IMPULSE OSCILLOMETRY CAN BE USED TO EVALUATE AND DIFFERENTIATE AIRWAY RESISTANCE AND ELASTANCE AMONG ELDERLIES SMOKERS FROM NON-SMOKERS

Tamara Costa-Guimaraes[1], Maysa A R Brandao-Rangel[2], Renilson Moraes Ferreira[3], Claudia M M Russi[1], Amanda C Araujo-Rosa[4], Lucas P Sales-Dias[1], Jovana A C Mahler-Quirino[4], Camila M Murata[4], Aline Cardoso-Moraes[4], Gabriel G Rocha[4], Silvia C Nunez[1], Claudio R Frison[4], and Rodolfo Vieira[1]

[1]Universidade Brasil
[2]Federal University of Sao Paulo
[3]Universidade Federal de Sao Paulo
[4]Brazilian Institute of Teaching and Research in Pulmonary and Exercise Immunology (IBEPIPE)

April 28, 2020

Abstract

Background: The respiratory system changes with age and understanding these changes may help detect and prevent respiratory dysfunctions in the elderly. In addition, although the influence of smoking on lung function is well known, its influence on lung function and mechanics of elderly are unknown. Impulse oscillometry system (IOS) is a technique for measurements of lung mechanics, which don't need patient effort and a minimal collaboration, beyond to reflect more precisely airway resistance/obstruction and lung tissue elastance than spirometric measurements. Aims: Thus, the present study aimed to investigate whether IOS could be or not be sensible enough to differentiate the effects of smoking in the pulmonary response of non-smokers from smokers' elderlies. Methods: The present study compared 30 elderlies never smokers (70,96 ± 6,61) with 30 elderlies' current smokers (69,96 ± 5,94 years old and 35,33 ± 24,93/packs/year tobacco load), without asthma or any other pulmonary disease in terms of lung function and mechanics. Results: The following differences between elderly never smokers versus smokers for spirometric values were found (FVC $p<0.02$; FEV1 $p<0.04$; FEV1/FVC $p<0.04$; PEF $p<0.01$; MEF25% $p<0.02$; MEF50% $p<0.02$; MEF75% $p<0.01$, IVC $p<0.01$) and for oscilometric values (Z5hz $p<0.03$; R5Hz 0.01; R20Hz $p<0.04$; X5Hz $p<0.02$), while RFres and R5Hz-R20Hz did not present differences ($p>0.05$). Conclusions: Impulse oscilometry can detect small airway resistance/obstruction to better differentiate the functional pulmonary alterations among never smokers from smokers' elderlies.

What is already known about this topic?

Impulse oscillometry system is a very sensible method to evaluate slight pulmonary alterations, but its efficacy to detect the effects of smoking on elderly population is unknown.

Lung function decreases along aging, but very restricted information is available about the lung mechanics.

Smoking accelerates the impairment of lung function, but no study has evaluated such effects in elderly population, as well as in the lung mechanics.

What does this article add?

Smoking negatively affects lung mechanics and not only lung function.

Impulse oscillometry system is a method sensible enough to detect and differentiate pulmonary alterations induced by smoking in elderlies.

Lung mechanics measured by impulse oscillometry system is capable to detect in a much more detailed view, which lung structure is affects in smokers and non-smokers elderlies.

INTRODUCTION

The worldwide rise in the populational aging resulted in increases of chronic diseases prevalence[1]. This general aging trend without health prevention programs focused in early diagnostic and interventions results in increased health related costs[2]. These issues as well as the mortality are enhanced by smoking[3].

There was a huge increase in chronic obstructive pulmonary disease (COPD) rates[4]. According to the Global Initiative for Chronic Obstructive Pulmonary Disease (GOLD COPD) COPD is defined as a common, preventable and treatable disease that is characterized by persistent respiratory symptoms and airflow limitation that is due to airway and/or alveolar abnormalities usually caused by significant exposure to noxious particles or gases[5].The progressive airflow limitation in COPD is commonly characterized by reduced relation of FVC/FEV1 ([?] 0.7) post-bronchodilator during spirometric test[5]. Impulse oscilometry (IOS) is a variant of forced oscillation technique (FOT) that allows the evaluation of lung mechanics without any respiratory effort[6].

