Development, dissemination, implementation and evaluation of a clinical pathway for oxygen therapy

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Abstract

Background: Oxygen is commonly administered to patients in hospital, but prescribing and monitoring of such therapy may be suboptimal. The objective of this study was to develop, disseminate, implement and evaluate a multidisciplinary clinical pathway for the administration of oxygen.

Methods: The authors developed a clinical pathway for the ordering, titration and discontinuation of oxygen, which was disseminated through teaching sessions, in-service training sessions and information posters in a medical clinical teaching unit (CTU). Implementation of the pathway was ensured by means of reminders and patient-centred audit and feedback to CTU nurses and house staff. During a 3-month intervention phase, consecutive patients requiring supplemental oxygen were treated according to the pathway. During a 1-month "wash-out" phase followed by a 3-month non-intervention phase, patients were treated at the discretion of the CTU team. Clinical and economic data were collected in both phases.

Results: In the 2 phases, patient characteristics, the concentration and duration of oxygen prescribed, the frequency of oxygen saturation monitoring, the frequency of arterial blood gas testing and the clinical outcomes were similar. However, there were more discontinuation orders in the intervention phase ($p < 0.001$). In the intervention phase, costs were higher for monitoring of oxygen saturation ($44.95/patient v. $36.17/patient, $p = 0.048$) and for order transcription ($2.71/patient v. $1.28/patient, $p < 0.001$); total costs, including those for personnel, were also higher in the intervention phase ($76.93/patient v. $56.67/patient, $p = 0.02$). The cost of education about the oxygen pathway was $45.71/patient. When the education cost was included, the total cost of oxygen therapy during the intervention phase was $122.64/patient; this was significantly higher than the total cost of oxygen therapy during the non-intervention phase ($56.67/patient) ($p < 0.001$).

Interpretation: This multidisciplinary, multimethod oxygen pathway led to changes in oxygen-prescribing behaviour, consumed more resources than standard management and was not associated with changes in patient outcome. Appropriate management of oxygen prescribing and monitoring by physicians and nurses takes time and costs money.

Practice guidelines are systematically developed statements to assist decision-making about appropriate health care for specific clinical circumstances.[1] Guidelines can be linked to form clinical pathways or algorithms,[2] which organize, sequence and time the care of a "typical, uncomplicated patient."[3] Although controlling health care costs is one force driving the development and use of guidelines, their economic impact is unclear. Some guidelines are used to teach physicians and physicians-in-training about optimal patient management. However, optimal care, whether achieved through guidelines or by other methods, may easily increase health care costs.

Selecting a topic for guideline or pathway development typically involves considering the prevalence and burden of a problem, the availability of evidence, and the likelihood of effecting changes in care.[4] We previously found insufficient documen-

Research

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This article has been peer reviewed.

CMAJ 2000;162(1):29-33

tation of the indications for and the titration, monitoring and discontinuation of oxygen on our medical clinical teaching unit (CTU).[5] We describe here a multidisciplinary clinical pathway for oxygen management designed to educate health care workers and optimize practice. We hypothesized that teaching sessions and individualized audit and feedback about oxygen ordering and monitoring would modify caregivers' behaviour and increase hospital costs.

Methods

This study was conducted in a 28-bed medical CTU in a 453-bed hospital in Hamilton, Ont. The CTU is staffed by 2 internists, 1 chief medical resident, 2 senior residents, 4 junior residents, 4 medical students, 14 respiratory therapists, 42 nurses and 4 ward clerks. Rotation periods are 4 months (for the senior residents), 2 months (for the medical students and junior residents) and 1 month (for the attending physicians). The management decisions of the CTU team are executed primarily through house staff orders.

Between September 1996 and March 1997 we prospectively identified consecutive CTU patients who required any supplemental oxygen. Patients who required home oxygen were excluded before admission.

A multidisciplinary team with representation from nursing, respiratory therapy, general internal medicine and respirology agreed on the objective of promoting more rational prescribing and monitoring of oxygen therapy on the CTU. We critically appraised the literature on oxygen use for hospitalized patients and reviewed our institutional procedure manual to create an oxygen order form, a clinical pathway for administering and monitoring oxygen therapy (Fig. 1) and an oxygen titration table.

