Gaps in the inpatient management of chronic obstructive pulmonary disease exacerbation and impact of an evidence-based order set

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A Kitchlu, T Abdelshaheed, E Tullis, S Gupta. Gaps in the inpatient management of chronic obstructive pulmonary disease exacerbation and impact of an evidence-based order set. Can Respir J 2015;22(3):157-162.

BACKGROUND: Evidence-based, guideline-recommended practices improve multiple outcomes in patients admitted with acute exacerbation of chronic obstructive pulmonary disease (AECOPD), but are incompletely implemented in actual practice. Admission order sets with evidence-based diagnostic and therapeutic guidance have enabled quality improvement and guideline implementation in other conditions.
OBJECTIVE: To characterize the magnitude of care gaps and the effect of order sets on quality of care in patients with AECOPD.
METHODS: The authors prospectively designed a standardized chart review protocol to document process of care and health care utilization before and after implementation of AECOPD order sets at an academic hospital in Toronto, Ontario.
RESULTS: A total of 243 total AECOPD admissions and multiple important care gaps were identified. There were 74 admissions in the pre-order set period (January to June 2009) and 169 in the order set period (October 2009 to September 2010). The order set was used in 78 of 169 (46.2%) admissions. In the order set period, we observed improvements in respiratory therapy educational referrals (five of 74 [6.8%] versus 48 of 169 [28.4%]; P<0.01); venous thromboembolism prophylaxis prescriptions (when indicated) (15 of 68 [22.1%] versus 100 of 134 [74.6%]; P<0.01); systemic steroid prescriptions (55 of 74 (74.3%) versus 151 of 169 [89.4%]; P<0.01]); and appropriate antibiotic prescriptions (nine of 24 [37.5%] versus 61 of 88 [69.3%]; P<0.01). The mean (± SD) length of stay also decreased from 6.5±7.7 days before order sets to 4.1±5.0 days with order sets (P=0.017).
CONCLUSIONS: Care gaps in inpatient AECOPD management were large and evidence-based order sets may improve guideline adherence at the point of care. Randomized trials including patient outcomes are required to further evaluate this knowledge translation intervention.

Key Words: *Chronic obstructive pulmonary disease; Knowledge translation; Length of stay; Medical order entry systems; Quality improvement*

Les lacunes dans la prise en charge de l'exacerbation de la maladie pulmonaire obstructive chronique chez les patients hospitalisés et les répercussions d'un modèle d'ordonnances fondé sur des données probantes

HISTORIQUE : Les pratiques fondées sur des données probantes et recommandées selon les directives améliorent de multiples résultats chez les patients hospitalisés en raison d'exacerbations aiguës de la maladie pulmonaire obstructive chronique (ECMPOC), mais ne sont pas toutes mises en œuvre en milieu réel. Les modèles d'ordonnances comportant des directives diagnostiques et thérapeutiques fondées sur des données probantes ont permis d'améliorer la qualité et d'adopter des directives à l'égard d'autres problèmes de santé.
OBJECTIF : Caractériser la gravité des lacunes et l'effet de modèles d'ordonnances sur la qualité des soins aux patients ayant des ECMPOC.
MÉTHODOLOGIE : Les chercheurs ont conçu un protocole prospectif standardisé d'analyse des dossiers pour attester le processus de soins et l'utilisation des soins de santé avant et après l'adoption de modèles d'ordonnances pour les ECMPOC dans un hôpital universitaire de Toronto, en Ontario.
RÉSULTATS : Les chercheurs ont constaté 243 hospitalisations à cause d'une ECMPOC et de multiples lacunes graves. Ils ont recensé 74 hospitalisations avant l'utilisation des modèles d'ordonnance (de janvier à juin 2009) et 169 après leur adoption (octobre 2009 à septembre 2010). Le modèle d'ordonnances a été utilisé dans 78 des 169 hospitalisations (46,2 %). Pendant la période où il était utilisé, ils ont observé des améliorations aux aiguillages vers une éducation en inhalothérapie (cinq sur 74 [6,8 %] par rapport à 48 sur 169 [28,4 %]; P<0,01), la prophylaxie de la thromboembolie veineuse (au besoin) (15 sur 68 [22,1 %] par rapport à 100 sur 134 [74,6 %]; P<0,01), la prescription de stéroïdes systémiques (55 sur 74 (74,3 %) par rapport à 151 sur 169 [89,4 %] P<0,01]) et la prescription pertinente d'antibiotiques (neuf sur 24 [37,5 %] par rapport à 61 sur 88 [69,3 %]; P<0,01). Le séjour moyen (± ÉT) a également diminué, passant de 6,5±7,7 jours avant l'utilisation des modèles d'ordonnance à 4,1±5,0 jours par la suite (P=0,017).
CONCLUSIONS : La prise en charge des ECMPOC comportait des lacunes importantes, et des modèles d'ordonnances fondés sur des données probantes peuvent accroître le respect des directives au point de service. Il faudra réaliser des essais aléatoires incluant les résultats des patients pour mieux évaluer cette intervention de transfert du savoir.

