

ORIGINAL RESEARCH

How often does spirometry testing induce cardiac arrhythmias?

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Originally submitted 16th June 2008; resubmitted 3rd October 2008; revised version received 11th December 2008; accepted 31st January 2009; online 30th April 2009

Abstract**Aims:** To describe the frequency and type of arrhythmia induced by forced expiratory and inspiratory flow-volume loop manoeuvres.**Methods:** 735 subjects (548 men) aged from 10 to 98 years old (mean 54 years, SD \pm 15) were submitted to a conventional medical examination and spirometry testing prior to a maximal cardiopulmonary exercise test (CPET). A continuous digital electrocardiogram (ECG) was recorded during spirometry and CPET, and later reviewed and interpreted by the same physician (who supervised all the procedures).**Results:** 470 subjects (64%) had cardiac arrhythmias during one or both procedures. About 60% of the arrhythmias were supraventricular, but 35 subjects (5%) presented more complex arrhythmias including frequent premature ventricular beats (n=31) or non-sustained ventricular tachycardia (n=4). While arrhythmias were more often exposed by the CPET ($p < 0.01$), in 68 cases (10% of the total sample) arrhythmias were only induced by spirometry; these included four cases of non-sustained supraventricular tachycardia (n=4).**Conclusions:** Spirometry is a safe procedure with regard to induction of cardiac arrhythmias. Spirometry-induced arrhythmias tend to be simple and were always short-lasting. In some cases, ECG recording during spirometry showed arrhythmias that would not be induced by a progressive maximal exercise test.

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CG Araújo and LC Vianna. *Prim Care Resp J* 2009; 18(3): 185-188.

doi:10.4104/pcrj.2009.00023

Keywords spirometry, pulmonary function testing, palpitations, arrhythmias, cardiopulmonary exercise testing, electrocardiogram**Introduction**

Palpitations are one of the most common reasons for which patients seek the advice of a physician.^{1,2} Quite often, clinical examination yields no major signs or abnormalities and the physician may feel the need to request further testing. Considering the broad aspect of cardiac arrhythmias, ranging from the very benign to the potentially lethal, it is desirable to document the arrhythmia by electrocardiogram (ECG) recording. However, despite the well-established role of complementary procedures such as resting, exercise and ambulatory ECG monitoring, it is relatively common that these procedures fail to produce objective data regarding the patient's symptoms.³

Lung function tests, particularly spirometry, are very often performed in clinical practice. In addition, spirometry testing

is also performed regularly prior to maximal cardiopulmonary exercise testing (CPET) in order to identify respiratory volume or flow limitations at rest and also to analyse correctly cardiopulmonary data obtained during exercise. Although pulmonary function testing is one of the most common procedures in medical offices and hospitals, both for screening and diagnostic purposes, there are very limited data in the literature regarding its safety and its potential for cardiovascular complications.^{4,6} It is theoretically conceivable that sudden autonomic modulations, rapid and dramatic intrathoracic and/or right atrial pressure changes, and thoracic organ displacements during the performance of a forced maximum expiratory flow-volume loop manoeuvre, could potentially induce short-lasting cardiac arrhythmias.⁴ About 30 years ago, Montenegro *et al.*⁶ obtained ECG data in

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150 patients with a mean age of 55 years, most of them with COPD, and found a discrete although significant increase in the frequency of supraventricular premature beats during pulmonary function testing. In contrast, Fields *et al*,⁴ failed to show similar findings in a group of 42 patients during pre- and post-bronchodilator spirometry. Interestingly, this report was followed by a letter to the editor in which a Greek author claimed to have previously reported, in 1972, an increase in occurrence of supraventricular premature beats in a sample of 99 subjects with COPD and 33 others without pulmonary disease during forced vital capacity manoeuvres.⁵ Italian authors also obtained ECG data during methacholine bronchial provocation testing of 46 patients without known cardiovascular diseases and found that the type and frequency of arrhythmia – about 20% of them presented isolated supraventricular or ventricular premature beats – were quite similar to resting conditions.⁷

These previous studies have reported data from small samples under quite distinct clinical conditions. With the increasing clinical use of CPET, and the need for a forced flow-volume loop manoeuvre to be obtained pre-procedure, it seemed appropriate to obtain more systematic information from a large sample of subjects sequentially submitted to forced flow-volume loop manoeuvres and CPET. The aim of the present study, therefore, was to detect and compare the frequency and type of arrhythmia induced during spirometry and CPET.

