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Can airway obstruction be estimated by lung auscultation in an emergency room setting?

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Summary
Objective: Lung auscultation is a central part of the physical examination at hospital admission. In this study, the physicians' estimation of airway obstruction by auscultation was determined and compared with the degree of airway obstruction as measured by FEV_1/FVC values.
Methods: Two hundred and thirty-three patients consecutively admitted to the medical emergency room with chest problems were included. After taking their history, patients were auscultated by an Internal Medicine registrar. The degree of airway obstruction had to be estimated ($0 =$ no, $1 =$ mild, $2 =$ moderate and $3 =$ severe obstructed) and then spirometry was performed. Airway obstruction was defined as a ratio of $FEV_1/FVC < 70\%$. The degree of airway obstruction was defined on FEV_1/FVC as mild ($FEV_1/FVC < 70\%$ and $> 50\%$), moderate ($FEV_1/FVC < 50\%$ $> 30\%$) and severe ($FEV_1/FVC < 30\%$).
Results: One hundred and thirty-five patients (57.9%) had no sign of airway obstruction ($FEV_1/FVC > 70\%$). Spirometry showed a mild obstruction in 51 patients (21.9%), a moderate obstruction in 27 patients (11.6%) and a severe obstruction in 20 patients (8.6%). There was a weak but significant correlation between FEV_1/FVC and the auscultation-based estimation of airway obstruction in Internal Medicine Registrars (Spearman's $\rho = 0.328$; $P < 0.001$). The sensitivity to detect airway obstruction by lung auscultation was 72.6% and the specificity only 46.3%. Thus, the

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negative predictive value was 68% and the positive predictive value 51%. In 27 patients (9.7%), airway obstruction was missed by lung auscultation. In these 27 cases, the severity of airway obstruction was mild in 20 patients, moderate in 5 patients and severe in 2 patients. In 82 patients (29.4%) with no sign of airway obstruction ($FEV_1/FVC > 70\%$), airway obstruction was wrongly estimated as mild in 42 patients, as moderate in 34 patients and as severe in 6 patients, respectively. By performing multiple logistic regression, normal lung auscultation was a significant and independent predictor for not having an airway obstruction (OR 2.48 (1.43–4.28); $P = 0.001$).

Conclusion: Under emergency room conditions, physicians can quite accurately exclude airway obstruction by auscultation. Normal lung auscultation is an independent predictor for not having an airway obstruction. However, airway obstruction is often overestimated by auscultation; thus, spirometry should be performed.

Introduction

Background

Nearly 200 years ago, the French physician, Dr. Laennec invented the stethoscope.[1] By the end of the 19th century, the analysis of lung sounds was well established and the stethoscope had become the hallmark of the physician.[1,2] The lung auscultation was acknowledged by a series of editorials and reviews in leading pulmonary journals[3,4] and by a state of the art review.[5]

The complex acoustic signal arising within the lung contains much information about the underlying pathophysiology of the lung.[2] In ten mite allergic subjects, Oud et al.[6] performed an allergen challenge test and compared the fall in forced expiratory volume in 1 s (FEV_1) with the lung sound recorded with a microphone attached to the trachea. The recordings were digitised and spectral analysis performed. With this method, 60–90% of pulmonary sound data can correctly classify the FEV_1-values. In normal subjects, Kraman[7] found a linear relation between airflow and lung sound amplitude, and Skykoff et al.[8] that breath sound amplitude varied directly with the square of flow in subjects breathing either normally or through resistors. Age-determined changes of the lung sounds have also been shown.[9]

''Time-consuming'' skills such as chest auscultation should be important filters for more diagnostic technology.[10] But, there is some evidence that the auscultatory proficiency is not very well among Internal Medicine trainees.[11] In a recent publication by Reilly[12] it was found that physical examination can have a substantial effect on the care of medical inpatients.

The value of lung auscultation under emergency room condition is not known. Even under lung function condition, 60% of patients with a significant fall in FEV_1 during a methacholine challenge did not have any clinical signs of airway obstruction.[13] Therefore, it might be especially difficult to accurately estimate patients' airway obstruction under emergency room conditions, where it is often noisy and people are under time pressure. Thus, we performed a prospective study to compare the estimation of airway obstruction by lung auscultation with spirometric data.

Methods

Study design

A consecutive sample of patients with chest problems were included in the study. The study was conducted in the Medical Emergency Room of the University Hospital Basel in Switzerland with an annual attendance of 10,000–12,000 during a 6-week period in November/December 2001.