Chronic obstructive pulmonary disease (COPD) is among the most prevalent chronic diseases and is the fourth leading cause of death worldwide (1-4). In particular, acute exacerbation of COPD (AECOPD) is the leading cause of hospitalization in Canada and exerts a disproportionate economic toll (5,6). Evidence-based management of AECOPD can reduce morbidity and mortality, and high-quality practice guidelines are available to direct patient care (7-10). Despite this, gaps between best evidence and actual practice in the inpatient management of AECOPD have been documented in areas as diverse as education, nonpharmacotherapeutic interventions and pharmacotherapy (11-20). Expected consequences of these care gaps include increased length of stay (LOS), morbidity, mortality, recurrent exacerbations and recurrent hospitalizations (readmissions) (18). Accordingly, this is considered to be a high-priority area for quality improvement and knowledge translation (11,12,14,21,22).

Preformatted order sets can present clinicians with a template for care orders including diagnostic tests, medications and other relevant items based on best evidence. As such, they present a convenient strategy for point-of-care continuing education, and a relatively inexpensive tool that can be used to improve quality of care and patient outcomes (23). They have been shown to be effective in several diseases, either when used in print form (24-27) or when incorporated into a computerized provider order entry (CPOE) system (23,27-29). Given the existing care gaps and variations in the management of inpatient AECOPD, authors have suggested that evidence-based order sets should be implemented and evaluated for this condition (17).

We sought to characterize care gaps in the management of inpatient AECOPD, clinician uptake of a preformatted AECOPD order set providing point-of-care guidance and education, and the impact of this tool on the process and quality of care.

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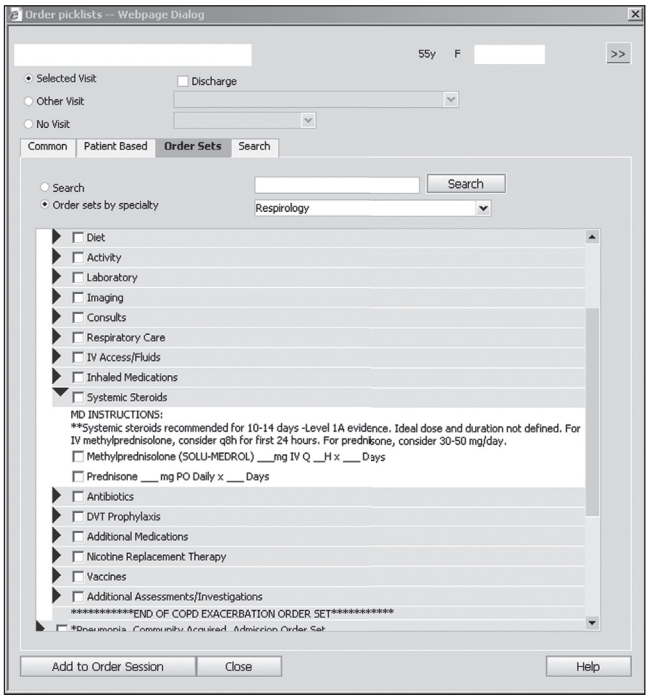

