaudal direction of the gravity vector and results in a hydrostatic pressure gradient between lungs[5-8].

During spontaneous breathing in humans, there is a ventilation increase in the dependent pulmonary area in either right or left lateral decubitus. This behavior is due to the vertical pleural pressure gradient, which causes a decrease in lung volume and high compliance in the dependent lung[5-10].

A better physiological understanding of the effects of corporal position on cardiopulmonary function and gas exchange could lead to the use of corporal positioning, especially vertical positions, not only to minimize the deleterious effects of prolonged rest, but also to minimize invasive and pharmacological actions and to optimize treatment strategies for cardiopulmonary diseases and therapeutic resources such as pulmonary re-expansion and clearance techniques for improving regional ventilation[1-3].

The use of the lateral decubitus position and the influence of gravity on therapeutic routines for optimizing pulmonary re-expansion and clearance are well documented in the scientific literature. However, there is a scarcity of studies examining the influence of this position in isolation on regional lung ventilation in young individuals. Thus, the objectives of this study were to evaluate the influence of the lateral decubitus position on radioaerosol pulmonary deposition during nebulization in young individuals and to report the effects of this position on therapeutic routines.

Methods

Eight healthy male volunteers with a mean age of 23.6±2.5 years old and who were non-smokers with no previous history of cardiopulmonary disease participated in this study. The protocol was approved by the Human Research Ethics Committee of the Health Sciences Center of the Universidade Federal de Pernambuco (UFPE), Recife, PE, Brazil, protocol nº 014/1999, according to resolution 196/96. An informed consent form was signed by all volunteers.

The sample size was estimated based on a pilot study carried out with four volunteers who underwent both phases of the study. To calculate the effect size, GPower 3.1 software was used, considering an α=0.05, a statistical power of 1-β=0.95 and taking into account the means and the standard deviation of the number of counts present in the dependent lung in the lateral decubitus position. Thus, the estimated sample size totaled 16 scintigraphic analyses of the dependent lung. Each of the eight individuals participated in the two phases of the study, i.e., the right and the left lung.

The study consisted of two phases carried out in random order. For the first phase, the decubitus position in which the aerosol would be inhaled (right or left) was determined by drawing lots. After an interval of five to seven days, the second phase of inhalation was performed in the other decubitus position. Both phases were carried out in the morning and under the same conditions of temperature, humidity and barometric pressure.

Initially, the individuals underwent a clinical evaluation emphasizing the respiratory system. The evaluation consisted of anamnesis, respiratory rate measurement, respiratory pattern analysis, measurement of maximal inspiratory pressure beginning with residual volume, maximal expiratory pressure beginning with total pulmonary capacity *(Manometer Marshal Town Instrumentation Industries MV - 120)* and expiratory peak flow measurement *(Astech Peak Flow Meter, Center Laboratories, NY, USA)*.

Pulmonary scintigraphy was carried out by inhalation of diethyl triamine pentaacetic acid that had been labeled with technetium (99mTc-DTPA) and had an average radioactivity of 25 millicuries (mCi)[11]. The nebulization of radioaerosol was carried out with a *Venticis® II Medical device, class II, CE 0459 (Ventibox/CIS Bio International, France)*, whose mouthpiece was attached to a one-way valve (inspiratory and expiratory branch) that was connected to the radioisotope nebulizer. The oxygen flow generated 8 L/min of fog with a total volume of 5 ml 0.9% saline solution.

After each patient had been previously instructed to breathe through his mouth slowly and deeply, nine minutes of inhalation was performed in the lateral decubitus position. When the inhalation was completed, the patient rinsed his mouth and drank water in order to cleanse the radioaerosol deposited from his oropharynx and esophagus.

At the end of inhalation, the images were acquired using a dual head scintillation camera *(Vertex Dual Head / ADAC Laboratories - California - CA, 1994)* with a 128 x 128 x 16 matrix; images were limited to 200000 counts. The patients were placed in a horizontal supine position and instructed not to move during image acquisition.

In order to analyze the deposition of aerosol in several lung segments, regions of interest (ROI) were delimited in cross-sectional order (upper, middle and lower regions) (Figure 1A) and in longitudinal order (central, intermediate and peripheral regions) (Figure 1B)[12-16].

