Original Article

Inspiratory Capacity in Chronic Obstructive Pulmonary Disease: A Measure of Hyperinflation and Relation with Other Parameters – A Cross-Sectional Study

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Abstract

Introduction: Chronic obstructive pulmonary disease (COPD) is a leading cause of morbidity and mortality worldwide. Lung hyperinflation or air trapping is the hallmark of COPD and the primary cause of dyspnea, poor quality of life, and advertent disease prognosis associated with the disease. Debates continue to rise against the use of forced expiratory volume 1 as the single-main evaluative parameter for patients with COPD. Inspiratory capacity (IC) together with spirometry on the other hand has been shown to be a dependable parameter that can indicate the presence and management of lung hyperinflation. **Patients and Methods:** This cross-sectional study included fifty patients of COPD presenting to the department of respiratory medicine. All patients underwent spirometry and 6-min walk test (6MWT). They were grouped according to the GOLD guidelines for airflow limitation, body mass index (BMI), 6MWT, BODE index, number of exacerbations (NoEs), COPD "ABCD" assessment tool, and IC. *t*-test and one-way analysis of variance were applied. **Results:** There were 37 males and 13 females. A positive correlation was found between IC and 6MWT and BMI (coefficient of 0.678 and 0.149, respectively). There was a negative correlation between IC and NoEs and BODE index (coefficient of − 0.257 and − 0.631, respectively). IC correlated strongly with the GOLD classification for airflow limitation and combined assessment of COPD. A statistically significant difference between pre- and post-IC values showed IC as the predictor of lung hyperinflation. **Conclusion:** IC can be used along with 6MWT, BMI, BODE index and NoE for the prognostication and management of COPD.

Keywords: 6-min walk test, BODE index, chronic obstructive pulmonary disease, dynamic hyperinflation, forced expiratory volume, Global Initiative for Obstructive Lung Disease, inspiratory capacity

Introduction

Chronic obstructive lung disease (chronic obstructive pulmonary disease [COPD]) is characterized by destruction of gas-exchanging air spaces that leads to airflow limitation which, over a period, leads to air trapping and hyperinflation of the lungs. Hyperinflation depresses the diaphragm and impairs the intercostal muscle contractility, thus increasing the work associated with breathing and contributing to breathlessness.

For long, there has been a need for parameters other than spirometry for assessment and prognosis of COPD since spirometric response to therapy has not shown to be associated with clinical outcomes or modifying therapy. As patients with similar forced expiratory volume 1 (FEV_1) tend to have different clinical parameters, the existence of other variables such as 6-min walk test (6MWT), number of exacerbations (NoEs), body mass index (BMI), BODE index, and inspiratory capacity (IC), which play a role in the pathogenesis and predict mortality better than FEV_1 in COPD, has been recognized.

A reduction in IC is useful to measure the degree of dynamic hyperinflation (DH), the principal cause of dyspnea in COPD. IC, being less dependent on the degree of obstruction and mechanic compression associated with forced expiratory maneuvers, is

Access this article online

Quick Response Code:

Website: www.ijrconline.org

DOI: 10.4103/ijrc.ijrc_2_18

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How to cite this article: Parekh AB, Kshatriya MR, Khara NV, Paliwal RP, Patel SN. Inspiratory capacity in chronic obstructive pulmonary disease: A measure of hyperinflation and relation with other parameters – A cross-sectional study. Indian J Respir Care 2018;7:93-6.

more sensitive than FEV_1 to various therapies of COPD such as corticosteroids, beta agonists, and theophylline.[1-6]

The aim of this study was to assess the efficacy of IC as a tool for the measurement of hyperinflation and its usefulness for the assessment and management of COPD by correlating it with other parameters of COPD such as GOLD staging, BODE index, NoE, BMI, and 6MWT.

Patients and Methods

This was a cross-sectional analytical study conducted at the Department of Respiratory Medicine, Pramukhswami Medical College and Shree Krishna Hospital, HM Patel Centre for Medical Care and Education, Karamsad, Anand, Gujarat. The synopsis of the study was submitted to the Institutional Human Research Ethics Committee and approval was taken to perform the study. A written informed consent was obtained from all the patients.

A total of fifty diagnosed patients of COPD were analyzed. All participants of both sexes between the ages of 35 and 70 years, diagnosed to have COPD according to the GOLD guidelines (2011), were included in the study. Patients not fulfilling the age criteria and patients with alternate or coexistent diagnosis, for example, bronchial asthma, pulmonary fibrosis, bronchiectasis, interstitial lung disease, and others were excluded from the study. Those with a history of cardiac disease, ischemic heart disease, valvular heart disease, congenital heart disease, those who were immunocompromised due to human immunodeficiency viral infection and diabetes mellitus, organ transplant recipients, and those with systemic lupus erythematosus were also not included in the study.

A detailed history including demographic details, past history of any significant illness, and drug history was recorded. The BMI of all patients was calculated according to CDC recommendations using the following standard formula: weight in kg/height in m^2. A thorough physical examination of all the patients was performed.

