

Efficacy of the 6-Minute Walk Test in Evaluating Ambulatory Oxygen Therapy

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OBJECTIVE: To compare oxyhemoglobin saturation (SpO₂) observed during the 6-minute walk test with that of pulse oximetry carried out during activities of daily living (ADLs). The efficacy of the 6-minute walk test for determining adequate oxygen flow to prevent arterial desaturation during ADLs was also analyzed.

PATIENTS AND METHODS: We studied 37 patients diagnosed with chronic obstructive pulmonary disease (COPD)—mean (SD) forced expiratory volume in 1 second, 26% (9%) of predicted—and compared SpO₂ values obtained in the 6-minute walk test with those obtained with ambulatory pulse oximetry during ADLs. Eleven of the 20 patients with exercise-induced desaturation agreed to use portable liquid oxygen and were randomized to ambulatory pulse oximetry on 2 consecutive days, both with and without the administration of oxygen. Oxygen flow was adjusted on successive 6-minute walk tests until a mean SpO₂ greater than 85% was reached.

RESULTS: The mean SpO₂ for all patients was 84% (7%) during the 6-minute walk test and 89% (4%) during ADLs ($P < .001$). Cumulative percentages of time with SpO₂ less than 90%, 88%, and 85% were higher during the 6-minute walk test than during ADLs ($P < .001$). During the walk test, desaturation was detected in 27% of patients, but was not confirmed by ambulatory pulse oximetry during ADLs. In the subgroup of 11 patients using portable liquid oxygen no significant differences were found between SpO₂ values recorded during the walk test and during ADLs with the appropriate oxygen flow.

CONCLUSION: The 6-minute walk test is an effective method for detecting desaturation during ADLs and for establishing the oxygen flow needed to correct exercise-induced desaturation.

Key words: 6-minute walk test. Ambulatory pulse oximetry. Portable liquid oxygen. COPD.

Eficacia de la prueba de los 6 minutos de marcha en la valoración de la oxigenoterapia de deambulaci3n

OBJETIVO: Comparar la saturaci3n de la oxihemoglobina (SpO₂) observada durante la prueba de los 6 min de marcha (P6m) con la SpO₂ de la pulsioximetría ambulatoria realizada durante las actividades de la vida diaria (AVD). Se analiz3 también la eficacia de la P6m en determinar el flujo de oxígeno adecuado para prevenir la desaturaci3n arterial durante las AVD.

PACIENTES Y MÉTODOS: Se estudi3 a 37 pacientes diagnosticados de enfermedad pulmonar obstructiva cr3nica —valor medio (\pm desviaci3n est3ndar) del volumen espiratorio forzado en el primer segundo $26 \pm 9\%$ del valor de referencia— en los que se compararon los valores de SpO₂ obtenidos en la P6m y la pulsioximetría ambulatoria. De los 20 pacientes con desaturaci3n al esfuerzo, 11 aceptaron el oxígeno líquido port3til y realizaron la pulsioximetría ambulatoria de forma aleatorizada en 2 días consecutivos con y sin la administraci3n de oxígeno. El flujo de oxígeno se estableci3 en la P6m con pruebas sucesivas hasta lograr una SpO₂ media superior al 85%.

RESULTADOS: La SpO₂ media en el total de pacientes fue del $84 \pm 7\%$ en la P6m y del $89 \pm 4\%$ en la pulsioximetría ambulatoria ($p < 0,001$). Los porcentajes de tiempo acumulado con SpO₂ $<$ del 90, del 88 y del 85% fueron superiores en la P6m ($p < 0,001$). Durante la P6m, en un 27% de los pacientes se detect3 desaturaci3n, que no se confirm3 con la pulsioximetría ambulatoria. En el subgrupo de 11 pacientes no se observaron diferencias significativas entre la P6m y la pulsioximetría ambulatoria realizadas con el flujo de oxígeno ajustado.

CONCLUSI3N: La P6m es un m3todo eficaz para detectar la desaturaci3n durante las AVD y establecer el flujo de oxígeno para corregir la desaturaci3n al esfuerzo.

Palabras clave: Prueba de los 6 minutos de marcha. Pulsioximetría ambulatoria. Oxígeno líquido port3til. EPOC.

Introduction

Continuous home oxygen therapy is the only treatment that increases survival in chronic obstructive pulmonary disease (COPD) patients with chronic

respiratory insufficiency^{1,2} and international treatment guidelines, such as those of the Global Initiative for Chronic Obstructive Lung Disease,³ recommend it as basic therapy in such cases. Although long-term domiciliary oxygen therapy has proven effective if administered at least 16 hours per day (as recommended by the various guidelines⁴⁻⁶), it seems clear from the Nocturnal Oxygen Therapy Trial (NOTT)¹ that the benefits of continuous (24-hour) oxygen therapy are greater. In recent years, the introduction of liquid

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oxygen has made it possible to increase the hours of therapy and to administer treatment outside of the patient's home.