Setting and patients selection

Two hundred and thirty-three consecutive patients with a chest problem admitted to the Medical Emergency Room were included during a 6-week period. Patients were older than 18 years of age, conscious and had to be able to understand the study. Patients were interviewed and the degree of airway obstruction by auscultation was estimated by Internal Medicine Registrars before having access to relevant clinical information including laboratory investigations, chest radiography, ECG, etc. The estimated airway obstruction was then compared with the spirometry data which were collected after the lung auscultation had been performed. The spirometry was performed within

2 h after admission to the medical emergency room.

Later on, patients were worked-up based on the physicians' judgement including laboratory investigations, chest radiography or other imaging studies, etc. Patients' final diagnosis were taken from the hospital-discharge letter to the Family Physician.

Twelve registrars were on call at the medical emergency room during the study period. They had a mean postgraduate training duration of 3.0±2.1 years.

The study was approved by the local Ethics Committee and the patients had to give a written informed consent.

Methods of measurement and data analysis

Estimation of airway obstruction by auscultation

The Registrars were asked to describe the lung auscultation and to tick their findings on the patient file (normal lung auscultation, wheeze, rales, crackles). Finally, the estimated airway obstruction (0 = no airway obstruction, 1 = mild airway obstruction, 2 = moderate airway obstruction, 3 = severe airway obstruction) had to be ticked on the patient file. The registrars estimated the degree of airway obstruction based on their individual training and experience without having been trained especially before the study.

Lung function measurements

Spirometry was performed using a Spirovit SB10 Spirometer (Schiller AG, Baar, Switzerland). Forced expiratory manoeuvres were repeated until two readings of FEV_1 within 100 ml were obtained, the largest of which was used for the analyses. Values for FEV_1 and FVC were recorded as a percentage of the predicted values of Quanjer et al.[14] Values for FEV_1 and FVC >80% predicted were seen as normal. Airway obstruction was defined as a ratio of FEV_1/FVC <70%. To overcome the problem of having combined airway obstruction and restriction, the degree of airway obstruction was defined on FEV_1/FVC as mild (FEV_1/FVC <70% and >50%), moderate (FEV_1/FVC <50% >30%) and severe (FEV_1/FVC <30%).[15]

Data analysis

Statistical analysis was performed with SPSS Version 11.0 for Windows. Differences between subgroups were assessed using one-way ANOVA. Spearman's ρ was calculated to assess correlations between auscultatory performance, technical investigations and the final diagnosis. Factors that were significantly associated with normal or abnormal lung function were identified in univariate logistic regression. To identify independent predictors for normal or abnormal lung function, factors significantly associated with normal lung function in univariate analysis were introduced in a multiple stepwise logistic regression. A *P* value of <0.05 was considered to be statistically significant.

3. Results

Two hundred and thirty-three consecutive patients were included in this study. One hundred and thirty-five patients (57.9%) showed no airway obstruction (FEV_1/FVC >70%). Mild obstruction was found in 51 patients (21.9%), moderate obstruction in 27 patients (11.6%) and severe obstruction in 20 patients (8.6%). Table 1 shows the descriptive data of these groups. There were no differences between groups in regard to age, sex, BMI and pack years of smoking.

Table 1 Subject characteristics of the 233 patients.

	All patients	No obstruction	Mild obstruction	Moderate obstruction	Severe obstruction	*P*
N	233	135	51	27	20	
Age (years)	58.1±19.5	56.9±19.9	57.9±20.7	62.8±17.7	60.3±16.2	0.512
Women	100 (42.9%)	64 (47.4%)	17 (33.3%)	10 (37%)	9 (45%)	0.329
BMI (kg/m^2)	25.7±5.5	26.2±6	25.5±4.5	25.2±3.7	23.3±5.8	0.139
Smoking (pack years)	36.9±24	33.3±25.8	34.1±18.9	39.4±19.1	55±27.8	0.315
FEV_1% predicted	58.1±25.8	65.3±23	58.2±28.8	42.8±14.6	30.3±19.2	<0.001
FVC% predicted	66.4±31.5	63.6±23.2	70.5±37.2	65.3±26.7	76.5±58.9	0.261
FEV_1%FVC	72.5±17.9	84.6±8.8	65.6±3	53.5±5	33.8±8.2	<0.001

Mean values±SD.
BMI: body mass index; FEV_1: forced expiratory volume in 1 s; FVC: forced vital capacity.

By lung auscultation, a normal spirometry was estimated in 82 patients (35%), a mild obstruction in 63 patients (27%), a moderate obstruction in 68 patients (29%) and a severe obstruction in 20 patients (9%). In 27 patients (9.7%), airway obstruction was missed by lung auscultation. In these 27 cases, the severity of airway obstruction was mild in 20 patients, moderate in 5 patients and severe in 2 patients. In 82 patients (29.4%) with no sign of airway obstruction ($FEV_1/FVC > 70\%$), airway obstruction was wrongly estimated as mild in 42 patients, as moderate in 34 patients and as severe in 6 patients.