Training sessions for house staff focused on oxygen physiology, indications, delivery, titration, monitoring and hazards. The indication for oxygen and the desired mode and concentration were recorded by a physician on the oxygen order form. The form offered a choice of possible indications, as modified from the American College of Chest Physicians/National Heart, Lung and Blood Institute conference on oxygen therapy.[6] Reordering or a discontinuation order was required every third day. In-service training sessions for CTU nurses were similar to those for house staff. Nurses were asked to follow the clinical pathway for oxygen monitoring and the oxygen titration tables, both of which were posted in patients' rooms. Educational posters throughout the CTU reinforced the rational use of oxygen.

Each day the research nurse recorded the ordering, administration, monitoring, titration and discontinuation of oxygen therapy for patients on the CTU. The research nurse also provided immediate individual audit and feedback to the nurses and the house staff concerning oxygen therapy. Verbal reminders about optimal oxygen therapy were given frequently.

We used a prospective before-and-after design comprising a 3-month intervention phase, a 1-month wash-out phase and a 3-month non-intervention phase. During the intervention phase, consecutive patients requiring oxygen were managed by means of the oxygen order forms, the oxygen clinical pathway and the oxygen titration table. During the wash-out phase, there was no intervention and no data were recorded. During the non-intervention phase, oxygen therapy was managed at the discretion of the CTU team (i.e., no intervention); consecutive patients requiring oxygen were followed and data were collected as for the intervention phase.

We recorded patient characteristics and the indications for oxygen therapy; the health care worker who initially prescribed, reordered and discontinued oxygen therapy; the timing of these orders; the mode (mask or nasal prongs), concentration and duration of oxygen administration; and monitoring by arterial blood gas testing or oxygen saturation level (SpO_2). Patients were followed until discharge, transfer to another ward or death. All transfers to the intensive care unit (ICU) and all deaths on the CTU were adjudicated independently by 2 of the authors (C.W. and F.V.) to determine the reason for transfer or death and to examine whether oxygen poisoning or deprivation was a factor. To detect inappropriate underuse of oxygen, we adjudicated not only

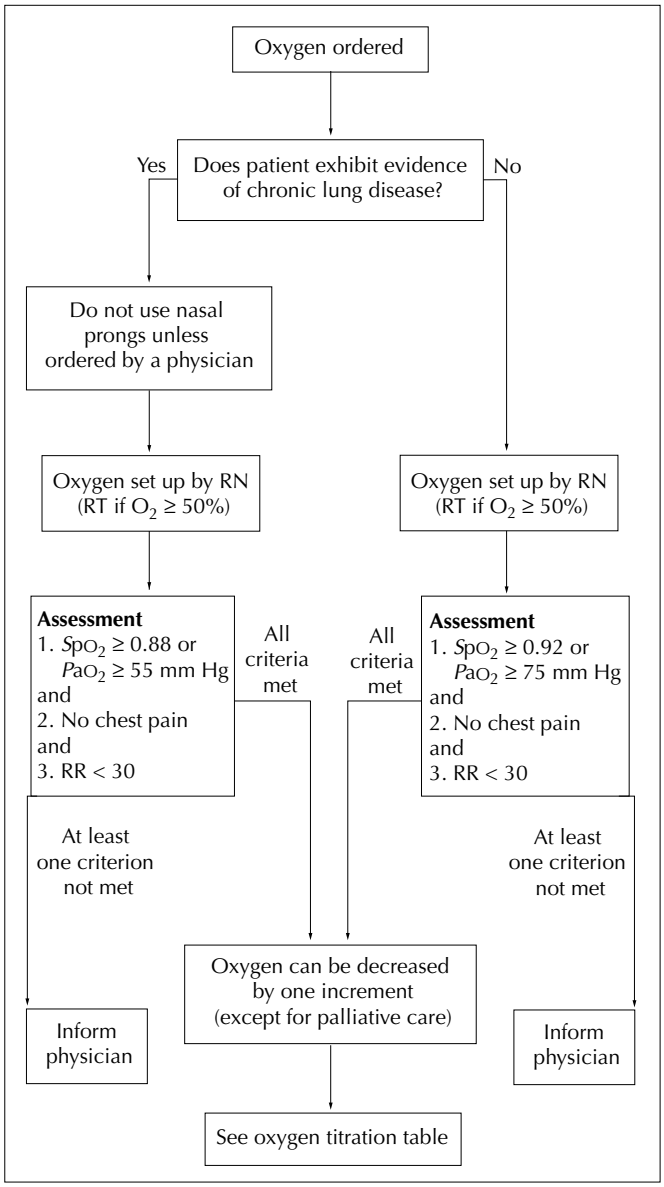

Fig. 1: The clinical pathway used on the clinical teaching unit for monitoring and administering oxygen. RN = registered nurse, RT = respiratory therapist, SpO_2 = oxygen saturation as measured by pulse oximetry, PaO_2 = partial pressure of oxygen (arterial), RR = respiratory rate. Oxygen titration table is not presented in this article.