The number of counts captured by the scintillation cameras in each ROI was used to compare aerosol pulmonary deposition in each lung between the two phases. In order to ensure the studied regions were identical, the ROI delimitations were saved to a computer after the first phase and reused in the second phase. Similarity was ensured by maintaining the same number of pixels for each ROI in both phases. The qualitative analysis of the images was carried out using the highest number of pixels for each lung.

Initially, the Kolmogorov-Smirnov test was used to evaluate the distribution pattern of the sample. Then, a paired Student's *t*-test was applied. The results were expressed as mean and standard deviation. Data were analyzed using SPSS 13.0 statistical software *(SPSS Inc., Chicago, IL, USA)*. A 95% confidence level was applied in all tests.

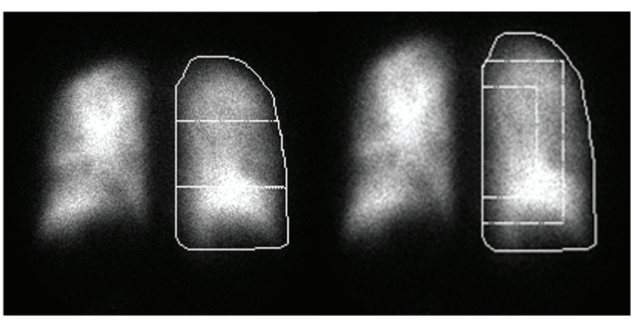


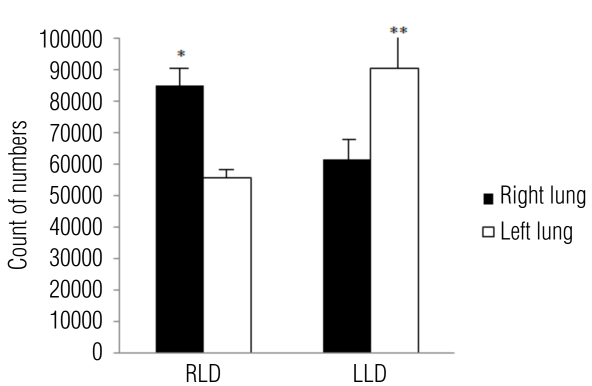
Figure 1. Delineation of regions of interest (ROI) in cross-sectional order (A): upper, middle and lower region and longitudinal order (B): central, intermediate and peripheral region.

Results

Nebulization in the right lateral decubitus position resulted in a higher count ($p \leq 0.04$) in the posterior ROI of the right lung (mean = 85308±5155.70) than in the posterior ROI of the left lung (mean = 55777±1612). In the left lateral decubitus position, a higher count was observed in the left lung ($p \leq 0.02$) (mean = 90457±15152.71) than in the posterior ROI of the right lung (mean = 61462.40±8042.86) (Figure 2).

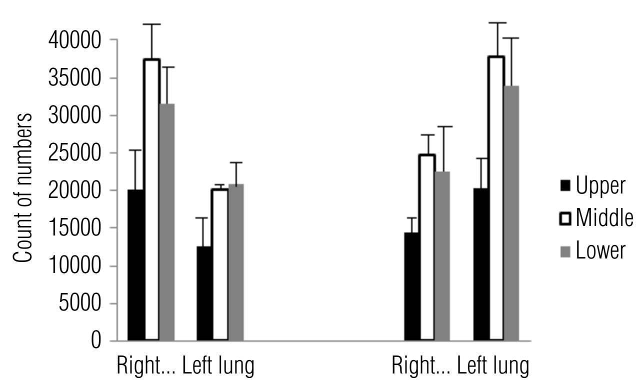
Upon comparing the ROI between the right and left lateral decubitus positions in cross-sectional order, it was observed that the variation in count was higher in the middle and lower regions of the dependent lung than in the upper region. The following values were observed with the right lung dependent in the decubitus position: upper region (mean = 20169±4842), middle region (mean = 37390.20±9080.79) and lower region (mean = 31478.60±5155.70). The following values were observed with the left lung dependent in the decubitus position: upper region (mean = 20321.20±4803.34), middle region (mean = 37770±7907.35) and lower region (mean = 33966±6125.67). There were no statistically significant differences when both sides were compared (Figure 3).