Several studies have reported that IOS can better differentiate the lung response between asthmatics smokers versus nonsmokers[7], but such evaluation never has been performed in elderlies. Considering the need of pulmonary alterations early detection in elder smokers, the present study tested the hypothesis that lung mechanics study by (IOS) could be a useful method to evaluate the impact of smoking in elderly's lung function decline.

METHODS

Ethical considerations and study design

All experimental proceedings used in the present study has been approved by institutional ethical committee under number 1.021.635, according to the national recommendations for clinical studies and also followed the ethical standards of the Declaration of Helsinki.

Elderlies were recruited from House of Elderlies in the municipality of São José dos Campos – SP, Brazil. In total, 30 healthy, never smokers' elderlies (12 men and 18 women; 70,96 ± 6,61 years old) and 30 current smokers (7 men and 23 women; 69,96 ± 5,94 years old). The inclusion criteria were men and women above 60 years old, did not presenting any respiratory disease, capable to perform the forced maneuver for spirometric test. Specifically for smokers, they should be current smokers, for at least 15 years, as a 35,33 ± 24,93/packs/year (tobacco load).

Evaluation of Lung Function by Spirometry

Lung Function was evaluated by spirometry by Master screen PFT Oscillometry system (Jaeger, Germany), by using the forced maneuver, according to the ATS recommendations[8]. The evaluated parameters were forced vital capacity (FVC), forced expiratory volume in the first second (FEV1), the ration between (FEV1/FVC), peak expiratory flow (PEF), maximal expiratory flow at 25% of FVC (MEF25%), maximal expiratory flow at 50% of FVC (MEF50%) and maximal expiratory flow at 75% of FVC (MEF75%).

Evaluation of Lung Mechanics by Impulse Oscillometry

Lung mechanics was evaluated by impulse oscillometry by using the Masterscreen PFT Oscillometry system (Jaeger, Germany)[9]. The following parameters have been measured: R5Hz (total resistance of respiratory system), R20Hz (resistance of proximal airways), R5Hz-R20Hz (resistance of distal airways), X5Hz (reactance

- elasticity of the lung tissue) and Z5Hz (impedance of the respiratory system) and Fres (frequency of resonance of the respiratory system). The results were expressed as percentage of predicted value.

Statistical Analysis

The software GraphPad Prism 5.0 was used to perform the statistical analysis. The analysis of normality was performed by Shapiro Wilk test. The data were presented as mean ± standard deviation. The unpaired t-test was used and the p value <0.05 was considered significant.

RESULTS

Patients characteristics

Sixty elderly, being thirty current smokers (12 men and 18 women; 69,96 ± 5,94 years old and 35,33 ± 24,93/packs/year tobacco load) and thirty non-smokers/never smokers (7 men and 23 women; 70,96 ± 6,61 years old).

Spirometry study

The Figure 1 present the spirometric results comparing elderly smokers versus non-smokers. Figure 1 A shows that FVC was significantly reduced in elderly smokers x non-smokers ($p<0.002$). Figure 1 B shows that FEV1 was significantly reduced in elderly smokers x non-smokers ($p<0.04$). Figure 1 C shows that FEV1/FVC was significantly reduced in elderly smokers x non-smokers ($p<0.04$). Figure 1 D shows that PEF was significantly reduced in elderly smokers x non-smokers ($p<0.01$). Figure 1 E and 1 F shows that MEF25% and MEF50%, respectively, was significantly reduced in elderly smokers x non-smokers ($p<0.02$). Figure 1 G and 1 H, shows that MEF75% and IVC, respectively, was significantly reduced in elderly smokers x non-smokers ($p<0.01$).

Oscilometric study

The Figure 2 present the oscilometric results comparing elderly smokers versus non-smokers. Figure 2 A shows that Z5Hz was significantly reduced in elderly smokers x non-smokers ($p<0.03$). Figure 2 B shows that R5Hz was significantly reduced in elderly smokers x non-smokers ($p<0.01$). Figure 2 C shows that R20Hz was significantly reduced in elderly smokers x non-smokers ($p<0.04$). Figure 2 D shows that R5Hz-R20Hz did not present differences comparing elderly smokers x non-smokers ($p>0.05$). Figure 2 E shows that X5Hz was significantly increased in elderly smokers x non-smokers ($p<0.02$). Figure 2 F shows that Fres did not present differences comparing elderly smokers x non-smokers ($p>0.05$).