the cases in which oxygen had been administered during the intervention and non-intervention phases, but also those of patients admitted to the CTU during the study period who did not receive oxygen, but were transferred to the ICU or died.

Our costing perspective was at the hospital level, to capture data relevant to local decision-makers. Using our institutional costing model, we derived the costs of oxygen therapy for patients admitted to the CTU. We used data from our hospital supplier (the Huff Barrington Owens Company [HBOC, 1994]) for material costs including delivery hardware, gas consumption, oximeters and arterial blood gas analyses. These costs did not include overhead, because this was the same for both phases. We used a hospital database (the Management Information Systems [MIS, 1992]) to calculate nonphysician personnel costs, specifically for workload measurements of the ward clerks' time for transcription of the oxygen orders and the nurses' time to set up the delivery system, change it every 2 days and monitor oxygenation. We validated these estimates using time-motion studies. We used the first-year residents' salary to estimate costs of house staff time for procuring samples for arterial blood gas testing and for oxygen prescribing and monitoring. We used the 1998 Ontario Ministry of Health schedule of benefits to determine physician fees for interpretation of blood gas results. We recorded the time required by the research nurse and the respiratory therapists to conduct the educational sessions and the time required by nurses and residents to attend those sessions (hereafter, these are referred to as the educational costs). Because our goal was to determine the cost of the intervention rather than the cost of doing research, we excluded the time spent by the research nurse in collecting data for the study.

The data are presented as means and standard deviations and as medians and interquartile ranges. Dichotomous outcomes were analysed with χ^2 analysis. Continuous outcomes with skewness were compared with the nonparametric Wilcoxon rank-sum test. We used logistic regression to calculate crude and adjusted odds ratios for arterial blood gas procurement (the dependent variable) given intervention. The independent variables considered for adjustment were age, sex, primary diagnosis, season of admission and whether the attending physician was a respirologist (in case oxygen prescribing and monitoring was different under the supervision of a respirologist). We considered a 2-tailed p value less than 0.05 statistically significant.

The total costs of monitoring and testing were determined by summing personnel and nonpersonnel costs and multiplying by the number of tests performed. We determined a mean cost of oxygen administration per patient for both the intervention and the non-intervention phases. All costs are reported in 1998 Canadian dollars; where necessary, costs for earlier periods were adjusted to 1998 values by means of the health care component of the Consumer Price Index.[7]

Results

Of 130 patients included in the study, 62 were treated during the intervention phase and 68 during the non-intervention phase (Table 1). No patients were lost to follow-up. The patient groups in the 2 phases were similar: the mean age was approximately 70 years, about half of the patients were female, and three-quarters were admitted from the emergency department. The admission diagnoses were primarily cardiorespiratory. About half of the patients in each group (29/62 [47%] in the intervention phase and 39/68 [57%] in the non-intervention phase) were discharged home. The overall mortality rate was 22% (14/62 patients) in the intervention phase and 16% (11/68 patients) in the non-intervention phase. The foregoing differences were not significant. Four patients were admitted to the ICU in each phase; except for one admission to the ICU during the intervention phase, these admissions were unrelated to oxygen status. The exception was for a 70-year-old man admitted to the CTU with infectious exacerbation of chronic obstructive pulmonary disease (COPD); the oxygen pathway was not followed, and, after receiving uncontrolled oxygen by nasal prongs, he experienced severe hypercarbic respiratory failure necessitating mechanical ventilation.