Figure 1) *Order set screen capture: systemic steroid selection*

METHODS

As part of a quality-improvement strategy in the respirology and general internal medicine (GIM) services at a quaternary care academic hospital in Toronto (Ontario), an evaluation of care before and after the implementation of order sets was prospectively designed. The 'pre-order set period' (standard blank sheet ordering only) was designated as the six-month period before implementation of the AECOPD order set (January to June 2009). Order sets were then implemented in a staggered fashion between July and September 2009. The 'order set period' was designated as the 12-month period following full implementation (October 2009 to September 2010). The present study was approved by the hospital's institutional ethics review board.

Order set development and deployment

As part of a hospital-wide quality improvement program, an AECOPD admission order set was developed by a multidisciplinary team of respirology and internal medicine ward physicians and allied health team members (nurses, a pharmacist, a respiratory therapist and a ward supervisor). Content was based on the most recent Canadian Thoracic Society (CTS) guideline recommendations (8,10), where applicable, and expert opinion and existing practice where evidence was unavailable. The order set provided comprehensive admission instructions, including options for code status, infection control precautions, diet, monitoring, referrals, investigations, respiratory care requirements (eg, oxygen and noninvasive ventilation [NIV] instructions), medications and vaccinations. Where there was a strong level of evidence to direct practice, physician prompts were integrated into the order set, including the CTS guideline level of evidence supporting the recommendation and, where possible, its expected outcome (Figure 1).

Printed order sets required clinicians to choose among options by checking off a box associated with each order and/or by crossing out specific orders, and writing in any extra orders in blank lines at the end of the order set. These printed order sets were developed first and, after field-testing and feedback-driven improvements, were converted to an identical electronic format and integrated into the CPOE system, which presented content in drop-down menus, requiring clinicians to click on relevant checkboxes before finalizing the composite orders.

TABLE 1
Patient characteristics

Characteristic	Pre-order set (n=74)	Order set (n=169)	P
Age, years, mean ± SD	67.6±10.2	67.9±10.7	0.81
Male sex	43 (58.1)	105 (62.1)	0.55
FEV_1 <50%*	13 (17.6)	57 (33.7)	0.01
>3 exacerbations in the past year	13 (17.6)	55 (32.5)	0.02
Antibiotics in the past 3 months	20 (27.0)	55 (32.5)	0.39
Current smoker	44 (59.5)	69 (40.8)	<0.01
Home oxygen use	7 (9.5)	39 (23.1)	0.01
Chronic corticosteroid use	2 (2.7)	18 (10.6)	0.04
Diabetes mellitus	16 (21.6)	45 (26.6)	0.41
Cardiac disease†	27 (36.5)	60 (35.5)	0.88
Infiltrate on admission x-ray	9 (12.2)	42 (24.9)	0.03
Fulfill ≥2/3 Anthonisen criteria‡	16 (24.6)	34 (26.8)	0.75

*Data presented as n (%) unless otherwise indicated. *On most recent pre-admission spirometry; †Defined as a documented history of congestive heart failure or coronary artery disease; ‡Increased dyspnea, increased sputum production or increased sputum purulence (in patients with no chest x-ray infiltrate) (49). FEV_1 Forced expiratory volume in 1 s*

Physicians and house staff were encouraged, but not required, to use the order sets for all new AECOPD admissions. New house staff rotated into these services every one to two months, and received an orientation about the order sets at the beginning of their rotation. The printed order set was placed among other standardized printed order sets, both on the ward and in the emergency department, from where most patients are admitted. On conversion to electronic format, the CPOE-based order set was made available through a search function and among a list of 'quick picks' presented to all users each time they opened the CPOE system.

Data collection

A standardized data collection spreadsheet with a graphical user interface for data entry through simple radio button, tick box and text entry fields was developed. Data included patient characteristics, and prespecified process-of-care and health care utilization measures that were supported by evidence. Initially, 10 electronic charts were reviewed by both data reviewers to ensure accuracy and usability, and the graphical user interface was optimized accordingly. Two physicians in the internal medicine training program then reviewed electronic charts to collect data. Consecutive AECOPD admissions during the period of interest were identified through ward logbooks and hospital administrative records (using *International Classification of Diseases* code J441 [chronic obstructive pulmonary disease with acute exacerbation]).

