Tubing Length for Long-Term Oxygen Therapy

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BACKGROUND: Most patients on long-term oxygen therapy use stationary oxygen delivery systems. It is not uncommon for guidelines to instruct patients to use tubing lengths no longer than 19.68 ft (6 m) when using an oxygen concentrator and 49.21 ft (15 m) when using cylinders. However, these concepts are not based on sufficient evidence. Thus, our objective was to evaluate whether a 98.42-ft (30-m) tubing length affects oxygen flow and F_{IO_2} delivery from 1 cylinder and 2 oxygen concentrators. METHODS: The 3 oxygen delivery systems were randomly selected, and 1, 3, and 5 L/min flows and F_{IO_2} were measured 5 times at each flow at the proximal and distal outlets of the tubing by a gas-flow analyzer. Paired Student *t* test was used to analyze the difference between flows and F_{IO_2} at proximal and distal outlets of tubing length. RESULTS: A total of 45 flows were measured between proximal and distal outlets of the 98.42-ft (30-m) tubing. Flows were similar for 1 and 3 L/min, but distal flow was higher than proximal flow at 5 L/min (5.57 × 5.14 L/min, $P < .001$). F_{IO_2} was lower at distal than proximal outlet tubing at flows 1, 3, and 5 L/min, but the mean difference between measurements was less than 1%. CONCLUSIONS: Tubing length of 98.42 ft (30 m) may be used by patients for home delivery oxygen with flows up to 5 L/min, as there were no important changes in flows or F_{IO_2}. *Key words: oxygen inhalation therapy; laboratory test; instrumentation.* [Respir Care 2015;60(2):179–182. © 2015 Daedalus Enterprises]

Introduction

Long-term oxygen therapy (LTOT) plays an important role in management of hypoxemic patients[1,2] due to its benefits related to lung function,[3] survival,[4] pulmonary hypertension, and exercise.[5] However, the effect of LTOT on quality of life remains controversial.[6] Some studies have shown a reduced quality of life in patients under LTOT[5,6] due to the excessive noise produced by the oxygen concentrators (OCs) and/or limitation of patient's mobility.[7-9]

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The authors have disclosed no conflicts of interest.

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Usually, the majority of patients on LTOT use stationary oxygen delivery systems (ODS) such as cylinders and OCs. It is not uncommon for oxygen providers and guidelines to instruct patients to use tubing lengths no longer than 19.68 ft (6 m) when using an OC and 49.21 ft (15 m) when using cylinders.[10] This is the usual recommendation for tubing lengths in the literature.[8,11]

Despite the idea that longer tubing would cause reduction in flow and/or F_{IO_2}, we believe that health professionals, oxygen suppliers, and guidelines are establishing their concepts on insufficient evidence. As far as we are aware, only one study investigated the oxygen tubing length and output flows.[11] The authors showed significant reduction in flow at 2 L/min for tubing length greater than 100 ft when using cylinders as an oxygen source and additional flow loss at greater tubing lengths (100–200 ft) with 3–5 L/min from an OC.[11] However, F_{IO_2} was not assessed in this study.

Further investigation would provide more evidence for adequate instructions to the patients. Thus, our objective was to evaluate whether 98.42-ft (30-m) tubing affects oxygen flow and F_{IO_2} delivery from stationary cylinders and OCs.

Methods

This was an experimental study conducted at the Pulmonary Rehabilitation Center at Escola Paulista de Medicina, Federal University of São Paulo, São Paulo, Brazil with ODS. Three ODS were randomly selected to assess flows and oxygen concentration: 2 OCs (one by Respironics Millennium [Respironics, Murrysville, Pennsylvania] and the other by Invacare Platinum XL [Invacare, Elyria, Ohio]) and a 6 m^3 stationary oxygen cylinder (White Martins, Danbury, Connecticut). One OC of each brand available in our division was randomly chosen; just 1 oxygen cylinder was evaluated, as there was only one brand available in our division at the period of the study.