The sensitivity to detect airway obstruction by lung auscultation was 72.6% and the specificity 46.3%. Thus, the negative predictive value (NPV) was 68% and the positive predictive value (PPV) 51%.

There was a significant correlation between FEV_1/FVC and the auscultation-based estimation of airway obstruction in Internal Medicine Registrars (Spearman's $\rho = 0.328$; $P < 0.001$) (Fig. 1).

The unadjusted OR analysis (logistic regression) for having normal lung function demonstrated a statistically significant relationship with normal lung auscultation (OR 2.48 (1.49–4.15); $P < 0.001$) and BMI (OR 1.026 (1.008–1.044); $P = 0.005$). An inverse relationship was found with wheezing (OR 0.274 (0.14–0.536); $P < 0.001$) and CRP (OR 0.995 (0.991–0.999); $P = 0.039$). After adjustment, normal lung auscultation was the significant and independent predictor for not having an airway obstruction (OR 2.48 (1.43–4.28); $P = 0.001$).

Final diagnosis based on the medical records and the discharge letter to the family practitioners are shown in Table 2. There were 278 final diagnosis: 217 patients had one diagnosis and 16 patients had two or more diagnosis. Most frequent diagnosis were left heart failure (18%), chest wall pain (10.4%), COPD (9.7%) and asthma (7.5%). Missed airway obstruction was found in several diagnosis (Table 3). Airway obstructions were wrongly estimated most frequently in left heart failure and pneumonia (Table 4).

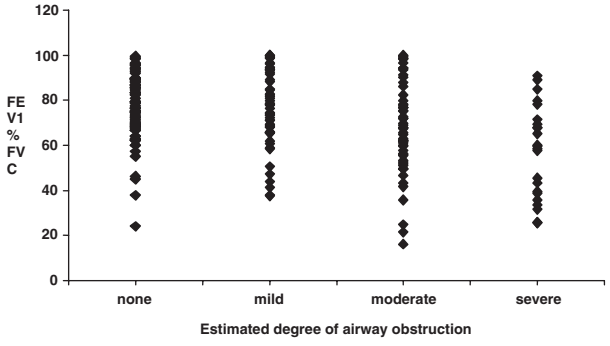

Figure 1 Estimation of airway obstruction compared to the severity of airway obstruction: 0 = no obstruction, 1 = mild obstruction, 2 = moderate obstruction, 3 = severe obstruction.

4. Discussion

Under emergency room conditions, auscultation-based estimation of airway obstruction by Internal Medicine Registrars correlated weakly but significantly with FEV_1/FVC. Lung auscultation had a NPV of 68% but a PPV of only 51%. Twelve percent of airway obstructions were missed by lung auscultation and 28% were wrongly stated as having airway obstruction. However, normal lung auscultation was the only significant and independent predictor for not having an airway obstruction.

By our knowledge, this is the first study investigating the value of lung auscultation for prediction of airway obstruction under emergency room conditions. After taking the patients' history and auscultating the lungs, Internal Medicine Registrars' estimated airway obstruction correlated with the measured airway obstruction. The association of lung sounds and lung function changes has been controversially discussed in laboratory-based studies with bronchoprovocation challenge tests: Oud et al.[6] found that about 60–90% of pulmonary sound data can correctly classify FEV_1-values by using computed spectral sound information. Tracheal sound patterns can predict the methacholine- or histamine-induced airway obstruction,[16–18] although these tracheal sound patters do not seem to be proportionally related to the lung function measurements.[16] On the contrary, however, Baumann et al.[13] reported no clinical signs of airway obstruction in about 60% of patients despite a significant fall in FEV_1 under a bronchoprovocation challenge test.

The sensitivity of the Internal Medicine Registrars to detect airway obstruction was 72.6% with only a specificity of 46.3%. Therefore, the NPV of normal lung auscultation was 68% and the PPV only 51%. This has been further emphasised using multiple logistic regression, in which normal lung auscultation was the only independent predictor for not having an airway obstruction. In a study by Gavriely et al.,[19] nearly 500 active workers were screened by computer-based analysis of the lung sounds. Based on their data, similar negative (NPV 87%) and positive predictive (PPV 62%) values for having lung disease can be calculated. By combining lung sound analysis with spirometry data, the NPV and PPV

Table 2 Severity of airway obstruction as defined by spirometry in different diagnostic groups.