Discussion

The present study showed for the first time that elderlies' smokers present impaired lung function and mechanics compared with non-smokers, especially in distal airways. In addition, the present study also showed for the first time that IOS is a sensible and useful tool to better differentiate the lung mechanics of elderlies, since no effort is needed, such as in spirometry.

The findings showing impaired lung function in elderlies smokers agree with previous studies demonstrating that in adults the smoking impairs the lung function[10,11]. However, there is a high rate of non-smoking elderlies who did not present respiratory symptoms, but present increased obstruction and resistance of distal airways[11-13]. In some cases, passive smokers, independent of age, can present normal lung function, with impaired lung mechanics, reinforcing that lung mechanics assessment can predict early alterations of the airways[11-14]. It is also known that elderlies' smokers present accelerated decline in the lung function (FVC, FEV1 and FEV1/FVC), compared with non-smokers[10, 11, 15, 16]. In the present study, we also observed impaired lung function in elderlies' smokers.

However, the evaluation of lung mechanics by IOS displayed more detailed information, demonstrating increased elastance of proximal airways, as demonstrated by severe reduction in the proximal airway resistance (reduced R20Hz) and by a severe increase (2x fold) in the distal airway resistance (increased X5Hz). These results reinforce or reflect the strong reduction in MEF75%, which preferable demonstrates the obstruction

of the small airways. It has been also reported that reduction in MEF75% reflects histological alterations of small airways[17]. Such findings reinforce the typical COPD characteristics, with increased resistance and air flow limitation of small airways and decrease of the elastance of proximal airways[18]. Of note, it has been established that small airways alterations precede emphysema development[18]. In addition, the consequences of smoking specifically on small distal airways has been reported[19].

The X5Hz represent the lung elastic recoil forces, which is related to the inertial forces of the distal airways, of the lung tissue and thorax[20]. In this way, it is possible that elderlies' smokers present initial airway obstruction due to elastolysis of the elastic fibers in the distal airways[17-22]. In fact, the smoking habit induces the obstruction of small airways, beyond functional abnormalities and chronic obstructive pulmonary disease[22]. Therefore, the absence of proximal airway obstruction does not mean that smoking is not damaging the lungs[19]. Furthermore, the consequences of smoking can be variable, in terms of affecting different regions of the lungs, depending of individual susceptibility[18, 19].

The present study discusses a perspective of extreme clinical relevance, since IOS is a very simple, easy and effort independent pulmonary function test, really feasible to be performed by elderlies and children, who normally are unable to perform the spirometry maneuvers properly[6,9,20]. In fact, the present study detected a very good sensibility of IOS to detect fine differences between the lung mechanics of elderlies' smokers from non-smokers. However, some points need to be clarified, as study' limitation: (i) the study involved elderly smokers with high tobacco load, (ii) the study did not randomized the volunteers among men and women, (iii) the study was performed only with 30 elderly in each group. Thus, further investigations should be done using a larger number of volunteers randomized by gender and also with different tobacco load.

Conclusions

Impulse oscilometry systems (IOS) present enough sensibility to detect differences in airway resistance and elastance between elderlies' smokers from non-smokers, showing that smokers present reduced proximal airway resistance (R20Hz), below the normal level, indicating that elderlies' smokers present reduced airway elastance in comparison with elderlies' non-smokers. In addition, IOS was able to demonstrate by X5Hz (reactance) that smokers present increased airway obstruction and resistance of distal airways, compared with non-smokers. In fact, IOS is useful tool to detect airway response in elderlies for being a method which is not effort dependent and is rapidly to be applied.

