Notes

Exercise Tolerance during Nasal Cannula and Transtracheal Oxygen Delivery[1–4]

SUSAN W. WESMILLER, LESLIE A. HOFFMAN, FRANK C. SCIURBA, PETER F. FERSON, JONAS T. JOHNSON, and JAMES H. DAUBER

SUMMARY Previous studies have reported that exercise tolerance improves with transtracheal oxygen delivery. However, patients were not blinded to the delivery technique used, introducing a potential source of bias. The purpose of this study was to compare exercise tolerance during nasal cannula and transtracheal delivery using a randomized double-blinded technique. Subjects (n = 11) performed 12-min walks on the same day while receiving nasal cannula and transtracheal delivery. Nine of 11 subjects walked farther with transtracheal delivery, a significant increase ($p < 0.01$). Mean increase in walk distance was 95 ± 86 feet. In addition, a trend was seen toward greater improvement in walk distance with greater flows through the catheter ($r = 0.58$, $p < 0.06$). Time into the walk when desaturation ($Sa_{O_2} < 90\%$) first occurred was not significantly different. We conclude that exercise tolerance improves when oxygen is delivered by transtracheal catheter. This improvement is unrelated to an increase in Sa_{O_2}. We speculate that the increase in exercise tolerance may be related to other physiologic effects of flow through the catheter.

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Since the first use of transtracheal oxygen delivery was reported by Heimlich (1), a number of benefits have been attributed to use of this oxygen delivery method. These include decreased oxygen requirement (1–13), improved patient compliance (2–4), decreased costs (1, 5, 8, 11), and decreased hospitalization (1–3, 7, 11). In addition, patients have reported relief of dyspnea (1, 2, 6, 10). Most (10, 11, 13, 14), but not all (12), of these reports have suggested that exercise tolerance improves with transtracheal use.

In these prior studies, testing was not done on the same day. As a consequence, acute effects of transtracheal use could not be distinguished from changes in patient condition that might have occurred over time. Also, patients were not blinded to the method used for oxygen delivery. This knowledge may have biased the outcome since, after electing to use transtracheal delivery, patients may have been motivated to demonstrate improved exercise performance. Finally, it is not always clear from these former studies whether the increase in exercise tolerance resulted from an improvement in Sa_{O_2} or whether an independent factor related to intratracheal flow was responsible. The purpose of this study was to compare exercise tolerance during nasal cannula and transtracheal delivery using a double-blinded technique.

A total of 11 subjects (nine men and two women) 46 to 72 yr of age (mean, 61 ± 8 yr) were included in the study. All were receiving transtracheal oxygen (SCOOP®; Transtracheal Systems, Englewood, CO) and had moderate to severe obstructive airway disease ($FEV_1/FVC < 60\%$) and severe hypoxemia ($Pa_{O_2} \leq 55$ mg Hg while breathing room air at rest).

A patient profile is shown in table 1. Significant abnormalities in spirometric values were present, with FEV_1/FVC ratios ranging from 20 to 58% (33 ± 13%). Duration of transtracheal catheter use ranged from 1 to 42 months (mean, 10 ± 11 months) at the time of data collection. Duration of oxygen use prior to transtracheal catheter insertion was 20 ± 14 months (range, 8 to 60 months).

All subjects performed two 12-min walks using a randomized, double-blind testing method. For nasal cannula walks, subjects received oxygen at 0.25 L/min through their transtracheal catheter to provide a sensation of flow and the usual flow prescribed for exercise through the cannula. For transtracheal walks, subjects received 0.5 L/min via their cannula and the usual flow prescribed for exercise through the catheter. This flow rate was not changed during the 12 min of data collection. To blind the data collector (SWW) and subject, the oxygen delivery system was assembled by a third person. Patients were seated with their equipment behind their chairs. They were not able to see how the equipment was assembled or the flow settings, nor did they know when the changes were occurring. Both walks were performed on the same day, with the order randomized. During the walks, Sa_{O_2} and heart rate were recorded at 1-min intervals for the 12 min (N-200 Pulse Oximeter; Nellcor, Hayward, CA). Between walks, subjects rested (seated) a minimum of 15 min or until Sa_{O_2} returned to baseline. For five subjects, the nasal cannula walk was completed first. For the remaining six, the transtracheal walk was completed first.