	All	No obstruction	Mild obstruction	Moderate obstruction	Severe obstruction
Asthma	21	5 (23.8%)	6 (28.6%)	6 (28.6%)	4 (19%)
COPD	27	5 (18.5%)	6 (22.3%)	8 (29.6%)	8 (29.6%)
Pneumonia	31	14 (45.1%)	10 (32.2%)	3 (9.7%)	4 (13%)
Acute bronchitis	7	4 (57.1%)	3 (42.9%)		
Pneumothorax/lung embolism	8	7 (87.5%)	1 (12.5%)		
Left heart failure	50	35 (70%)	8 (16%)	6 (12%)	1 (2%)
Acute coronary syndrome	18	11 (61.1%)	3 (16.7%)	2 (11.1%)	2 (11.1%)
Palpitations	10	6 (60%)	3 (30%)	1 (10%)	
Chest wall pain	29	18 (62.1%)	6 (20.7%)	2 (6.9%)	3 (10.3%)
Abdominal pain (e.g. GRD)	8	5 (62.5%)	3 (37.5%)		
Hyperventilation	4	2 (50%)	2 (50%)		
Pleuritis	10	6 (60%)	2 (20%)	2 (20%)	
CO-Inhalation-injury	12	10 (83.4%)	1 (8.3%)	1 (8.3%)	
Chest pain unknown origin	35	23 (65.8%)	6 (17.1%)	4 (11.4%)	2 (5.7%)
Others	8	5 (62.5%)	1 (12.5%)	2 (25%)	
Total	278 (100%)	156 (56.1%)	60 (21.6%)	37 (13.3%)	25 (9%)

Table 3 Diagnosis with additional airway obstructions by spirometry which were missed by lung auscultation.

	All	Mild obstruction	Moderate obstruction	Severe obstruction
Asthma	1	1		
COPD	1	1		
Pneumonia	2	1	1	
Acute coronary syndrome	3	2	1	
Palpitations	4	3	1	
Chest wall pain	5	5		
Abdominal pain (e.g. GRD)	2	2		
Hyperventilation	1	1		
CO-Inhalation-Injury	2	1	1	
Chest pain unknown origin	5	3	2	
Others	1	1		
Total	27 (100%)	20 (74%)	5 (18.5%)	2 (7.5%)

could be increased by approximately 8%. In our study, we did not use computer based lung sound analysis; we investigated the Internal Medicine Registrars' auscultation based estimation of a possible airway obstruction, which reflects the general clinical practice. Auscultation study assessing the proficiency of Internal Medicine trainees using taped sounds did not show good correlations.[11] However, this study used taped sound records and the physicians did neither take the patients' history nor perform physical examinations.

In the current study, there was a variety of chest diseases in which an airway obstruction defined by spirometry have been missed by lung auscultation. We can only hypothesise that our Internal Medicine Registrars concentrated on the main symptom or problem of the patients and did not extend their

Table 4 Final diagnosis in patients in whom airway obstruction could not be correctly estimated by lung auscultation.

	All	Mild obstruction	Moderate obstruction	Severe obstruction
Asthma	5	3	1	1
COPD	4	1	3	
Pneumonia	10	4	6	
Acute Bronchitis	4	3	1	
Pneumothorax/Lung embolism	6	5	1	
Left heart failure	27	11	12	4
Acute coronary syndrome	5	2	3	
Palpitations	1	1		
Chest wall pain	3	2	1	
Hyperventilation	1	1		
Pleuritis	4	3	1	
CO-Inhalation-Injury	3	3		
Chest pain unknown origin	5	2	3	
Others	4	1	3	
Total	82 (100%)	42 (51.2%)	34 (41.5%)	6 (7.3%)

history taking widely enough. Wrongly estimated airway obstruction was frequently found in left heart failure and pneumonia. The value of adventitious sounds in lung auscultation has been nicely discussed in a state-of-the-art-paper by Pasterkamp et al.[5] Although it has been shown that the proportion of breath cycle occupied by wheezing is inversely related to the FEV_1,[20] and the intensity of breath sound can be decreased at the maximal bronchial constriction in a histamine bronchoprovocation challenge test,[21] all these adventitious sounds such as wheezing or rales are not specific.[5] Therefore, our findings support the need and importance of performing spirometries and not only to rely on lung auscultation.

The current study has some limitations: The Internal Medicine Registrars were not trained specifically in lung auscultation before the study. Therefore, we do not know the level of their auscultatory skills and we cannot control that. The registrars estimated the degree of airway obstruction based on their clinical experience but the criteria for the choice of the degree of airway obstruction were not defined. Therefore, we do not know, how they distinguished a possible airway obstruction on lung auscultation. Information about dyspnea or chest tightness and the observed respiratory rate during history taking or auscultation will have certainly influenced their decision. However, the current study reflects the daily life situation.

In summary, under emergency room conditions, normal lung auscultation is an independent and reliable predictor for not having an airway obstruction. However, airway obstruction can be missed or wrongly estimated by lung auscultation; thus, there is a real need and urge to perform spirometry.

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