Flow and F_{IO_2} were measured at 1, 3, and 5 L/min by a gas flow analyzer (VT Plus, Fluke Biomedical, Everett, Washington) previously calibrated at zero flow and at F_{IO_2} 0.21 connected to the oxygen cylinder or the oxygen concentration (proximal flow and F_{IO_2}). Measurement was recorded after a 2-min period once flow stability was reached (Fig. 1A).

Then, a 98.42-ft (30-m) tubing length was connected to the oxygen cylinder or concentrator, and the same gas analyzer was now connected to the distal end of the tubing. In the same way, 2 min elapsed for stabilization of the flow, after which F_{IO_2} and flow were recorded (distal F_{IO_2} and flow; see Fig. 1B). Stability of the flows and F_{IO_2} was defined as when these 2 parameters had reached steadiness for 20 s at the tubing outlet as read on the gas-flow analyzer graph. Reproducibility was tested at each flow 5 times in a random sequence.

Statistical Analysis

Measurements of oxygen flows and concentration were expressed as mean and standard deviation. Paired Student *t* test was used to analyze the difference between flow and F_{IO_2} at proximal end and at 98.42 ft (30 m) tubing length (distal flow). The level of significance was set at $P \leq .05$.

Results

A total of 45 flow measurements were performed: 15 measurements from each ODS. Flows measured were similar between proximal and distal outlets of the 98.42-ft (30-m) tubing at 1 and 3 L/m; distal flow was higher than proximal flow at 5 L/min (5.57×5.14 L/min, $P < .001$) (Fig. 2). When the ODS flows were individually evaluated, only the 5 L/min flow from the cylinder was significantly different, with distal flow higher than proximal flow (Table 1).

A total of 45 F_{IO_2} measurements were performed: 15 measurements from each ODS. The F_{IO_2} at 1 and 5 L/min flows were significantly lower at the distal than proximal outlet tubing (Fig. 3). When the ODS F_{IO_2} measurements were individually evaluated, the distal F_{IO_2} was usually lower than the proximal outlet, but with a very small difference that may not have any clinical influence (Table 2).

QUICK LOOK

Current knowledge

Long-term oxygen therapy (LTOT) plays an important role in management of hypoxemic patients due to its benefits related to lung function, survival, pulmonary hypertension, and exercise. Quality of life may be reduced in patients under LTOT due to the excessive noise produced by the oxygen concentrators (OCs) and/or limitation of patient's mobility from stationary oxygen systems.

What this paper contributes to our knowledge

Tubing length of 98.42 ft (30 m) may be used by patients with home OCs and flows up to 5 L/min. Despite commonly held beliefs, longer tubing lengths had no clinically important changes in flows or oxygen purity.

Discussion

Inadequate instructions regarding length of oxygen tubing can greatly affect patients in their daily activities, LTOT compliance, and quality of life. A review highlighted factors influencing the compliance of patients using LTOT and emphasized novel strategies and interventions that may prove to be of significant benefit. The authors suggested that the use of a stationary OC or liquid oxygen with incorporated tubing up to 50 ft (15.24 m) in length, in conjunction with an additional small M-6 cylinder (2 kg, 4 h/use) or a small portable liquid reservoir (~2 kg, 5 h/use) could be an ideal and complete home oxygen system.[12] In our study, we observed that long tubing (30 m) should be safe for patient use, as no important difference was observed between proximal and distal measured flows, except at 5 L/min. In addition, the difference in F_{IO_2} between proximal and distal outlets was less than 1% in all 3 ODS.