Oxygen management outcomes are recorded in Table 2. Prescribing started on the CTU was ordered by house staff for approximately three-quarters of the patients in both phases. The median fraction of inspired oxygen (FiO_2) pre-

Table 1: Characteristics of patients on the clinical teaching unit (CTU) of a Hamilton hospital receiving oxygen during the intervention phase (use of clinical pathway for oxygen administration) and the subsequent non-intervention phase

Characteristic	Phase of study: Intervention phase *n = 62*	Phase of study: Non-intervention phase *n = 68*	*p* value
Mean age (and SD), yr	72.3 (14.0)	70.7 (14.1)	0.52
Sex, no. (and %) female	28 (45)	36 (53)	0.39
Primary diagnosis, no. (and %) of patients			0.33
Pneumonia	14 (22)	14 (20)	
Pulmonary edema	5 (8)	6 (9)	
COPD	3 (5)	12 (18)	
Pulmonary embolus	2 (3)	1 (1)	
Lung cancer	1 (2)	4 (6)	
Metabolic disorders	4 (6)	6 (9)	
CNS disease	8 (13)	6 (9)	
Gastrointestinal disease	4 (6)	2 (3)	
Other*	21 (34)	17 (25)	
Median length of stay† (and IQR), days	8 (5, 12)	7.5 (4, 12)	0.41
Final status, no. (and %) of patients			0.77
Discharge home	29 (47)	39 (57)	
Transfer to ward	13 (21)	13 (19)	
Transfer to ICU	4 (6)	4 (6)	
Transfer to CCU	1 (2)	1 (1)	
Discharge to nursing home	1 (2)	0 (0)	
Died on CTU	14 (22)	11 (16)	

Note: SD = standard deviation, COPD = chronic obstructive pulmonary disease, CNS = central nervous system, IQR = interquartile range, ICU = intensive care unit, CCU = coronary care unit.
*Renal, hematologic or other conditions.
†On the CTU.

scribed on day 1 in the CTU was 0.28 in both phases (p = 0.43). In addition, the median FiO_2 delivered was the same in both phases (0.24 v. 0.23, p = 0.19). The median arterial oxygen saturation (SaO_2) was similar (0.94 for both groups, p = 0.17), and saturation was measured with the same frequency in both groups (median number of measurements per patient 20.5 v. 17.5, p = 0.48). A comparable number of samples were drawn for arterial blood gas testing (p = 0.41). There was no difference in median duration of oxygen administration (3 v. 2 days, p = 0.16). Discontinuation was ordered by house staff for 32 (52%) of the 62 patients in the intervention phase but only 5 (7%) of the 68 patients in the non-intervention phase (p < 0.001).

The unadjusted odds ratio for arterial blood gas procurement in the intervention phase was 1.54 (95% confidence interval [CI] 0.72-3.29). The adjusted odds ratio for patient and caregiver factors was unchanged (1.52 [95% CI 0.79-2.93]).

Oxygen delivery costs ($15.61/patient v. $10.14/patient, p = 0.10) and costs for arterial blood gas testing ($13.66/patient v. $9.09/patient, p = 0.26) were similar in the 2 phases. Costs were higher in the intervention phase for saturation measurement by the nurses ($44.95/patient v. $36.17/patient, p = 0.048) and for order transcription by the ward clerk ($2.71/patient v. $1.28/patient, p < 0.001). Total costs related to oxygen administration and management were also higher during the intervention phase ($76.93/patient v. $56.67/patient, p = 0.02). The cost of the educational component was $45.71/patient. When educational costs were included in costs for the intervention phase, the difference in total costs between the 2 phases was even greater ($122.64/patient v. $56.67/patient, p < 0.001).

Table 2: Oxygen ordering, administration, monitoring and discontinuation during the intervention phase and the subsequent non-intervention phase

Oxygen-related activity	Phase of study: Intervention phase *n = 62*	Phase of study: Non-intervention phase *n = 68*	*p* value
Staff starting oxygen, no. (and %) of patients			0.52
House staff	47 (76)	48 (70)	
Nurse	1 (2)	4 (6)	
Attending physician	3 (5)	5 (7)	
Medical student	3 (5)	1 (1)	
No orders written	8 (13)	10 (15)	
Median concentration of oxygen prescribed (and IQR), FiO_2			
First order	0.28 (0.24, 0.32)	0.28 (0.25, 0.35)	0.43
All orders	0.24 (0.22, 0.26)	0.23 (0.21, 0.24)	0.19
Oxygen monitoring, median (and IQR)			
Saturation, SaO_2	0.94 (0.92,0.95)	0.94 (0.91,0.95)	0.17
No. of saturation values/patient	20.5 (12, 32)	17.5 (8.5, 25)	0.48
ABG tests/patient, no. (and %) of patients			0.41
0	41 (66)	51 (75)	
1	13 (21)	10 (15)	
2	2 (3)	4 (6)	
≥ 3	6 (10)	3 (4)	
Duration of oxygen therapy, days			
Mean (and SD)	4.5 (5.1)	3.1 (3.0)	0.07
Median (and IQR)	3 (1, 5)	2 (1, 5)	0.16
Staff discontinuing oxygen, no. (and %) of patients			
House staff	32 (52)	5 (7)	< 0.001
No discontinuation order while on CTU	30 (48)	63 (93)	

Note: ABG = arterial blood gases.

