

Office spirometry correlates with laboratory spirometry in patients with symptomatic asthma and COPD

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Abstract

Objectives: Spirometry remains underutilized in the evaluation of obstructive lung disease. While office spirometry (OS) has been compared to formal laboratory-based spirometry (LS) in healthy subjects, the correlation has never been formally assessed in patients with symptomatic obstructive lung disease. The aim of this study was to investigate the correlation in this population.

Methods: We used a retrospective study design to analyze spirometry data from patients that underwent both OS and LS. Two flow sensing office (portable) spirometers were used and compared with laboratory-based (body plethymograph) spirometer. Accuracy and reliability were assessed using Bland Altman analysis.

Results: Among 185 patients with symptomatic obstructive lung disease, 129 had undergone both OS and LS. Of these, 107 patients had both tests performed less than 90 days apart and were included in final analyses. Mean age was 54 years with mean FEV1 of 1.97 L (65% predicted). Ninety-two patients had airflow obstruction, as determined by a FEV1/FVC ratio of <70%. We found significant correlation in the values between OS and LS for both FEV1 and FVC ($r = 0.937$ and 0.90 , respectively, $P < 0.001$). Eighty-seven percent of patients had a concordant spirometry in terms of airflow obstruction. Correlation was independent of the office spirometer (and hence the Flow-sensing mechanism) used.

Conclusions: In patients with known asthma and chronic obstructive pulmonary disease (COPD), OS is accurate and reliable when compared to formal laboratory-based spirometry. Routine use of OS should be encouraged to improve spirometry utilization and healthcare outcomes in patients with Asthma and COPD.

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Key words

asthma – COPD – correlation – office based – spirometry

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Authorship and contributorship

Gurpreet Bamba contributed to Literature search, data collection, study design, analysis of data and manuscript preparation. Leena Jalota contributed to Literature search, analysis of data and manuscript preparation and review. Chandni Kapoor contributed to data collection, study design, analysis of data and manuscript review. Paul Mills contributed to study design, statistical analysis of data and manuscript preparation. Jose Joseph and Vipul Jain contributed to Literature search, data collection, study design, analysis of data, preparation and review of manuscript.

Ethics

The study was reviewed by the UCSF-Fresno Institutional Review Board and did not require individual consent for participation.

Conflict of interest

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

Introduction

Asthma and chronic obstructive lung disease (COPD) affect an estimated 64 million in the United States and 235 million people worldwide (1, 2). Asthma alone, affects about 8.2% of the US population leading to an increased healthcare utilization and missed work days (1). Besides smoking, the risk factors contributing to the rising prevalence of asthma and COPD, and the associated health care costs remain poorly understood (3). We have recently reported lack of spirometry utilization as an independent predictor of increased exacerbations in patients with asthma and COPD (4). In this study, we investigated the accuracy of office spirometry (OS) in patients with known or clinical suspicion of obstructive lung disease, in a *real-world* clinical setting.

Accuracy of diagnosis of asthma and COPD remains a problem, both in terms of overdiagnosis and underdiagnosis (5). Although, the American Thoracic Society (ATS) and other major societies emphasize use of spirometry in the diagnosis and evaluation of both asthma and COPD (6, 7), data clearly suggest underutilization of spirometry in patients with obstructive lung disease in the United States (8–10). Although, most practitioners prefer LS due to perceived lack of benefit and accuracy of OS in patients with asthma and COPD (6), access to timely LS remains a significant challenge. Furthermore, getting formal LS for everyone may not be realistic, and empiric treatment with *no testing* at all has consequently become the norm rather than the exception. Respiratory symptoms alone have a poor sensitivity and limit the accuracy of a clinical diagnosis (11). OS is readily available, expected to improve clinical diagnosis; and may influence therapy. Indeed, OS has been shown to improve diagnosis of COPD (12). Correlation between OS and LS in patients without obstructive lung disease was recently reported (13). The aim of this study was to investigate the correlation between OS and LS in patients with known or suspected obstructive lung disease.