Analyzing the ROI in longitudinal order, it was observed that the variation in count was as follows: with right lung in dependent decubitus, central region (mean = 12539.60±2735.70), intermediate region (mean of 51490.80±13072.24) and peripheral region (mean = 33817±4839.17); with the left lung in dependent decubitus, central region (mean = 12199±1189.81), intermediate region (mean = 45500.20±5242) and peripheral (mean = 44159.20±9025); $p > 0.05$ when comparing both sides. The variation in count was higher in the intermediate and peripheral regions of the dependent lung in the decubitus position, as demonstrated in Figure 4.



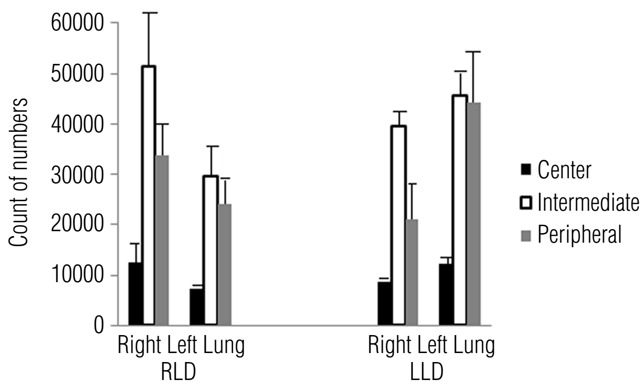
RLD=right lateral decubitus; LLD=left lateral decubitus; *p≤0.04; **p≤0.02.

Figure 2. Deposition of aerosol in left and right lungs on both phases of the study.



RLD=right lateral decubitus; LLD=left lateral decubitus.

Figure 3. Deposition of radioaerosol activity in the upper, middle and lower lung regions on both phases of study.



RLD=right lateral decubitus; LLD=left lateral decubitus.

Figure 4. Deposition of radioaerosol activity in central, intermediate and peripheral lung regions on both phases of study.

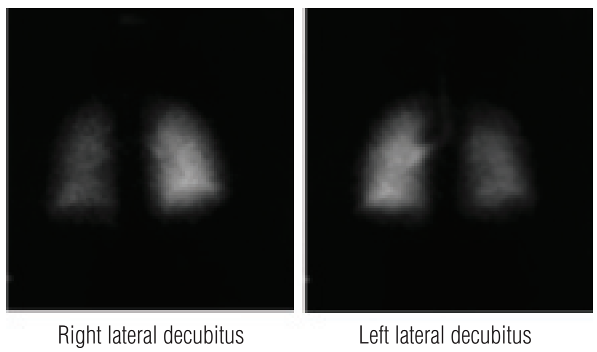


Figure 5. Scintigraphic images show posterior lung behavior supine-dependent decubitus aerosol deposition.

The qualitative analysis of images demonstrates that the variation of aerosol deposition in the lung segments is dependent on the decubitus position (Figure 5).

Discussion

The deposition of aerosol particles during nebulization was dependent on the lateral decubitus position that the volunteer assumed in both phases of the study.

Similar results were observed in a study on elderly patients carried out by Krieg et al.[5] in which pulmonary scintigraphy was used with ten healthy volunteers aged 65 or older to evaluate the distribution of pulmonary ventilation in a seated position and the right lateral decubitus position . The authors observed an increase in pulmonary ventilation in the dependent pulmonary areas in both positions.

In order to evaluate the images, Krieg et al.[5] divided the lung into three regions in craniocaudal order (apical, medium and basal) and into two regions in lateromedial order (lateral and medial). They observed that the highest deposition of particles occurred in the medium and basal region in the seated position and in the medial region of the dependent lung in the lateral decubitus position.

In spite of methodological differences involving the age of the sample, the division of ROI and use of the seated position for comparison, the aforementioned study corroborates the present results, because the scintigraphic images from the present study showed a higher deposition of aerosol in the intermediate and peripheral regions in longitudinal order and in the middle and lower regions in the cross-sectional order of the dependent lung.

These findings are supported by basic pulmonary physiology, which demonstrates that differences in regional ventilation are the result of variation in vertical pleural pressure, and that these differences are influenced by gravity[17-23].

The lateral decubitus position is characterized by high regional ventilation in the dependent lung. This preferential ventilation may result from a combination of three mechanical elements: gravity, the relative lowering of the mediastinum toward the support plane and the cranial position of the inferolateral hemidiaphragm caused by the hydrostatic pressure of the viscera on its lower face[5-9].