All testing was done by the same individual (SWW) using a standardized protocol (15–17). All subjects were familiar with the exercise protocol because of performing 12-min walks as part of another protocol. In addition, two practice walks were performed during the week prior to data collection. All subjects gave informed consent for study participation.

Prior to data collection, mean Sa_{O_2} was 94 ± 3% (range, 88 to 97%) when using nasal cannula delivery and 94 ± 2% (range, 91 to 97%) for transtracheal delivery (table 1). To achieve this Sa_{O_2}, subjects required oxygen at 3.9 ± 1.6 L/min with nasal cannula, and 2.4 ± 1.5 L/min with transtracheal delivery.

The total distance walked using the nasal cannula ranged from 52 to 1,370 feet (mean, 670 ± 398 feet) (table 2). Distance for the transtracheal walks ranged from 298 to 1,470 feet (mean, 765 ± 370 feet), a significant increase ($p < 0.01$) when analyzed using a paired *t* test.

Nine of the 11 subjects walked farther when using transtracheal delivery. The increase in distance for the nine who improved with the transtracheal delivery ranged from 26 to 246 feet (mean, 95 ± 86 feet). When the transtracheal flow rate and the distance walked were compared, a trend was seen toward greater improvement in walk distance with greater flows through the catheter ($r = 0.58$, $p < 0.06$).

Mean Sa_{O_2} decreased to 88.5 ± 7.8% during the first minute of the nasal cannula walk and to 88.6 ± 6.3 during the first minute of the transtracheal walk (figure 1). The Sa_{O_2} of the two patients who were most oxygen

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[4] Correspondence and requests for reprints should be addressed to Susan W. Wesmiller, R.N., M.S.N., University of Pittsburgh, School of Nursing, 367 Victoria Hall, Pittsburgh, PA 15261.

TABLE 1

PATIENT PROFILE

Patient No.	Age (yr)	FVC* (L)	FEV_1* (L/s)	FEV_1/FVC	Prewalk Sa_{O_2} NC	Prewalk Sa_{O_2} TT	O_2 Requirement during Walk (L/min) NC	O_2 Requirement during Walk (L/min) TT
1	56	1.81 (48)	0.36 (12)	20	97	97	4.0	2.0
2	50	3.71 (74)	0.85 (23)	23	88	91	6.0†	6.0
3	46	1.63 (33)	0.45 (18)	28	97	97	3.0	1.5
4	72	1.00 (41)	0.50 (29)	50	96	94	2.0	1.0
5	58	2.98 (64)	0.73 (22)	24	96	95	2.5	1.0
6	59	2.80 (61)	0.83 (25)	30	96	96	4.0	2.0
7	64	3.06 (75)	0.69 (24)	23	95	96	6.0	3.0
8	68	4.26 (111)	2.47 (94)	58	93	93	4.0	2.0
9	70	2.32 (61)	1.06 (41)	46	92	92	6.0	4.0
10	61	1.65 (37)	0.58 (18)	35	94	95	1.5	1.0
11	67	1.40 (46)	0.37 (17)	26	93	93	4.0	2.5
Mean	61	2.42 (59)	0.81 (29)	33	94	94	3.9	2.4
SD	8	1.03 (22)	0.59 (23)	13	3	2	1.6	1.5

Definition of abbreviations: NC = O_2 delivery by nasal cannula; TT = transtracheal O_2 delivery.
* Values in parentheses are percent predicted.
† Subject was inadequately oxygenated during NC delivery.

TABLE 2

DISTANCE TRAVELED AND MAXIMAL HEART RATE WHEN SUBJECTS PERFORMED 12-MIN WALKS USING NASAL CANNULA AND TRANSTRACHEAL OXYGEN DELIVERY

Patient No.	12-Min Walk* (feet) NC	12-Min Walk* (feet) TT	Difference (feet)	Maximal Heart Rate NC	Maximal Heart Rate TT	Difference Heart Rate
1	670	735	+65	134	144	+10
2	52	298	+246	138	148	+10
3	890	980	+90	125	127	+2
4	966	960	−6	126	130	+4
5	880	840	−40	114	114	0
6	1,050	1,220	+170	134	134	0
7	1,370	1,470	+100	121	132	+11
8	280	470	+190	100	99	−1
9	336	362	+26	155	140	−15
10	525	598	+73	114	115	+1
11	352	482	+130	130	140	+10
Mean	670	765	+95	126	129	+3
SD	398	370	86	15	15	8

For definition of abbreviations, see table 1.
* $p < 0.01$.
† Maximal value recorded during 12-min walk.