Materials and methods

Study design and patients

The study was conducted at two outpatient sites: (i) a university-based chronic lung disease management program and (ii) pulmonary outpatient clinic at the Community Regional Medical Center, a 600-bed community-based academic hospital affiliated with the UCSF School of Medicine. Patients seen (between February 2012 and September 2013) with clinical symptomatology of obstructive lung disease (cough,

wheezing or dyspnea in patients with or without history of physician diagnosed asthma or COPD) and received OS were included in the study. From this cohort of patients with OS, patients who also had LS within 90 days of the OS (and met ATS criteria for acceptability and repeatability) were selected for analyses. LS was performed in the pulmonary function laboratory based in the hospital. The study protocol was approved by institutional review board (IRB # 2013085). For our study, airflow obstruction was defined as fixed FEV1/FVC ratio of <70%. Baseline characteristics, smoking habits, spirometric indices, treatment or medication changes for management of obstructive lung disease within the duration between OS and laboratory spirometry, were extracted from the patient's electronic medical record.

Office spirometry

Flow sensing office spirometers (EasyOne; NDD, Zurich, Switzerland) and (Microloop; Micro Medical, Chatham, Kent, UK) were used. Both spirometers were routinely calibrated by respiratory therapists as per manufacturer's instructions. Spirometry (both office and laboratory) was performed by trained respiratory therapists.

EasyOne™ spirometer: The EasyOne™ spirometer uses digital ultrasonic flow measurement technology. Its flow sensor is equipped with two ultrasonic transducers, mounted at different sides of the flow channel. To determine gas flow (and molar mass), ultrasonic pulses are transmitted in upstream and downstream direction. Precisely measured transit-times are the basis for determining flow and molar mass.

The Microloop™ Spirometer: The Microloop™ spirometer uses electronic rotating vane-flow sensor and employs a Gold Standard Turbine measurement technology to measure expired air directly at BTPS (Body Temperature and Pressure with Saturated Water).

Laboratory spirometry

PFTs were performed using body plethysmograph (Medgraphics Cardiorespiratory Diagnostics, Elite DX, Saint Paul, MN, USA), that uses a bidirectional pitot tube flow sensor allowing comprehensive diagnostics, including measurement of airways resistance and thoracic gas volumes.

Statistical analyses

Mean and standard deviations of the baseline demographics were calculated using SPSS (IBM SPSS Statistical Software Version 21, Chicago, IL, USA). The correlation between normally distributed continuous

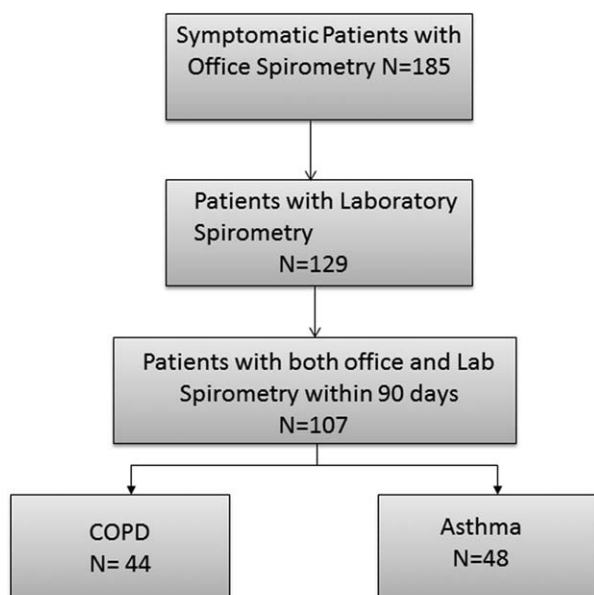


Figure 1. Study Design: selection of patients with clinical symptomatology of obstructive lung disease.

variables was calculated using Pearson Product-Moment correlation method. Accuracy and reliability of office and laboratory-based spirometers were assessed using Bland Altman plots. To evaluate agreement at different flows and volumes, as has been described previously (14), we assessed correlation across ranges of FVC and FEV1 by stratifying the data into tertiles. A P value of <0.05 was considered statistically significant.