Most LTOT system providers and healthcare professionals rely on deficient data when managing oxygen-dependent patients. Moreover, there has been a historical belief that the length of the tubing could affect the oxygen flow in different ODS. Most guidelines still indicate that tubing up to 19.68 ft (6 m) should be used with OCs and 49.21 ft (15 m) with cylinders.[10]

Cullen and Koss[11] recommended tubing lengths up to 200 ft (60.96 m) for flow up to 3 L/min or 100 ft (30.48 m) for 4–5 L/min for Invacare and similar OCs. The authors

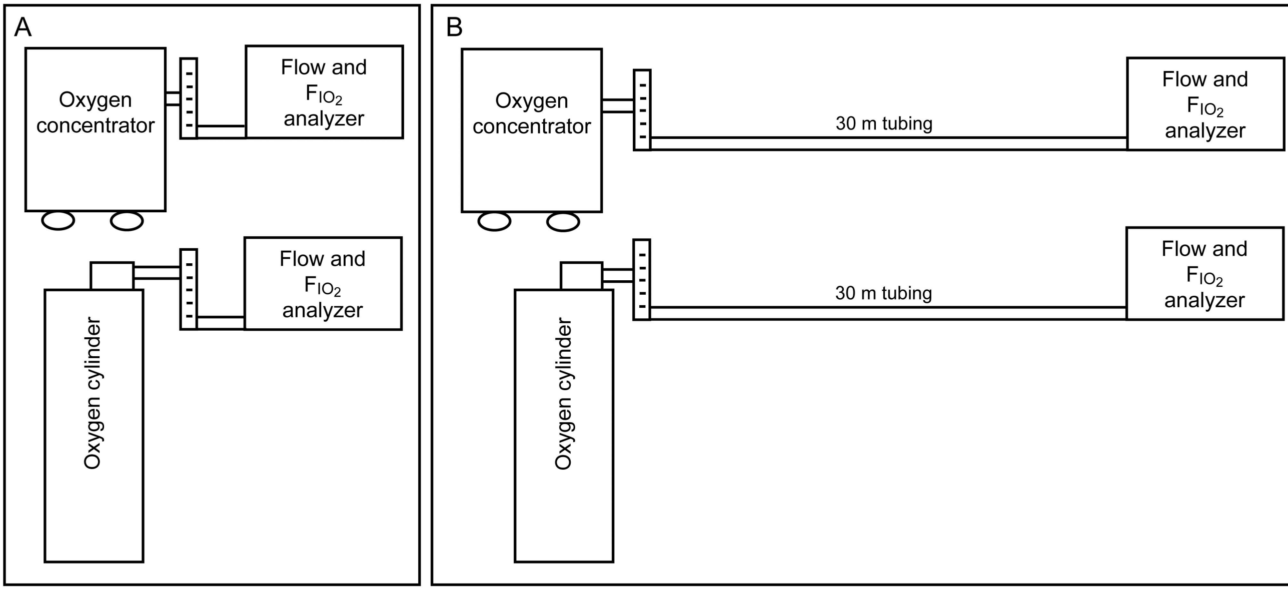

Fig. 1. Scheme of flows and F_{IO_2} measurements at proximal outlet (A) and distal outlet (B).

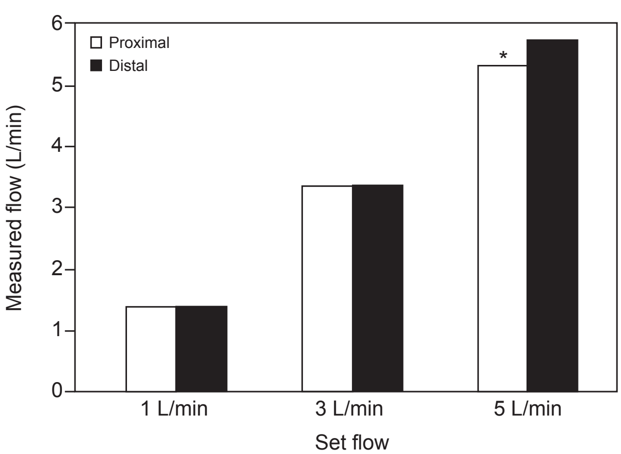

Fig. 2. Mean values of proximal and distal tubing length flows. White bars represent proximal measured flows, and black bars represent distal tubing length measured flows. *$P < .05$.