Methods

Subjects

Subjects were referred to our centre for clinical diagnosis and/or exercise testing and were further classified into three groups: (a) asymptomatic as regards the cardiovascular system (n=235); (b) known coronary artery disease (n=212); or (c) the presence of other relevant diseases (n=288) including arterial hypertension, cardiomyopathies, a history of palpitations or syncope, thyroid disease, valvular diseases and chronic obstructive pulmonary diseases. None were professional athletes. A further classification divided the subjects into those with mild or moderate pulmonary disease (n=44) and those without pulmonary disease (n=691). All subjects read and signed a specific informed consent form before undertaking the procedures.

Procedures

In a single visit, while regularly using their prescribed medications (if any), subjects were submitted to a conventional medical examination and resting spirometry followed by a maximal CPET. Continuous ECG recording was obtained in a single lead and digitally recorded (Elite PC, Micromed, Brazil) during spirometry and exercise testing, and was later reviewed and interpreted by the same physician

(who also supervised all the procedures). Room temperature and relative humidity were set at 22°C and 40–55%, respectively.

Spirometry

A minimum of two and a maximum of five flow-volume loop manoeuvres were performed using a properly calibrated pneumotachograph (Cardiovit AT-10, Schiller, Switzerland), following the American Thoracic Society/European Respiratory Society recommendations.⁸ Approximately 2–4 minutes were spent doing the manoeuvres.

Maximal Cardiopulmonary Exercise Test (CPET)

CPETs were typically conducted using an electronically-braked cycle ergometer, with direct collection and analysis of expired gases (VO2000, MedGraphics, USA), following an individualised ramp protocol with a planned duration of 8–12 mins.⁹ Subjects were verbally encouraged to exercise to volitional fatigue (exhaustion). A detailed description of the maximal CPET protocol is provided elsewhere.¹⁰

Statistical analysis

The means and frequencies were calculated for the continuous and categorical variables. Group comparisons were made using the Pearson chi-square test for categorical variables. A p value <0.05 was considered statistically significant. All data were analysed with the Statistical Package for the Social Sciences, version 13.0 (SPSS, USA).

Results

Among the 735 subjects (548 men) aged from 10 to 98 years old (mean 54 years, SD ± 15) who were enrolled, 470 (64%) had cardiac arrhythmias during one or both procedures. As expected, arrhythmias occurred more often in those with pre-existing disease (p<0.01, see Table 1). While about 60% of the arrhythmias detected were supraventricular (half of them one or more isolated premature beats), 35 subjects (5% of the total sample) presented more complex arrhythmias including frequent premature ventricular beats (n=31) or non-sustained ventricular tachycardia (n=4). Arrhythmias were more often induced by exercise testing compared to spirometry (402 vs. 240) (chi-square = 71.81; p<0.01; Table 1). However, in 68 cases (10% of the total sample), arrhythmias were provoked by flow-volume loop manoeuvres, including four cases of asymptomatic non-sustained supraventricular tachycardia (n=4). In eight cases – one asymptomatic subject, six coronary artery disease patients and two with other diseases – frequent premature ventricular beats were induced by spirometry, with only two patients showing a similar pattern during CPET (two patients with coronary disease). Interestingly, no episodes of ventricular tachycardia occurred during spirometry.

No difference was found in the inducibility of cardiac arrhythmias during spirometry between those subjects with

Table 1. Frequency of cardiac arrhythmias according to the procedures performed and pre-existing clinical conditions

	All subjects (n=735)	Asymptomatic (n=235)	Coronary artery disease (n=212)	Other diseases (n=288)
Spirometry	240 (199 M)	57 (45 M)	96 (84 M)	87 (70 M)
CPET	402 (312 M)	105 (57 M)	138 (121 M)	159 (114 M)
Spirometry and CPET	172 (142 M)	31 (24 M)	78 (69 M)	63 (49 M)
Exclusively spirometry	68 (57 M)	26 (21 M)	18 (15 M)	24 (21 M)
Exclusively CPET	230 (170 M)	74 (53 M)	60 (52 M)	96 (65 M)

CPET: cardiopulmonary exercise testing, M: men.

pulmonary disease (6%) and those without (chi-square = 0.38; $p=0.54$). It is worth noting that among the 44 patients with pulmonary diseases, only 12 presented rhythm disturbances – in almost all, this was a single supraventricular beat.