The results of the present study suggest, as much quantitatively as qualitatively, that aerosol deposition during nebulization is induced in the dependent areas of lungs when using a diaphragmatic respiratory pattern associated with corporal positioning. These findings show not only how aerosol deposition behaves according to lateral decubitus position, but also how pulmonary ventilation behaves in the decubitus position.

The use of gravity and corporal positioning as a therapeutic resources for facilitating pulmonary reexpansion and clearance has been well described in the literature, although they have rarely been studied in isolation. These therapeutic resources are frequently associated with other bronchial hygiene techniques, which has tended to obfuscate their specific role[24-28].

Among the various techniques, postural drainage (PD) had been widely used in respiratory physical therapy for removal of bronchial secretion for many years. However, it has been replaced by new techniques such as autogenic drainage, active cycle of breathing technique, PEP - mask®, FLUTTER®, total slow expiration with the glottis open in a lateral posture (ELTGOL) and exercises with inspiratory controlled flow (EDIC), etc.[24-28].

By definition, PD aims to drain tracheobronchial secretions using the effects of gravity and involving several postures based on the anatomy of the bronchial tree. There are few published studies on the effectiveness of PD for such clearance, and evidence about its effectiveness is still inconclusive as a stand-alone technique[24-28].

Lannefors and Wollmer[30] analyzed mucociliary clearance by means of scintigraphic analysis in nine patients with cystic fibrosis and compared three techniques of respiratory physical therapy: PD, positive expiratory pressure (PEP) and physical exercise. There were no significant differences between the results of each technique, although when both lungs were analyzed regarding PD, the authors observed a greater mucociliary clearance in the dependent lung, which contradicts the theoretical basis of PD.

Regarding pulmonary aerosol deposition, a higher count was observed in the dependent lung in both the present study and in Lannefors and Wollmer[30], whether in the right or left lateral decubitus, indicating an antigravity action.

The postures used in the PD technique are not as important for bronchial clearance therapy today as in the past. Recent studies have linked the benefits of PD to an association with other techniques[24,26-30].

Based on the physiology of ventilation and respiration during the lateral decubitus position, it can be observed that the use of this position by itself, apart from any other maneuver, produces an important spontaneous clearance of dependent inferolateral areas of the lung[29].

ELTGOL is a slow expiration technique performed in a lateral posture whose objective is to remove secretions in the medium and peripheral airways and thus improve mucociliary clearance in the dependent lung[24].

A study by Postiaux et al.[29] involving eight patients with pulmonary pathology was divided into control and intervention stages and evaluated mucociliary clearance through pulmonary scintigraphy. No significant differences in mucociliary clearance were found in the control stage when the inferolateral and supralateral lung were compared. However, when comparing the control stage to the ELTGOL technique, a significant difference was found 40 minutes after performing the maneuvers.

Martins et al.[24] analyzed the effect of ELTGOL on mucociliary clearance in 20 patients with chronic obstructive pulmonary disease by means of scintigraphic analysis of the total pulmonary area and the peripheral, intermediate and central areas of both lungs. The study was carried out in two stages (control and intervention) in a randomized order with a one week interval between the stages. The images taken in the right lateral decubitus position revealed no significant difference in mucociliary clearance in the peripheral region of the left lung, but an increase in the peripheral region of the right lung, which shows the selectivity of the technique in these patients[24].

These results confirm the physiological basis of ELTGOL, which uses changes in pulmonary ventilation promoted by the lateral decubitus position. In the present study, a higher deposition of aerosol particles was observed in the intermediate and peripheral regions of the dependent lung than in the supralateral region, which was also seen in Martins et al.[24].

This study has some limitations that should be pointed out. The first was the absence of a pulmonary perfusion evaluation in these volunteers in the proposed decubitus positions. The second was that no evaluation of pulmonary clearance was performed with the participants due to the technical impossibility of carrying out this procedure at the research laboratory.

Conclusion

Pulmonary aerosol deposition in the lateral decubitus position is preferentially distributed in the decubitus-dependent lung, with greater deposition in the intermediate and lower segments and in the middle and peripheral pulmonary regions. Our findings reinforce techniques and therapeutic resources that, based on ventilation physiology, seek to optimize the treatment of several pathologies, facilitate inhalation therapy and improve bronchial clearance. Thus, this study could serve to renew interest the effects of corporal positioning on therapeutic routines.

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