Table 1. Flows Values at 1, 3, and 5 L/min Measured at Proximal and Distal Tubing Length According to 3 Different Devices

	Proximal Measured Flow	Distal Measured Flow	*P*
Oxygen concentrator 1			
1 L/min	1.08 ± 0.05	1.15 ± 0.16	.24
3 L/min	3.07 ± 0.07	3.30 ± 0.22	.55
5 L/min	5.18 ± 0.03	5.68 ± 0.35	.36
Oxygen concentrator 2			
1 L/min	1.12 ± 0.02	1.24 ± 0,18	.66
3 L/min	3.02 ± 0.09	3.17 ± 0.17	.21
5 L/min	5.15 ± 0.09	5.55 ± 0.43	.02
Cylinder			
1 L/min	1.17 ± 0.02	1.25 ± 0.16	.88
3 L/min	3.01 ± 0.09	3.17 ± 0.26	.22
5 L/min	5.12 ± 0.05	5.49 ± 0.43	.21

Data are shown as mean ± SD.

observed that the cylinder regulator/flow meter system suffered the greatest flow loss, with significant reductions in flow at 2 L/min for tubing lengths greater than 100 ft (30.48 m). The authors attributed the changes in flow to the individual oxygen system operational mechanism.

In the analysis of flow using 3 randomly selected ODS, we observed that there was no change in flow for 1 and 3 L/min and only a slight increase for 5 L/min flow comparing proximal and 30-m output flows. This is not expected, but there are 2 possible explanations. First, the flow analyzer has some variability (approximately 2% according to the manufacturer′s instructions manual); second, as we have observed previously,[12] there is a normal flow variation in flow meters. For flow reading at the tubing distal end, the flow analyzer had to be disconnected from the proximal end and connected to the distal end and another 2 min elapsed, which may have introduced some flow variation. It is possible that the difference in flow seen may be accounted for by these 2 sources of variation. However, these differences in flow do not seem to have clinical importance, as the mean difference in F_{IO_2} was less than 1%. Moreover, no difference in flow was seen when the tested flow was 1 L/min; a small difference of 0.03 L/min was seen at 3 L/min and approximately 0.4 L/min at 5 L/min. These variations are in keeping with our previous observation of flow meter variation as flow is increased[12]

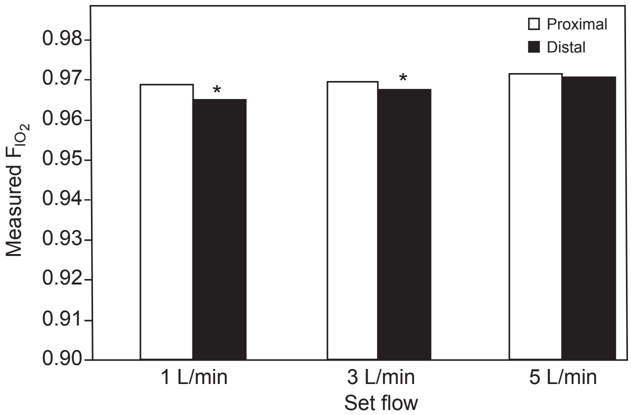

Fig. 3. Mean values of proximal and distal tubing length F_{IO_2}. White bars represent proximal measured F_{IO_2}, and black bars represent distal tubing length measured F_{IO_2}. $*P < .05$.

Table 2. F_{IO_2} Values at 1, 3, and 5 L/min Measured at Proximal and Distal Tubing Length Flow According to 3 Different Devices