Results

Study population: baseline characteristics

A total of 185 patients with clinical symptomatology of obstructive lung disease were identified to have undergone OS, of which 129 also had LS. Of these, 107 patients were identified to have both tests performed less than 90 days apart (see Fig. 1). The mean period between the two spirometry studies was 68 ± 22 days. There were 47 males and 60 females. The mean age was 54 ± 12 years. Mean percent predicted FEV1 in the studied population was 65 ± 24 . Ninety-two patients had airflow obstruction, as determined by the FEV1/FVC ratio. Of these, 48 patients had history of asthma and 44 had a history of COPD. Fourteen percent of the studied patients were smokers ($n = 15$), 25% were former smokers ($n = 27$) while 61% were lifetime non-smokers ($n = 66$). Fifty-nine percent of patients ($n = 63$) had no changes in their medications for their

respiratory symptoms in the period between their spirometry studies.

OS correlated with laboratory spirometry

There was significant correlation in the values between OS and LS for both FEV1 and FVC ($r = 0.937$ and 0.90 , respectively, with $P < 0.001$), as well as the FEV1/FVC ratio ($r = 0.878$, see Fig. 2). The Bland-Altman plots show the difference between the two spirometer values with their 95% CI with the mean value of FEV1 and FVC. The difference in the measurement was <10 mL between the two spirometers used (see Fig. 3).

The spirometry values for FEV1 and FVC ratio were concordant in 87% of patients (using FEV1/FVC ratio of 70%). Of the 107 patients, only 14 (13%) had discordant FEV1/FVC ratio of less than 70%. Among the 14 patients with discordant FEV1/FVC ratio, 7 (50%) were found to have had their medications changed (six patients with increase in their inhaled steroid dose and one with initiation of montelukast) between the two spirometry studies (that led to reversal of airflow obstruction in four of the seven patients).

Correlation across ranges of flows and volumes

The distribution of FVC in all 107 study participants was reviewed and tertiles of FVC were created such that approximately one-third of the study population had $FVC < 2.19$ L ($n = 36$), one-third had $FVC 2.23$ – 3.18 L ($n = 36$) and one-third had $FVC > 3.18$ L ($n = 35$). After stratifying the study population into these tertiles, the correlations between OS and LS measurements were repeated (see Table 1). The correlations across ranges of both FVC and FEV1 were positive (ranged from $r = +0.458$ to $+0.884$) and generally were statistically significant, despite the loss in statistical power created by focusing on the subgroups.

Correlation is independent of flow sensing mechanism

There was significant correlation in the values between EasyOne™ model of OS ($n = 58$) compared with Lab spirometer correlation, for both FEV1 and FVC ($r = 0.872$ and 0.934 , respectively). Microloop office spirometer ($n = 49$) showed similar correlation in comparison to LS with the correlation coefficient for FVC and FEV1 being 0.929 and 0.952 , respectively. Correlation remained statistically significant irrespective of the office spirometer (and hence the Flow-sensing mechanism) used.