Statistical analysis

Data are expressed as proportions (percentages), means and SDs. All continuous variables were tested for normality. Variables were compared between subjects in the 'pre-order set' and 'order set' periods with a two-sample *t* test for continuous variables and a χ^2 or Fisher's exact test (as appropriate), for categorical variables; $P<0.05$ was considered to be statistically significant. All data were analyzed using SAS version 9.3 (SAS Institute, USA) for Windows (Microsoft Corporation, USA).

RESULTS

Patients

A total of 74 admissions were identified for AECOPD in the pre-order set period (18 [24.3%] to respirology and 56 [75.7%] to GIM) and 169 admissions in the order set period (41 [24.3%] to respirology and 128 [75.7%] to GIM), corresponding to a total of 243 admissions. The order set was used in 78 of 169 (46.2%) possible admissions,

TABLE 2
Documentation, testing and referrals ordered

Variable	Pre-order set (n=74)	Order set (n=169)	P
Code status documented	43 (58.1)	91 (53.8)	0.54
Infection control status documented	47 (63.5)	169 (100.0)	<0.01
Respiratory contact precautions documented (when indicated)*	0 (0.0)	16 (76.2)	<0.01
Nasopharyngeal swab ordered	4 (5.4)	29 (17.2)	0.01
Sputum cultures ordered (when indicated)†	14 (42.4)	60 (56.1)	0.17
Arterial blood gas completed (when indicated)‡	24 (75.0)	83 (76.9)	0.83
HbA1c ordered (among diabetic patients)	7 (43.8)	30 (66.8)	0.11
Inhaler technique education provided	0 (0%)	27 (16.0)	<0.01
Multidisciplinary consultations ordered			
Respiratory therapist	5 (6.8)	48 (28.4)	<0.01
Physiotherapist	12 (16.2)	51 (30.2)	0.02
Dietician	1 (1.4)	21 (12.4)	<0.01
Social worker	2 (2.7)	27 (16.0)	<0.01

*Data presented as n (%) unless otherwise indicated. *Respiratory contact precautions were recommended in the order set in patients presenting with documented fever and either new/increased cough or dyspnea; †Sputum culture was recommended in the order set in patients on antibiotics within the past three months, forced expiratory volumme in 1 s <50% of predicted, or >3 exacerbations per year (8); ‡Arterial blood gas analysis was recommended in the order set in patients on home oxygen, or if oxygen saturation was <90% on room air (8). HbA1c Glycated hemoglobin*

TABLE 3
Interventions and medications ordered

Variable	Pre-order set (n=74)	Order set (n=169)	P
Bilevel positive airway pressure ordered (when indicated)*	6 (60.0)	11 (68.8)	0.69
Any metered-dose inhaler prescribed	58 (78.4)	147 (87.0)	0.09
Spacer(s) ordered when metered-dose inhaler(s) prescribed	10 (17.2)	77 (52.4)	<0.01
Systemic steroids prescribed	55 (74.3)	151 (89.4)	<0.01
Antibiotics prescribed (when indicated)†	18 (72.0)	104 (87.4)	0.07
Antibiotics prescribed (when not indicated)†	18 (36.7)	14 (28.0)	0.35
Appropriate antibiotic class prescribed‡	9 (37.5)	61 (69.3)	<0.01
Venous thromboembolism prophylaxis prescribed (if not on systemic anticoagulation)	15 (22.1)	100 (74.6)	<0.01
Nicotine replacement therapy prescribed (among smokers)	10 (22.7)	35 (50.7)	<0.01
Pneumococcal vaccination prescribed (if not received within 5 years)§	1 (1.4)	17 (10.1)	0.02