A spirometry was performed on all patients using a COSMED Pony FX Spirometer COSMED THE Metabolic Company 2012 that complied with ATS/ERS recommendations. Standard equations were used for predicted values. A 6MWT was performed in all patients according to the ATS guidelines. All were diagnosed to have COPD according to the GOLD guidelines. They were divided according to age, sex, and severity of airflow limitation in COPD according to GOLD staging. They were also grouped according to IC, COPD "ABCD" assessment tool, 6MWT, BMI, NoEs, and BODE index. IC was measured before and immediately following the 6MWT.

Statistical analysis

Paired *t*-test was applied to check significant difference between pre- and post-IC. One-way analysis of variance (ANOVA) test was also applied to check the association between IC and GOLD classification for airflow limitation and COPD "ABCD" assessment tool. Pearson's correlation was used to find the correlation between IC and 6MWT, BMI, NoE, and BODE index.

Results

Of the fifty patients studied, 37 (74%) were men and 13 (26%) were women. The majority of patients were between the age group of 55 and 64 (42%) years with a range of 40–70 years and a mean age of 58 years. Thirty-five (70%) men had a smoking history, while none of the women ever smoked. Eight (16%) patients had a history of biomass fuel exposure, all of them being women. Eighteen of the fifty patients were healthy by weight and 17 patients were undernourished, while 2 patients were obese.

The most common occupation among the patients was farming (30%). Others were laborers, homemakers, government servants, and private servants.

Cough was the most common presenting symptom and was present in 42 (84%) patients. Other symptoms were chest pain, dyspnea, fever, hemoptysis, and others (abdominal pain, generalized weakness, and pedal edema).

When GOLD classification for airflow limitation in COPD was applied to them, 17 (34%) patients had Stage IV (very severe) disease, 13 (24%) patients had Stage III (severe) COPD, while 5 patients had moderate level of COPD.

Considering the COPD "ABCD" assessment tool, most of the patients (18 [36%]) belonged to Group C (high risk, less symptom), of which 16 were male and 2 were female patients.

In the study, 26 (52%) patients had a BODE index between 7 and 10. Patients with this score have a 52-month mortality of approximately 80%. Considering rest of the patients, 9 patients had a BODE index of 3–4, 8 patients had an index between 0 and 2, and 7 patients had an index between 5 and 6.

Among the fifty patients with COPD, 15 (30%) patients had a 6MWT of ≤149 m and another 15 patients had 150–240 m. Paired *t*-test applied to look for difference in the values of IC before and after the 6MWT showed $P < 0.0001$ [Table 1].

One-way ANOVA test was applied to find the association between IC and combined assessment of COPD according to the GOLD guidelines. This showed that there was a statistically significant mean difference ($P < 0.0001$) in the IC between the groups [Table 2].

Table 1: Inspiratory capacity values (L) before and after 6-min walk test (*n*=50)

Parameter	Mean±SD	*n*	Mean difference	95% CI for mean difference	*P*
Before 6MWT	1.98±0.59	50	0.27420	0.173-0.376	<0.0001
After 6MWT	1.71±0.698	50			

P<0.0001 Very highly significant. CI: Confidence interval, 6MWT: 6-min walk test, SD: Standard deviation

A *post hoc* Scheffe test as shown in Table 3 was applied to look at which of the specific pair differed. There was statistically significant difference between mean IC of Group A with Group C and Group D with $P = 0.001$ and 0.001, respectively. There was also statistically significant difference between mean IC of Group B with Group C and Group D with $P = 0.004$ and 0.005, respectively. Group C and Group D did not show statistically significant difference in their ICs with $P = 1.00$.

Similarly, P value was less than 0.0001 when one-way ANOVA was applied to find the association between IC and severity of airflow limitation as per the GOLD guidelines [Table 4].

Table 2: Association between baseline inspiratory capacity (L) and combined assessment of chronic obstructive pulmonary disease according to the GOLD guidelines (chronic obstructive pulmonary disease "ABCD" assessment tool)

Patient group	*n*	Mean±SD	*P*
A	9	2.58±0.34	<0.0001
B	7	2.499±0.538	
C	18	1.72±0.321	
D	16	1.71±0.571	
Total	50	1.98±0.586	

Test used: ANOVA. SD: Standard deviation, IC: Inspiratory capacity

Table 3: Pair-wise comparison of baseline inspiratory capacity in all groups using *post hoc* Scheffe test

Group pairs	*n*	Mean±SD	*P*
A	9	2.58±0.34	0.98
B	7	2.499±0.54	
A	9	2.58±0.34	<0.0001
C	18	1.72±0.32	
A	9	2.58±0.34	<0.0001
D	16	1.71±0.57	
B	7	2.499±0.54	0.004
C	18	1.72±0.32	
B	7	2.498±0.54	0.005
D	16	1.71±0.57	
C	18	1.72±0.32	1.000
D	16	1.71±0.57	