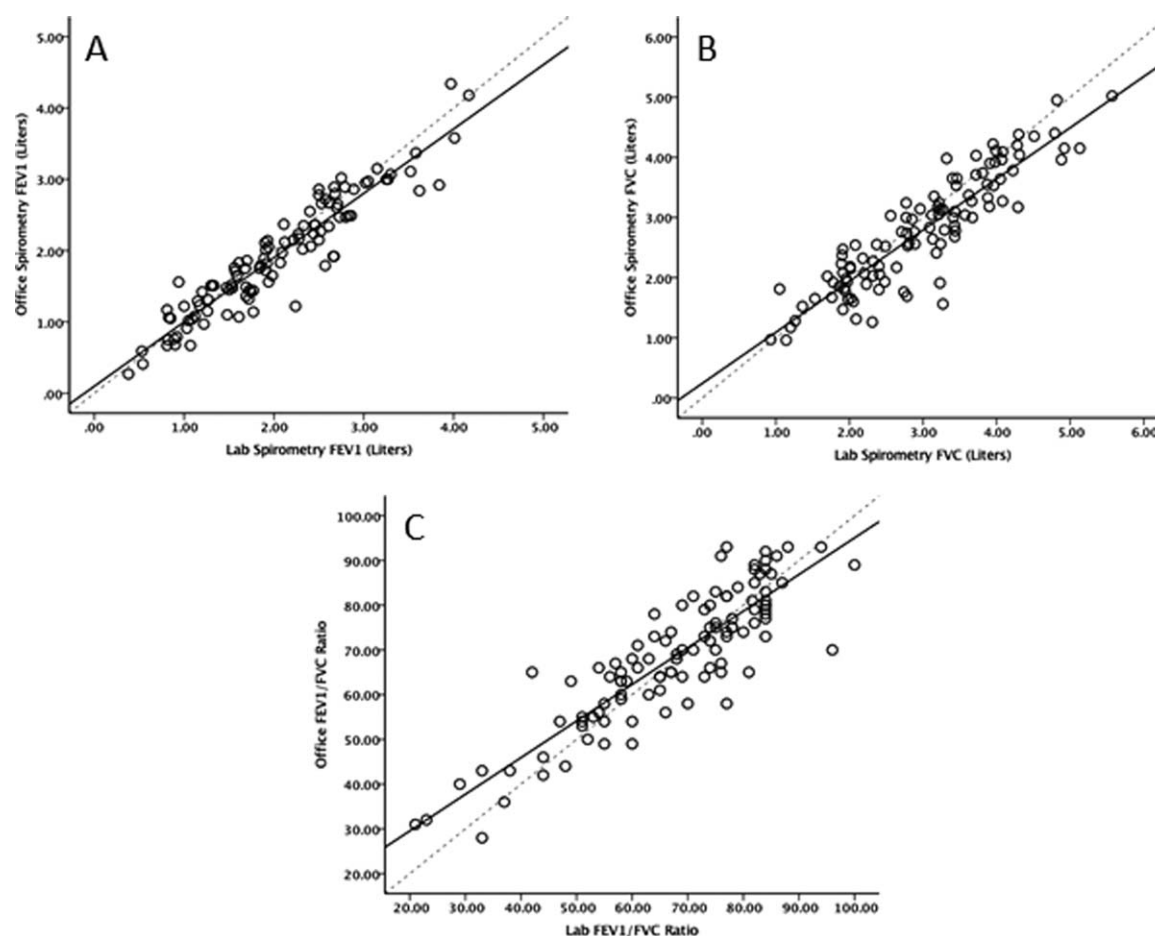


Figure 2. Correlation between Office spirometry and laboratory spirometry. (A) OS FEV1 vs LS FEV1; (B) OS FVC vs LS FVC; and (C) OS FEV1/FVC ratio vs LS FEV1/FVC ratio. Dashed line represents line of equality. Solid line shows the regression line.