Interpretation

As hypothesized, this clinical pathway of oxygen therapy changed prescribing and monitoring practices and consumed resources. Ascribing the success of this multifaceted intervention to any particular component is difficult, but individual audit and feedback provided by the research nurse were probably most instrumental, given prior evidence about the effectiveness of this approach.[8] The strengths of this study include the multidisciplinary development and execution of the clinical pathway, the specific a priori criteria used to measure oxygen prescribing and monitoring, the examination of both nurse and physician practice, and the detailed economic analysis. As expected, this pathway did not change clinical outcomes, reflecting the reality that some changes in process-of-care variables do not translate into changes in outcome; others do, but very large studies are often required to detect these differences. Randomizing either patients or caregivers to management by means of an oxygen pathway would be plagued by contamination, because house staff and nurses cross-cover patients on our CTU. Therefore, we used a before-and-after design and found that patients were similar in the 2 phases. Caregivers accepted the oxygen pathway, except for noncompliance with the pathway in 1 patient with COPD who received uncontrolled oxygen administration and experienced severe hypercarbic respiratory failure. Attributing this event to the pathway is difficult, although it could have resulted from unchecked

enthusiasm engendered by the pathway and inattention to associated dangers.

Previously, Fitzgerald and colleagues[9] reviewed data for 90 non-ICU patients and found that 15% had adequate oxygen monitoring but that oxygen had been discontinued on the basis of appropriate physiologic parameters for only 12%. Albin and associates[10] performed 507 random assessments of SaO_2 in hospitalized patients and found that 46% were receiving excessive oxygen and 16% were receiving insufficient oxygen. In another study, which involved 206 patients in a respiratory care unit,[11] 21% had their oxygen switched off, the flow rate was wrong in 14%, 8% were not wearing a face mask, and there was no prescription for 12% of the patients receiving oxygen. Kester and Stoller[12] found that among 50 patients for whom oxygen had been prescribed, 28% did not need it, according to clinical guidelines.

Research has consistently shown that oxygen therapy does not receive the same attention as other types of therapy, such as treatment with antibiotics.[13] We recommend enhanced multidisciplinary training, as well as evaluation of interventions (such as clinical pathways) within a cost-benefit paradigm that defines outcomes in the context of the educational mandates of teaching hospitals; long-term returns on investment should be considered in the evaluation. Meanwhile, team-oriented respiratory therapy services[14] may improve quality of care, increase knowledge about oxygen administration, minimize risk and obviate wasteful expenditure.[15] Such interventions could be particularly important for patients in whom oxygen has a narrow therapeutic window, such as seriously ill patients with an exacerbation of severe COPD. Other tools that might educate clinicians include clinical recommendations[16] and statements from the National Heart, Lung and Blood Institute,[6,17] the American College of Chest Physicians,[6] the American Thoracic Society[18] or the American Association for Respiratory Care.[15]

We thank Ellen McDonald and Nicole Krolicki for data collection, Barbara Hill for help with the preparation of the manuscript, Ida Porteus for facilitating the nurses' participation in the study, Ron Goeree for the economic analysis, and all the nurses and house staff on the St. Joseph's Hospital Medical Clinical Teaching Unit. We appreciate the support of Drs. Mitchell Levine and Peter Powles and thank Dr. Rick Hodder for his helpful suggestions on the manuscript.

This study was funded by the General Internal Medicine and Intensive Care Unit (GIM/ICU) Clinical Effectiveness and Outcomes Research Program of St. Joseph's Hospital and the Father Sean O'Sullivan Research Centre, Hamilton, Ont. Dr. Cook is a Career Scientist of the Ontario Ministry of Health; Dr. O'Brien is a Medical Research Council of Canada/Pharmaceutical Manufacturers Association of Canada Career Scientist.

Competing interests: None declared.

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