	Proximal Measured F_{IO_2}	Distal Measured F_{IO_2}	% Difference Between F_{IO_2}
Oxygen concentrator 1			
1 L/min	94.08 ± 0.04	93.86 ± 0.05*	0.22
3 L/min	94.76 ± 0.09	94.72 ± 0.04	0.04
5 L/min	94.94 ± 0.05	95.32 ± 0.04*	–0.38
Oxygen concentrator 2			
1 L/min	94.32 ± 0.24	93.48 ± 0.31*	0.84
3 L/min	95.28 ± 0.18	95.26 ± 0.09	0.02
5 L/min	95.76 ± 0.05	95.28 ± 0.04*	0.48
Cylinder			
1 L/min	99.90 ± 0.07	99.62 ± 0.04*	0.28
3 L/min	99.98 ± 0.04	99.64 ± 0.13*	0.34
5 L/min	99.92 ± 0.08	99.82 ± 0.04	0.10

$* P < .05$

Furthermore, Cullen and Koss[11] consider as clinically important flow reductions ≥ 20%. Our results showed < 10% change in flow measurements, and are therefore considered not clinically important if we use the same criteria.[11] It is important to point out that the ODS used in this study were verified by the manufacturer and considered adequate for the study.

To our knowledge, no other study has verified the F_{IO_2} output in tubing length up to 98.42 ft (30 m). Despite the statistical difference observed between proximal and distal F_{IO_2} measurements in all 3 ODS, the maximal difference between them was less than 1%, which may not influence the clinical treatment. This is also an important finding, considering the historical belief that the length of the tubing may also affect the F_{IO_2}.

Finally, we chose to analyze 98.42-ft (30-m) tubing, because this seems to be a length that could fit most of the patient's homes on LTOT with the studied ODS. This length should be enough to provide them with more freedom of movement within the home. In conclusion, tubing length at 98.42 ft (30 m) may be used by patients for home delivery oxygen with no important changes in flow or F_{IO_2}. Further studies, especially clinical ones, should be done to support these findings.

REFERENCES

1. Cazzola M, Donner CF, Hanania NA. One hundred years of chronic obstructive pulmonary disease (COPD). Respir Med 2007;101(6):1049-65.
2. Cranston JM, Crockett AJ, Moss JR, Alpers JH. Domiciliary oxygen for chronic obstructive pulmonary disease. Cochrane Database Syst Rev 2005:CD001744.
3. Hanania NA AN, Calverley P, Cazzola P, Donner CF, Make B. Treatments for COPD. Respir Med 2005;99 (suppl B):S28-S40.
4. Nocturnal Oxygen Therapy Trial Group. Continuous or nocturnal oxygen therapy in hypoxemic chronic obstructive lung disease: a clinical trial. Ann Intern Med 1980;93(3):391-398.
5. Zieliński J. Effects of long-term oxygen therapy in patients with chronic obstructive pulmonary disease. Curr Opin Pulm Med 1999;5(2):81-87.
6. Sant'Anna CA, Stelmach R, Zanetti Feltrin MI, Filho WJ, Chiba T, Cukier A. Evaluation of health-related quality of life in low-income patients with COPD receiving long-term oxygen therapy. Chest 2003;123(1):136-141.
7. Diego González EG, Méndez Lanza A, Mosquera Pestaña JA. Noise and machine failures: determining factors in the acceptance and behavior of O_2 concentrator. The Asturias project. An Med Interna 1996;13(9):430-433.
8. Shiner RJ, Zaretsky U, Mirali M, Benzaray S, Elad D. Evaluation of domiciliary long-term oxygen therapy with oxygen concentrators. Isr J Med Sci 1997;33(1):23-29.
9. Wedzicha JA. Effects of long-term oxygen therapy on neuropsychiatric function and quality of life. Respir Care 2000;45(1):119-124.
10. Global Initiative for Chronic Obstructive Pulmonary Disease - update 2014. http://www.goldcopd.org/uploads/users/files/GOLD_Report2014_Feb07.pdf. *Accessed March 29, 2014.*
11. Cullen DL, Koss JA. Oxygen tubing lengths and output flows: implications for patient care. Chron Respir Dis 2005;2(4):193-197.
12. Davidson J, Gazzeta C, Torres LC, Jardim JR, Nascimento OA. Precision and accuracy of oxygen flow meters used at hospital settings. Respir Care 2012;57(7):1071-1075.