About 21% (154/735) of the subjects reported a history of palpitations at medical interview. In 70% (110/154) of these cases, spirometry and/or CPET were able to induce cardiac arrhythmias. Interestingly, 15 of 104 men with a history of palpitations (just one woman had the same) had clinically irrelevant arrhythmias during flow-volume loop manoeuvres but not during CPET. None of the four subjects (two coronary artery disease patients a few months after percutaneous angioplasty with stent implantation, one case of previous myocarditis, and one case of asymmetrical septal cardiomyopathy) with non-sustained ventricular tachycardia during CPET had previously complained of palpitations.

Discussion

These data – from a cohort of over 700 consecutive cases, encompassing healthy and sick subjects of both genders, evaluated sequentially by spirometry and CPET – show that spirometry is a safe procedure in terms of its induction of cardiac arrhythmias, and that cardiac arrhythmias can be induced by both sudden (i.e. the flow-volume loop manoeuvre) and progressive maximal exercise, albeit that the frequency and type of arrhythmia differs between both procedures. In addition, spirometry-induced arrhythmias tend to be both simple and clinically irrelevant and were always short-lasting even in patients with mild or moderate obstructive pulmonary disease. In some cases (including men with a history of palpitations – i.e. an increase in sensitivity), ECG recording during spirometry showed arrhythmias not induced by progressive maximal exercise testing. Finally, in about a third of subjects who complained of palpitations, arrhythmias were not induced by either spirometry or maximal exercise testing.

Although our study was not designed to explain the cause of arrhythmias during spirometry, we observed that the large majority of supraventricular premature beats and even the rare

and short episodes of supraventricular tachycardia occurred during the 'take a full breath' phase of the flow-volume loop manoeuvre. Previous data from our research group¹¹ has indicated that a fast and maximal inspiratory effort induces a pronounced cardiac vagal stimulation, reflected by a heart rate deceleration in about 2-4 seconds, which could (at least theoretically) be implicated in these premature beats. Kingsepp *et al*,¹² have shown that the forced flow-volume loop has a significant influence on both blood pressure (>30 mmHg) and heart rate (>20 bpm) responses compared to baseline values. Another interesting theoretical possibility is the sudden mechanical contact between lung parenchyma and atrial or ventricular regions, triggering isolated depolarisation.

It is well known that pulmonary and cardiovascular diseases often coexist. Previous studies have shown somewhat controversial data in terms of frequency and type but not complexity of arrhythmia induced by pulmonary function testing. Our study is the only one to report cases of non-sustained supraventricular tachycardia during spirometry (four cases in 735 subjects). We believe that, considering the absence of complex arrhythmias, the modest and potentially non-relevant clinical differences found amongst the studies are most likely related to sample size, demographic and clinical characteristics (e.g. the percent of subjects with cardiovascular disease or palpitation complaints). Nevertheless, it should be emphasised that the combination of pulmonary and cardiovascular diseases substantially influence life expectancy. In this context, Engstrom *et al*,¹³ have shown that in a large sample of 68-year old Swedish subjects followed-up for a median of 13 years (about 45% of them died during the study period), those with poor pulmonary function and the presence of ventricular arrhythmia on long-term ECG monitoring have a more than two-fold increase in their relative risk of dying during follow-up, indicating that the association of these two clinical conditions in old men confers a poor prognosis.

This study has several limitations relating to design and interpretation. First, we have selected a convenience sample, including primarily Caucasian and upper socioeconomic strata subjects, which may somewhat influence the external validity of the present study. Second, a substantial number of the subjects

in this study have long-term chronic diseases, which might also have affected both the frequency and type of cardiac arrhythmias induced by spirometry and/or CPET. On the other hand, this study comprised a large number of consecutively enrolled subjects, evaluated by a single physician (CGSA) who supervised all procedures thus strengthening the quality of data collection.

In line with the limited amount of literature data,^{4,7} it seems that spirometry-induced cardiac arrhythmias are simple and most likely benign. Prospective data should be obtained in order to confirm these findings for very severe COPD patients with or without cardiovascular co-morbidities. It is also likely that spirometry testing might serve to reassure physicians and patients about the benign character of palpitation symptoms in some cases. However, long-term epidemiological data are needed before the benign prognosis of spirometry-induced cardiac arrhythmias can be established definitively. Meanwhile, if easily available, it might be informative (particularly in men with a history of palpitations) to add ECG recording during spirometry.

Conflicts of interest declaration

None to declare.

Acknowledgements

The authors would like to thank the CNPq – Brazilian National Research Council for scholarships and grant support for this study.

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