**Recommended in the order set when an admission arterial blood gas demonstrated a pH <7.3 (8); †Antibiotics were recommended in the order set when a chest x-ray infiltrate or ≥2/3 Anthonisen criteria were present (O'Donnell et al [8]); ‡In patients with a simple exacerbation, doxycycline, trimethoprim/sulfamethoxazole, a second -generation cephalosporin or an extended spectrum macrolide were recommended in the order set; in patients with a complex exacerbation (defined by the presence of one or more of: forced expiratory volume in 1 s <50% predicted, current use of home oxygen, chronic steroid use, ≥4 exacerbations per year, antibiotic use within the past three months or ischemic heart disease) a respiratory fluoroquinolone or amoxicillin/clavulanic acid were recommended in the order set (8,10); §Influenza vaccination rates were not reported because the pre-order set period did not include the influenza season*

including in 31 of 41 (75.6%) under respirology and 46 of 128 (35.9%) under GIM (P<0.01). Baseline characteristics for patients in each period are shown in Table 1.

Outcomes

Documentation, testing and referral-related care is detailed in Table 2, and interventions and medications ordered are summarized in Table 3. The mean (± SD) LOS was 6.5±7.7 days in the pre-order set period and 4.1±5.0 days in the order set period (P=0.017). One-month readmission rates were 20.3% and 13.0%, respectively (P=0.15).

DISCUSSION

Our study demonstrated large care gaps in the inpatient management of AECOPD at an academic quaternary care centre, and improvement in some of these evidence-based practices with the introduction of pre-formatted order sets. To our knowledge, the present study is the first to report the effects of order sets on quality of care in AECOPD.

Care gaps

Care gaps in the management of inpatient AECOPD have previously been measured in several different contexts. Lodewijckx et al (18) reviewed seven studies reporting on the quality of hospital ward and emergency room AECOPD care published between 2000 and 2009. They included reports from the United Kingdom (UK), the United States (US), Australia, and New Zealand, and both community and academic centers of varying sizes. In Canada, Choi et al (12) reviewed 105 AECOPD ward patients admitted in 2001, and Sandhu et al (17) reviewed 262 ward patients admitted in 2009; both studies were conducted at quaternary care academic centres. Although studies report similar types of gaps, their magnitude varies widely according to jurisdiction. For example, at baseline, 25% of our patients did not receive systemic corticosteroids, despite high-quality evidence that steroids reduce recovery time, relapse rates and LOS in AECOPD (8,10). This gap varied between 12% and 38% in studies reviewed by Lodewijckx et al (18) and was 45% in the report by Sandhu et al (17). Although relative contraindications to steroid therapy may have contributed to this gap, lack of guideline awareness was likely the principal barrier because steroid therapy is a universal and uniform recommendation across international guidelines (17). In contrast, criteria for NIV have varied across guidelines, and authors have used correspondingly variable criteria to identify candidate patients. NIV use was reported in 52% of patients with pH <7.26 and partial pressure of carbon dioxide (PCO_2) >60 mmHg in the US (20), 12.7% of patients with pH <7.35 and PCO_2 >45 mmHg in the UK (19) and 60% to 69% of patients with pH <7.3 in our study.

Our study provides novel patient-level details that are required for accurate measurement of certain care gaps. For example, Sandhu et al (17) reported antibiotic prescriptions in 83% of all AECOPD admissions, but these data were noted to be of limited value because only purulent AECOPD merits antibiotics according to best evidence (8,30). Choi et al (12) identified patients with purulent exacerbations, noting that 95% received antibiotics compared with 72% and 87% of our patients, before and after order set implementation, respectively. However, our study was the first to identify that a significant proportion of patients who should not have received antibiotics received them (Table 3). Furthermore, the CTS COPD guideline recommends first-line antibiotics for 'simple' AECOPD, while reserving respiratory fluoroquinolones and beta-lactam/beta-lactamase inhibitor combinations for 'complicated' AECOPD, as determined by the presence of clinical risk factors for resistant organisms (8,10). By identifying these risk factors in each patient, we were able to determine that at baseline, a majority of our patients actually received an inappropriate antibiotic class (Table 3) (in most cases, this was 'overtreatment' of simple AECOPD). Although some patients had received antibiotics within the past three months before admission (which could have impacted the admission antibiotic choice), this did not differ between pre-order set and order set periods (Table 1). Although this overtreatment may not have had a negative impact on these individual patients, our findings highlight the need for antibiotic stewardship to reduce the incidence of resistant organisms (31).