In order to determine whether the use of portable liquid oxygen is indicated, a decrease in exercise-induced oxyhemoglobin saturation (SpO_2) as measured by pulse oximetry must be shown, as well as adequate correction of desaturation with the administration of oxygen. Several types of stress tests have been used for this purpose. Of these, the most widely used is the 6-minute walk test.⁷

The 6-minute walk test is a simple and widely-used stress test that makes it possible to evaluate the functional status of COPD patients and their ability to carry out activities of daily living (ADLs). The test measures the distance walked on a flat surface in 6 minutes and requires a constant level of effort similar to that needed by the patient to carry out ADLs.^{7,8} The test has also been used to assess exercise-induced desaturation. Most guidelines consider a mean SpO_2 during exercise of less than 88% to be clinically significant desaturation.^{7,9} In Catalonia, Spain, exercise-induced desaturation is defined as a mean SpO_2 during the 6-minute walk test of less than 85%.¹⁰ Portable liquid oxygen therapy is considered to be effective if exercise-induced desaturation is corrected and an SpO_2 greater than 90%^{9,11} or 85%¹⁰ (depending on the guidelines used) is maintained. There is no clear evidence that the saturation level obtained in the 6-minute walk test is an accurate reflection of the level maintained during the patient's ADLs.¹² It has therefore been suggested that ambulatory SpO_2 be monitored during ADLs.

Working on the hypothesis that the 6-minute walk test is a good indicator of desaturation during ADLs in COPD patients and a useful test for determining adequate oxygen flow for portable liquid oxygen therapy, we carried out a study with the following objectives: *a*) to compare oxyhemoglobin desaturation observed during the 6-minute walk test with that of ambulatory pulse oximetry; and *b*) to analyze the efficacy of the 6-minute walk test for determining the oxygen flow needed to maintain adequate SpO_2 during ADLs.

Patients and Methods

For 6 months we studied consecutive patients diagnosed with COPD who had been referred to our outpatient department for evaluation for continuous oxygen therapy. Patients under 80 years in a stable phase of the disease who were autonomous in carrying out ADLs outside the home were included in the study.

The 6-minute walk test was always administered by the same trained person in a specially-equipped 25-meter long hospital corridor. We measured the distance covered by the patient when walking at a brisk pace for 6 minutes. During the test we recorded the patient's heart rate and SpO_2 as measured with a Minolta Pulsox-5 pulse oximeter (AVL Medical Instruments, Schuffhausen, Switzerland). Due to the high coefficient of variability of the 6-minute walk test and the fact that there is a learning effect, on the first day we conducted 3 consecutive tests without oxygen and with a minimum rest

period of 30 minutes before the first test and between each test. The results of the last test were considered valid. Standardized verbal encouragement with the words "you are doing very well" was used during the tests. The words "walk as quickly as you can" were used only when the procedure was explained to the patient. Test termination criteria established by international guidelines were used.⁷ Mean SpO_2 less than 85% during the 6-minute walk test was defined as exercise-induced desaturation.¹⁰ In addition to mean SpO_2 , cumulative percentages of time with SpO_2 less than 90%, 88%, and 85% (CT90%, CT88%, and CT85%) were also evaluated.

The same pulse oximeter used for the 6-minute walk test was used to carry out ambulatory pulse oximetry over a 24-hour period. The pulse oximeter had a memory card with a storage capacity of 24 hours. While being monitored, patients recorded activities and noteworthy events, specifying their duration. The period of sleep was excluded from analysis, and only daytime readings were taken into consideration. Given the difficulty of separating periods of rest and activity during the day, complete daytime readings were analyzed. Mean SpO_2 , CT90%, CT88%, and CT85% were evaluated.

For all patients, the SpO_2 values obtained during the 6-minute walk test were compared to those obtained during the period of ambulatory recording.

In the subgroup of patients who were candidates for portable liquid oxygen use and who had agreed to use it outside the home, a 6-minute walk test was performed on a second day of use in order to establish the oxygen flow needed to correct exercise-induced desaturation. Oxygen flow was considered to be adequate if a stable mean SpO_2 greater than 85% was maintained.¹⁰ If this level was not achieved, successive tests with progressively increasing oxygen flow were carried out, always with a 30-minute rest period between each test, until the required flow was reached. In such patients the ambulatory pulse oximetry monitoring at home was performed randomly on 2 consecutive days, 1 day with and 1 day without the administration of oxygen. We analyzed whether the oxygen flow established in the 6-minute walk test adequately corrected the SpO_2 in ADLs and compared the values (mean SpO_2 , CT90%, CT88%, and CT85%) obtained in the 2 tests.