References

1. Kennedy BK, Berger SL, Brunet A, et al. Geroscience: linking aging to chronic disease. Cell 2014; 159:709-713.
2. Wang C, Li F, Wang L, Zhou W, et al. The impact of population aging on medical expenses: A big data study based on the life table. Biosci Trends 2018;11(6):619-631.
3. Mons U, Brenner H. Demographic ageing and the evolution of smoking-attributable mortality: the example of Germany. Tob Control 2017;26(4):455-457.
4. Brandsma CA, de Vries M, Costa R, et al. Lung ageing and COPD: is there a role for ageing in abnormal tissue repair? Eur Respir Rev 2017;26(146):pii: 170073.
5. Global Initiative for Chronic Obstructive Pulmonary Disease (GOLD COPD). https://goldcopd.org/. Accessed at 12 April 2019.
6. Brashier B, Salvi S. Measuring lung function using sound waves: role of the forced oscillation technique and impulse oscillometry system. Breathe (Sheff) 2015;11(1):57-65.
7. Contoli M, Bellini F, Morandi L, et al. Assessing small airway impairment in mild-to-moderate smoking asthmatic patients. Eur Respir J 2016;47(4):1264-7.
8. Recommendations for a Standardized Pulmonary Function Report. An Official American Thoracic Society Technical Statement. Culver BH, Graham BL, Coates AL, et al. Am J Respir Crit Care Med 2017;196(11):1463-1472.
9. Schulz H, Flexeder C, Behr J, et al. Reference values of impulse oscillometric lung function indices in adults of advanced age. PLoS One 2013;8(5):e63366.

10. Katoh T, Ohmori H, Nakao H, et al. Effects of smoking on pulmonary function: a cross-sectional and longitudinal study. J UOEH 2001;23(4):403-409.
11. Gupta RP, Strachan DP. Ventilatory function as a predictor of mortality in lifelong non-smokers: evidence from large British cohort studies. BMJ Open 2017;7(7):e015381.
12. Betsuyaku T, Yoshioka A, Nishimura M, et al. Pulmonary function is diminished in older asymptomatic smokers and ex-smokers with low attenuation areas on high-resolution computed tomography. Respiration 1996;63(6):333-338.
13. Schivinski CIS, de Assumpção MS, de Figueiredo FCXS, et al. Impulse oscillometry, spirometry, and passive smoking in healthy children and adolescents. Rev Port Pneumol 2017;23(6):311-316.
14. García-Quero C, Carreras J, Martínez-Cerón E, et al. Small airway dysfunction impairs quality of life among smokers with no airflow limitation. Arch Bronconeumol 2019;pii: S0300-2896(19)30015-8.
15. Omori H, Nonami Y, Morimoto Y. Effect of smoking on FEV decline in a cross-sectional and longitudinal study of a large cohort of Japanese males. Respirology 2005;10(4):464-469.
16. Tantisuwat A, Thaveeratitham P. Effects of smoking on chest expansion, lung function, and respiratory muscle strength of youths. J Phys Ther Sci 2014;26 (2):167-170.
17. Cosio M, Ghezzo H, Hogg JC. The relation between structural changes in small airways and pulmonary function tests. N Engl J Med 1977;298:1277-1281.
18. Capron T, Bourdin A, Perez T, et al. COPD beyond proximal bronchial obstruction: phenotyping and related tools at the bedside. Eur Respir Rev 2019;28(152). pii: 190010.
19. Verbanck S, Schuermans D, Paiva M, et al. Small airway function improvement after smoking cessation in smokers without airway obstruction. Am J Respir Crit Care Med 2006;174(8):853-857.
20. Bickel S, Popler J, Lesnick B, et al. Impulse oscillometry: interpretation and practical applications. Chest 2014;146(3):841-847.
21. Kuperman AS, Riker JB. The variable effect of smoking on pulmonary function. Chest 1973;63(5):655–660.
22. Beasley, MB. Smoking-related small airway disease - a review and update. Adv Anat Pathol 2010;17(4):270–276.

Figure Legends

Figure 1 – Lung function parameters, 1A (Forced vital capacity - FVC), 1B (Forced expiratory volume in the first second - FEV1), 1C (Forced expiratory volume in the first second/Forced vital capacity - FEV1/FVC), 1D (Peak expiratory flow - PEF), 1E (Maximal expiratory flow at 25% - MEF25%), 1F (Maximal expiratory flow at 50% - MEF50%), 1G (Maximal expiratory flow at 75% - MEF75%) and 1H (Inspiratory vital capacity - IVC).

Figure 2 – Lung mechanics parameters, 2A (Impedance of respiratory system - Z5Hz), 2B (Total resistance of respiratory system - R5Hz), 2C (Resistance of proximal airways - R20Hz), 2D (Resistance of distal/small airways - R5Hz-R20Hz), 2E (Reactance - elasticity of the lung tissue - X5Hz), 2F (Resonance frequency of the respiratory system - Fres).