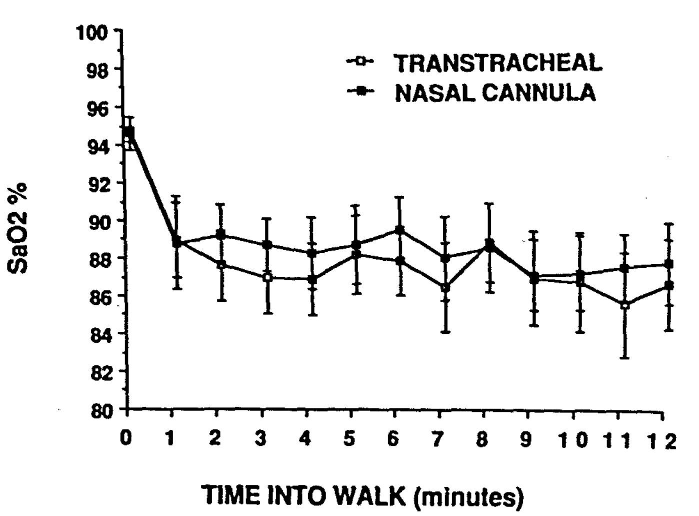

Fig. 1. Mean saturation during 12-min walk.

dependent decreased to ≤ 80% during the first minute of both walks. Two subjects (Subjects 1 and 3) did not desaturate at any time during data collection.

The time into the walk when desaturation (Sa_{O_2} < 90%) first occurred was not significantly different (cannula, 2.9 ± 3.3 min; catheter, 1.6 ± 1.3 min). Three subjects desaturated 1 to 4 min sooner with transtracheal oxygen delivery than with nasal cannula delivery, but in this time they had walked a greater distance. For most (seven of 11) subjects, the maximal heart rate recorded during the transtracheal walk was higher than during the nasal cannula walk (table 2).

At the conclusion of both walks, subjects were asked which system they felt delivered most of their oxygen flow during the first and second walk. Six of the 11 guessed incorrectly, including the two subjects who walked farther with nasal cannula delivery.

* * *

Heimlich and Carr (2) reported that patients (n = 100) experienced immediate relief of dyspnea at rest after use of transtracheal oxygen delivery. Banner and Goven (6) surveyed patients (n = 12) using transtracheal oxygen delivery (mean, 6.4 months of use). Patients reported that transtracheal delivery decreased breathlessness and made daily activities easier.

In unblinded testing, we (14) reported an increase in 12-min walk distance when subjects (n = 6) walked on the same day using nasal cannula and transtracheal oxygen delivery methods and also when this testing was done over time (10, 11). Results of the present study, in which blinded testing was used, confirm and extend the observation that transtracheal oxygen delivery can increase exercise tolerance.

The mechanism for improved exercise tolerance in patients receiving transtracheal oxygen is not known. Findings of our study support mechanisms other than improvement in oxygen saturation since Sa_{O_2} during the walk was not significantly different when using the two modes of oxygen delivery. In fact, three patients desaturated sooner when using transtracheal oxygen delivery despite having walked a longer distance. Also, the increase in walk distance was not related to a difference in baseline Sa_{O_2}.

We speculate that improved exercise tolerance may be related to the physiologic effects of the flow through the catheter. Support for this outcome is based on our finding that patients with higher transtracheal flows tended to have a greater increase in walk distance when using transtracheal oxygen delivery. Potential mechanisms include: (*1*) a decreased effective dead space, (*2*) mechanical support resulting in decreased work of breathing, (*3*) airway receptor stimulation resulting in a decreased sensation of dyspnea, and (*4*) the effect of constant flow ventilation (18). In fact, recent studies have demonstrated a decreased ventilation requirement in patients using transtracheal air or oxygen at rest (19). Further work is needed to clarify the specific mechanisms underlying the improvement seen in exercise tolerance.

In summary, we have shown in a randomized, double-blinded study that patients with COPD have a greater exercise tolerance when using transtracheal oxygen delivery than when using nasal cannula delivery. This exertional improvement is not related to improved arterial oxygenation. Further studies are necessary to elucidate the specific mechanisms.

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