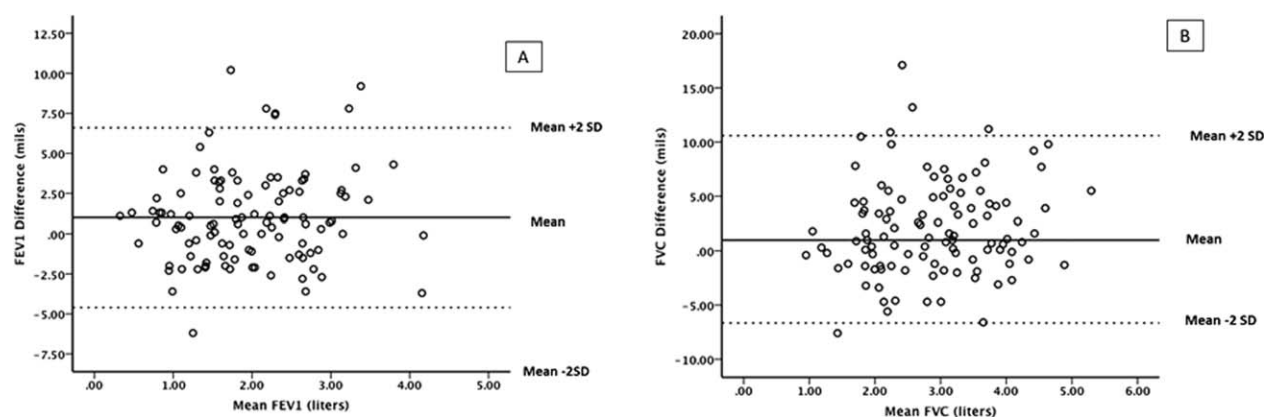


Figure 3. Bland–Altman plots for FEV1 (3A) and FVC (3B) values obtained from Lab and office spirometry. The difference between the two spirometers values with 95% CI is shown on Y axis. X axis shows the mean value for FEV1 and FVC obtained from both spirometers. There was excellent agreement in the values between office and Lab spirometry for both FEV1 and FVC (the difference in measurement was <10 mL between two spirometers). Dotted lines represent two standard deviations.

Table 1. Correlation across ranges of flows and volumes

FVC tertiles	FEV1: OS vs LS			FVC: OS vs LS		
	<i>N</i>	Pearsons coefficient	<i>P</i> value	<i>N</i>	Pearsons coefficient	<i>P</i> value
Tertile 1 <2.19 L	36	0.822	<0.001	36	0.458	0.005
Tertile 2 2.23–3.18 L	36	0.858	<0.001	36	0.692	<0.001
Tertile 3 >3.18 L	35	0.884	<0.001	35	0.746	<0.001

Correlation between OS and LS at various FVC tertiles as calculated by the two-tailed Pearsons correlation test.

OS, office spirometry; LS, laboratory spirometry; FEV1, forced expiratory volume in 1 s, FVC, forced vital capacity.

Discussion

Our data suggest that OS is an acceptable and accurate alternative to LS, for patients suspected with obstructive lung disease, independent of the spirometer. To our knowledge, this is the first report investigating correlation of OS with LS in patients with symptomatic obstructive lung disease. In patients with suspected occupational asthma, a smaller study ($n = 34$) recently reported the accuracy of hand held spirometer to laboratory-based spirometer in an effort to investigate how accurately trained primary-care physicians can perform spirometry. They found high correlations for pulmonary function parameters with highest correlation for FEV1 (15). Another more recent study in patients undergoing lung resection (without reported obstructive lung disease, $n = 30$) also found comparable correlation between OS and LS (13). Our study extends these observations in patients with symptomatic obstructive lung disease. These findings are important in that, the obtained OS values in patients with symptomatic obstructive lung disease may be relied upon for clinical decision making (both diagnostic and therapeutic) and subsequent monitoring in the absence of LS.

Across the nation, spirometry is underutilized in patients with COPD (16) and nearly half of patients with asthma do not get a spirometry, ever (9, 17). Further, physicians overestimate control on clinical evaluation alone, likely due to lack of sensitivity of clinical diagnosis in the absence of evaluation for airflow obstruction (11, 17). There are several barriers to the underutilization of OS (18). Most primary care physicians rely on performance of LS. A major limitation is access to laboratories that perform pulmonary function testing. Hospital-based laboratories often have long waiting lists, and once testing is performed there may be additional delays in result interpretation (19). Almost a fifth of physicians in a Canadian survey reported limited access as a reason for not ordering spirometry (20). For severe asthma, ATS now strongly emphasizes objective confirmation of airflow obstruction,

further increasing the need for access to spirometry (21).