SD: Standard deviation, IC: Inspiratory capacity

Table 4: Association between inspiratory capacity and severity of airflow limitation according to the GOLD guidelines

GOLD stage	*n*	Mean±SD	*P*
I	3	2.897±0.10	<0.0001
II	13	2.46±0.43	
III	14	1.898±0.38	
IV	20	1.59±0.46	
Total	50	1.98±0.59	

ANOVA IC: Inspiratory capacity, SD: Standard deviation

After applying the *post hoc* Scheffe test [Table 5], for difference between individual pairs, Stage I had statistically significant difference with Stage III and Stage IV with $P = 0.006$ and <0.0001, respectively, than with Stage II where $P = 0.467$. Stage II had significant difference with Stage IV instead of Stage IV with $P < 0.0001$. Stage III and Stage IV did not have a statistically significant difference with $P = 0.236$.

As shown in Table 6, Pearson correlation coefficient showed moderate-to-strong positive correlation between IC and 6MWT, as the coefficient was 0.678. A mild-to-weak positive correlation between IC and BMI was concluded, as the coefficient was 0.149.

A weak negative correlation was seen between IC and NoEs of COPD, with a coefficient of −0.257, and a moderate-to-strong negative correlation between IC and BODE index, with a coefficient of −0.631.

IC showed a positive correlation with 6MWT and a negative correlation with BODE index. The correlation with BMI was weakly positive and with NoEs was weakly negative.

Discussion

A cross-sectional study conducted by Madueño *et al*. showed significant correlation between the change in IC and dyspnea after exercise test (6MWT).[7] They opined that IC could be

Table 5: Pair-wise comparison of the inspiratory capacity with GOLD stages using *post hoc* Scheffe test

GOLD stage pairs	*n*	Mean±SD	*P*
I	3	2.896±0.095	0.467
II	13	2.46±0.43	
I	3	2.896±0.095	0.006
III	14	1.898±0.38	
I	3	2.897±0.095	<0.0001
IV	20	1.59±0.46	
II	13	2.464±0.43	0.12
III	14	1.898±0.38	
II	13	2.46±0.43	<0.0001
IV	20	1.59±0.46	
III	14	1.898±0.38	0.236
IV	20	1.59±0.46	

SD: Standard deviation

Table 6: Correlation between inspiratory capacity and body mass index, 6-min walk test, number of exacerbations, and BODE index

Variable	Pearson's correlation coefficient
BMI	0.149
6MWT	0.679
Number of exacerbations	−0.257
BODE index	−0.631

BMI: Body mass index, 6MWT: 6-min walk test

used in the place of spirometry in primary care settings, but it had poor correlation with quality of life as with FEV_1. The present study also showed a similar correlation. While both the studies addressed a similar issue, the cause of dyspnea in COPD is the underlying pathology of DH.

Another study published by Marin *et al*. tested the hypothesis that dyspnea during 6MWT could be associated with the development of lung hyperinflation.[8] In addition, they sought to prove that the use of spirometrically determined IC would simplify the measurement and provide a valid field alternative to more complex determinations of DH. The two most important findings of the study were that simple walking results in DH that can be easily determined using measured IC and the degree of DH correlated with the increased perception of dyspnea during walking. Another useful observation was that a spirometrically obtained IC could be used to accurately determine the degree of DH. This was corroborated in the present study and showed that there was a moderate-to-strong correlation between 6MWT and IC.

Celli *et al*. looked at the annualized rate of IC decline over a period of 4 years and the relationship between the baseline IC and mortality.[9] The study found that those with lower values of IC at baseline were associated with higher rates of exacerbations and death. Similarly, the correlation between IC and NoE in COPD was weakly negative in the present study, but there was a moderate-to-strong negative correlation between IC and BODE index, which is a predictor of mortality and morbidity in COPD.

A novel study conducted by Ofir *et al*. was based on the rationale that little is known about the underlying mechanisms causing dyspnea and airflow limitation in smokers with relatively preserved FEV_1.[10] Across groups, dyspnea intensity increased as ventilation expressed as a percentage of capacity increased and as inspiratory reserve volume decreased. The study concluded that changes in end-expiratory lung volume during exercise were greater in COPD patients than in healthy controls, and breathing pattern was correspondingly more shallow and rapid. A strong positive correlation with 6MWT was observed in the present study, suggesting that patients with high inspiratory reserve volume had good exercise tolerance.

Conclusion

Conventionally, FEV_1 has been used as a sole parameter for the evaluation of COPD. IC together with spirometry has been shown to be a dependable, inexpensive, and simpler parameter that can indicate the presence and management of lung hyperinflation. It correlates strongly with other parameters used to grade COPD such as 6MWT, BMI, NoE, COPD "ABCD" assessment tool, and BODE index. IC can change with the various therapeutic options for COPD and is even more sensitive than FEV_1 to such changes. Thus, IC along with the above parameters can be used as a tool for the management of COPD.

Acknowledgment

The author would acknowledge his teachers for their continuous and persistent support.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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