Statistical Analysis

For the statistical analysis we used SPSS version 10.0 software. We performed descriptive analysis, compared means with the Student *t* test, and assessed correlations with Pearson correlation coefficients. A *P* value less than .05 was considered significant.

Results

A total of 37 patients (36 men) with severe airflow obstruction were studied. Age and lung function data are shown in Table 1. The total number of hours recorded during ambulatory pulse oximetry was a mean of 22 (1) hours. We analyzed data for those hours corresponding to daytime activity, a mean of 15 (2) hours. Mean SpO_2 and CT90%, CT88%, and CT85% values obtained in the 6-minute walk test and by ambulatory pulse oximetry for all patients are shown in Table 2. During the 6-minute walk test, 20 patients showed desaturation, defined as a mean SpO_2 of less than 85%.

TABLE 1
Age and Lung Function Information for All Patients and for the 2 Subgroups (With and Without Exercise-Induced Desaturation)*

	Total Patients (n=37)	Without Desaturation (n=17)	With Desaturation (n=20)	P
Age, years	66 (9.1)	63.4 (9.3)	67.1 (8.9)	.2
PaO ₂ , mm Hg	62 (8)	66.4 (6.9)	58.4 (8)	.03
PaCO ₂ , mm Hg	47 (7)	44.7 (4.9)	48.5 (7.4)	.07
FVC, % pred	60 (18)	62.1 (18.7)	57.7 (18)	.47
FEV ₁ , % pred	26 (9)	27.1 (10.7)	25.3 (6.9)	.56
6MWT, m	283 (95)	313 (99.7)	257 (85)	.78

*Values expressed as mean (SD).
FVC indicates forced vital capacity; FEV₁, forced expiratory volume in 1 second; pred, predicted; 6MWT, 6-minute walk test.
The statistical comparison is between the subgroups with and without desaturation.

TABLE 2
SpO₂ for the Total Number of Patients in the 6-Minute Walk Test and Continuous Ambulatory Recording: Comparison of the 2 Tests in All Patients and in 2 Subgroups (With and Without Exercise-Induced Desaturation)*

	Total Patients (n=37)		Without Desaturation (n=17)		With Desaturation (n=20)	
	6MWT	Continuous Ambulatory Recording	6MWT	Continuous Ambulatory Recording	6MWT	Continuous Ambulatory Recording
Mean SpO ₂ , %	84 (7)	89 (4)‡	91 (2)	91 (2)	79 (6)	87 (4)‡
CT90%	77 (34)	51 (32)‡	53 (37)	34 (26)	97 (5)	66 (29)‡
CT88%	56 (42)	35 (30)‡	18 (24)	19 (17)	90 (20)	49 (31)‡
CT85%	42 (44)	19 (23)‡	1 (2)	6 (7)†	77 (29)	29 (27)‡

*Values expressed as mean (SD).
SpO₂ indicates oxyhemoglobin saturation; 6MWT, 6-minute walk test; CT90%, cumulative percentage of time with SpO₂ <90%; CT88%, cumulative percentage of time with SpO₂ <88%; CT85%, cumulative percentage of time with SpO₂ <85%.
†P<.002;‡P<.001.

TABLE 3
Correlation of SpO₂ Values Obtained in the 6MWT and in Daytime Continuous Ambulatory Recording (During Hours of Activity) in the 37 Patients Studied*

	6MWT	Daytime Continuous Recording	r	P
Mean SpO ₂ , %	84 (7)	89 (4)	0.7	<.01
CT90%	77 (34)	53 (32)	0.6	<.01
CT88%	56 (42)	35 (30)	0.51	<.01
CT85%	42 (44)	19 (23)	0.65	<.01

*Values expressed as mean (SD).
SpO₂ indicates oxyhemoglobin saturation; 6MWT, 6-minute walk test; AP, ambulatory pulse oximetry; CT90%, cumulative percentage of time with SpO₂ <90%; CT88%, cumulative percentage of time with SpO₂ <88%; CT85%, cumulative percentage of time with SpO₂ <85%.