A randomized controlled trial on OS in asthma and COPD failed to show a significant advantage of OS in improving diagnosis of asthma and COPD; although the authors stressed that the study was underpowered to show the difference with a potential type II statistical error (22). The authors reported most patients in primary care to have well-preserved lung function with airflow obstruction found only in 21% of their patients. These data have raised concern whether clinical decision making based on spirometry results alone may result in undertreatment of patients with clinically diagnosed asthma (23). However, Macy *et al.* confirmed the diagnosis of asthma using spirometry in nearly two-thirds of asthmatics in their study (24). Furthermore, lack of spirometry utilization has recently been shown to be an independent risk factor for severe exacerbations of asthma and COPD (4). Recent data suggest that while spirometry is underutilized in newly diagnosed asthma patients, use of controller medications in those diagnosed with asthma without spirometry is high (25). Clinical decision making alone without spirometry utilization may pose a risk of overdiagnosis and potentially overtreatment of patients with conditions that mimic asthma. Indeed, Aaron *et al.* investigated the diagnosis of asthma in obese and nonobese individuals with physician-diagnosed asthma, and reported confirmation of a diagnosis of asthma in only 16% (54 of 346 participants) using spirometry; while a third of patients were found to have no evidence of asthma (26). More recently, Jain *et al.* investigated misdiagnosis in patients with frequent exacerbators of clinically diagnosed asthma and COPD using a diagnostic algorithm that included serial spirometry, and found misdiagnosis in 26% (87 of 333 frequent exacerbators) (27). Spirometry utilization was strongly associated with a reduced risk of misdiagnosis (27). Taken together, these data suggest that OS may have a role in diagnosing airflow obstruction, but perhaps more importantly; in ruling

out airflow obstruction in patients with symptomatology of conditions that mimic asthma and COPD.

Misdiagnosis between asthma and COPD without the use of spirometry can lead to inconsistent care and poor outcomes (9, 10, 28). While challenging to discriminate clinically, the distinction may be reliably made using simple spirometry, by definition (28). Indeed, OS has been shown to influence physician's diagnosis and management plans, at least in patients with moderate to severe obstruction (29). Unfortunately, there are limited, if any, data from large trials that report beneficial outcomes of OS in real-world clinical practice. Nevertheless, office spirometers now offer advantages of being compact, portable, not requiring extensive calibration; and are relatively inexpensive (about a \$1000). By improving spirometry utilization overall, OS may potentially prevent both over and underdiagnoses (30). Further, it allows for easier monitoring of control and therapy. One may argue that office measurement of Peak expiratory flow rate (PEFR) may be simpler, cheaper and more convenient than spirometry; however, studies have shown that assessment of airway caliber through PEFR monitoring can often lead to underestimation or overestimation of changes in FEV1 (31). As such, peak flow measurements are not highly reliable in either children or adults, while spirometry is much more accurate (30, 32).

Our study had several limitations. Besides a relatively small sample size, it lacks a control group, inherent to the retrospective study design. Another limitation of our study was that the two spirometry studies were done about 68 days apart (vs the same day). We chose to compare the correlation within a 90-day period to simulate real-world clinical practice, where laboratory-based PFTs may be performed after several weeks. While this may be considered a large interval leading to significant variability, this was actually not observed in our analyses suggesting that spirometric indices from a portable spirometer alone may be relied upon, at least in the short-term period between clinical follow-ups in patients with symptomatic disease. Our data were limited to prebronchodilator testing and cannot be extrapolated to postbronchodilator and reversibility testing (which would not be expected to have correlation). However, these data could be obtained in a prospective trial and would provide valuable information around the utility of OS in real world conditions where clinicians are attempting to confirm the diagnosis during a clinic visit. Trained personnel performed the portable spirometry, which may be perceived as a limitation in the office setting. However, we believe that this is hardly a limitation and should be relatively easy to train personnel in performing porta-

ble spirometry (we believe within a few days). In addition, the newer portable spirometers do not require routine calibration. A particular strength of our study was the symptomatic study population, most relevant to use of OS in patients with established disease (vs screening), especially in objective monitoring of patients undergoing *step-down* (or *step-up*) therapy. We could not, however, characterize the severity of clinical symptomatology and effect on clinical outcomes, because of the retrospective nature of the study. Our data should be confirmed in a prospective study with a larger sample size.

Conclusions

OS is accurate and reliable as compared to formal LS (independent of the portable spirometer used). OS can and should be routinely used in patients with known asthma and COPD. Widespread use of OS will improve uptake of current guidelines recommending spirometry utilization, and further improve accuracy of diagnoses in patients with clinical symptomatology of obstructive lung disease. Nevertheless, when nondiagnostic (with a normal ratio in setting of reduced FVC and/or FEV1), comprehensive LS and lung function testing must be pursued.

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