TABLE 4
Comparison of SpO₂ With Portable Liquid Oxygen Between the 6MWT and Continuous Ambulatory Recording During Hours of Activity for the 11 Patients Using Portable Liquid Oxygen*

	6MWT	Continuous Ambulatory Recording	P
Mean SpO ₂ , %	90 (3)	92 (2)	.28
CT90%	53 (35)	22 (15)	.47
CT88%	29 (33)	11 (11)	.1
CT85%	8 (11)	6 (6)	.6

*Values expressed as mean (SD).
SpO₂ indicates oxyhemoglobin saturation; 6MWT, 6-minute walk test; CT90%, cumulative percentage of time with SpO₂ <90%; CT88%, cumulative percentage of time with SpO₂ <88%; CT85%, cumulative percentage of time with SpO₂ <85%.

A significant relation was observed between the SpO₂ values obtained in the 2 tests (Table 3). However, the mean SpO₂ obtained in the 6-minute walk test was lower than that observed during ambulatory recordings, and CT90%, CT88%, and CT85% were significantly higher (P<.001). During the walk test, desaturation was observed in 10 patients (27%), but was not confirmed by ambulatory pulse oximetry.

Patients were divided into 2 groups, according to whether or not they showed exercise-induced desaturation during the 6-minute walk test. Table 1 shows lung function values and distance walked in the 6-minute walk test for both groups. Significant differences (P<.05) between patients with and without desaturation (mean SpO₂ <85% or ≥85%) were found

only in resting PaO₂. Table 2 compares the results obtained by the 2 groups with and without desaturation in the 6-minute walk test with those obtained during continuous ambulatory recording of SpO₂. A significant difference (P<.001) between SpO₂ during the 6-minute walk test and during ADLs was observed in the group of patients with exercise-induced desaturation, for mean SpO₂ as well as for CT90%, CT88%, and CT85%. In the group of patients that did not show desaturation a significant difference (P<.002) between the 2 tests was observed only in CT85%.

Eleven of the 20 patients with exercise-induced desaturation agreed to use portable liquid oxygen and completed the second phase of the study. Three of them had shown desaturation in both tests, and 8 only in the

6-minute walk test. The mean oxygen flow rate was 4 (1) L per minute. PaO₂ for this subgroup was 57 (10) mm Hg and mean PaCO₂ was 47 (8) mm Hg. No significant differences between the 2 tests were observed in mean SpO₂ or CT90%, CT88%, or CT85% when the tests were carried out with adjusted oxygen flow (Table 4).

Discussion

Our study showed that the pulse oximetry during the 6-minute walk test detects exercise-induced desaturation better than pulse oximetry carried out during ADLs. It also showed that using the 6-minute walk test to establish oxygen flow during exercise corrected desaturation during ADLs, as confirmed by ambulatory pulse oximetry.

Several studies have shown the 6-minute walk test to be a good indicator of exercise capacity in patients with COPD and a good predictor of morbidity and mortality both in COPD patients¹⁴ and those having undergone lung resection.¹⁵ Interpretation of 6-minute walk test results have tended to focus on the evaluation of exercise capacity by distance walked,^{7,8} but the test also provides information on other factors that affect exercise capacity. Thus, several authors have shown that the 6-minute walk test is even more sensitive in detecting desaturation than maximal or submaximal tests using cycle ergometers,^{16,17} a fact which may be of clinical and physiological importance.¹⁸ Thus, walk tests—particularly the 6-minute walk test—have for some time been used to evaluate exercise-induced desaturation. In a review by Wijkstra et al,¹⁹ in which criteria for prescribing continuous oxygen therapy in various countries of Europe and the Americas were analyzed, the 6-minute walk test was the most frequently used both to detect exercise-induced desaturation and to establish the oxygen flow needed to correct it. Using the 6-minute walk test to identify patients with exercise-induced desaturation in their ADLs is simple and easy. However, there are several factors that may be sources of variation in the distances walked—and thus in the amount of effort exerted—and these will also affect SpO₂ response.^{7,13,20}

Monitoring SpO₂ during ADLs is extremely important, not only in order to detect even unsuspected desaturation, but also to ensure adequate correction with oxygen therapy. Soguel Schenkel et al²¹ monitored SpO₂ in COPD patients during ADLs and observed transient desaturation during such simple activities as eating, washing, or walking, even in the absence of marked resting hypoxemia, indicating the need for continuous oxygen therapy.

A recent study by Fussell et al¹² showed only a slight association between the SpO₂ in the 6-minute walk test and that recorded during continuous home monitoring. The authors assert that the 6-minute walk test identifies a greater number of patients as having exercise-induced desaturation than does ambulatory monitoring and feel

that this may lead to erroneous decisions in the prescription of portable liquid oxygen. In their study, they found that the results of the 6-minute walk test classified 16 of the 20 patients as candidates for portable liquid oxygen use, and ambulatory monitoring only 3. These findings are consistent with those of the present study, in which the SpO₂ obtained in the 6-minute walk test was significantly lower, and the percentage of time with SpO₂ less than 85% higher than that recorded during ambulatory home monitoring. Similarly, we observed that in a high percentage of patients (27%) the 6-minute walk test detected desaturation that was not confirmed in the daytime recordings of ambulatory pulse oximetry. However, our interpretation differs from that of Fussell et al.¹² In our opinion, while we analyzed only the periods of daytime activity on the continuous recording days, these periods were interspersed with many others when patients were at rest, and such periods are very difficult to identify with precision. This fact once again confirms that patients engage only in light physical activity in their daily lives. In the study of Fussell et al,¹² the complete 24-hour recording was analyzed. This included periods of sleep and, of course, all the many possible periods of rest. The 6-minute walk test consists of walking as quickly as possible for an established period of time and thus evaluates the activity that produces the greatest desaturation, as was pointed out by Soguel Schenkel et al.²¹

In our study, the mean SpO₂ and CT90%, CT88%, and CT85% observed in the 6-minute walk test correlated significantly with those observed during ambulatory recording. Fussell et al¹² obtained much weaker correlations when they compared the SpO₂ obtained in the 2 tests. The apparent discrepancy in the results between our study and theirs can be explained by the fact that the authors compared the lowest SpO₂ value obtained during the 6-minute walk test with the mean SpO₂ recorded in continuous recordings, which, for some patients, included hours of sleep. Due to measurement artefacts, the lowest SpO₂ recording is subject to considerable variability and we do not believe it to be the most objective parameter obtained in the walk test. Moreover, the inclusion of periods of sleep in continuous home pulse oximetry may lead to periods of arterial desaturation caused by pathophysiologic mechanisms other than those produced by exercise. In fact, in the study of Fussell et al¹² the periods of lowest saturation were during sleep.

The second objective of our study was to analyze the correction of exercise-induced desaturation achieved when the 6-minute walk test is used to determine adequate oxygen flow. In accordance with the guidelines of Catalonia,¹⁰ maintaining a stable SpO₂ above 85% was considered good correction, although in the majority of countries¹⁹ and in international guidelines³⁻⁵ maintaining a mean SpO₂ over 90% during the 6-minute walk test is recommended. Our results showed that in all patients desaturation during ADLs as measured by continuous pulse oximetry was corrected

adequately with the oxygen flow established during the 6-minute walk test. These data are important in view of the fact that using resting arterial blood gases to adjust the flow of portable liquid oxygen does not adequately correct desaturation during ADLs, as the studies of Morrison et al²² and Pilling et al²³ have shown.

There is no evidence that the correction of exercise-induced oxyhemoglobin desaturation has repercussions on the progress of COPD or on survival, but it would seem logical that inadequate treatment of chronic respiratory insufficiency will not achieve hoped-for benefits. In fact, the NOTT¹ and the Medical Research Council² have shown that the longer continuous oxygen therapy is used, the greater the benefits obtained. It is reasonable to suppose that only 16 hours a day of oxygen therapy not covering the hours of greatest daytime activity could have a negative effect on the progress of the disease. In a study analyzing the long-term efficacy of continuous oxygen therapy in 930 patients, Pepin et al²⁴ suggested that the use of oxygen during ADLs was one of the factors contributing to the benefits of continuous oxygen therapy. Fujimoto et al²⁵ showed that administering oxygen during exercise to COPD patients resulted not only in an increase in exercise capacity, but also in a reduction in the increase of pulmonary arterial pressure. It is well known that pulmonary hypertension is the principal factor related to poor prognosis in patients with COPD and desaturation (whether during sleep, rest, or exercise), and consequently the factor that determines survival in such patients.

We believe that it is important to prescribe the most suitable treatment for the patient in terms of both time and efficacy. This involves a totally individualized evaluation of the oxygen flow necessary to correct exercise-induced desaturation. In a previous study, we were able to demonstrate that patients who were prescribed portable liquid oxygen following correct individualized adjustment of oxygen flow showed a clear improvement in health-related quality of life as measured by the Chronic Respiratory Questionnaire, a decrease in dyspnea, and an increase in the number of hours spent walking outside the home as well as in distance walked during the 6-minute walk test.²⁶

In conclusion, our study showed the 6-minute walk test to be an easy, economical, and reliable way to detect exercise-induced desaturation in COPD patients and to establish the oxygen flow needed to correct desaturation during ADLs.

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