Our study also provides insight into nonpharmacological care, such as referrals to allied health professionals, which have been poorly described in previous reports (18). The combination of steroid therapy and inactivity related to exercise limitation in AECOPD can lead to rapid muscle loss and resulting delays in recovery of mobility (32). Early involvement of a physiotherapist may help to mitigate this process. Physiotherapy referrals were, in fact, the most common allied health referral in our study, followed by respiratory therapy (Table 2). Although respiratory therapy referrals have not previously been reported, inhaler technique education was provided to 20% of subjects in a UK study (19), and to 22% of subjects in the repost by Choi et al (12), compared with 0% and 16% of our subjects, before and after order set implementation, respectively.

Order set uptake

Order sets were used in only 46.2% of admissions in the order set period. This is better than previously reported first-year uptakes of 21.1% for a CPOE-based community-acquired pneumonia order set (33) and 32.3% for paper-based order sets for six GIM diagnoses (27). The only previous report of AECOPD order set uptake was by Sandhu et al (17), noting overall uptake of 19.1% for a paper-based version. Uptake was also significantly higher (57.9%) among respirologists in this report, although still lower than our 75.6% respirology ward uptake. These differences in uptake may, in part, be related to the fact that our study included CPOE-based order sets as opposed to exclusively paper-based order sets in that report.

Given that 'clinical ownership' appears to be an important predictor of order set implementability (34), our higher uptake may be partly explained by the end user and multistakeholder engagement used in our order set development process. However, several factors may have hindered uptake in our study. Although house staff were educated about order sets in their orientation meetings in accordance with previous recommendations, high house-staff turnover likely limited expected increases in order set usage over time due to familiarity alone (34). We did not engage in usability testing before order set launch, whereas other authors have reported that the configuration and integration of order sets into ordering work flow are important determinants of uptake (35). Accordingly, it is possible that order sets were avoided because they were more time consuming than conventional ordering (36). Munasinghe et al (37) successfully increased usage of multiple disease-specific order sets by fivefold over a 16-month period by improving integration into the CPOE system, highlighting the potential value of optimizing usability. We also did not employ administrative and clinical leaders in promoting order set use (34), and did not explore the possible influence of clinician factors such as experience and level of training (38).

Impact of order sets

We observed significant improvements in several aspects of documentation and referrals, as well as evidence-based use of tests, medications and nonpharmacotherapeutic interventions after the introduction of order sets (Tables 2 and 3).

There may be several explanations for these observed improvements in care. Most simple process-of-care outcomes, such as documentation of respiratory and infection control precautions, likely improved simply by virtue of their presence in the order set, acting as a prompt and a reminder to the clinician. Whereas the information required to document these would be available to the clinician at the time of ordering, we hypothesize that code status documentation did not improve because it would require the clinician to return to the bedside to ascertain patient wishes (in most cases). However, the order set may have reminded clinicians to address code status after admission orders were entered (27). There were also significant improvements in guideline-recommended practices such as corticosteroid prescription, appropriateness of antibiotic class prescription and use of preventive therapies including venous thromboembolism (VTE) prophylaxis, pneumococcal vaccination and nicotine replacement therapy (Table 3). These improvements more likely resulted from the influence of guideline recommendations, levels of evidence, and expected outcomes provided in the order set on clinician knowledge and decision-making. This is supported by our concurrent educational study of these order sets, which suggested improvements in clinical users' knowledge of guideline-recommended care with order set use (23). Similar improvements in the use of systemic steroids and metered-dose inhalers after order set implementation were previously demonstrated in children admitted for asthma exacerbation (34). In general medical patients, a 'tobacco order set' was also shown to improve prescription of nicotine replacement (39), and general medical and VTE order sets improved prescription of VTE prophylaxis (25,27).

Regarding practices that did not improve significantly, it is likely that barriers other than clinician recollection and/or knowledge played a more important role in determining those behaviours. For example, NIV use may have been hampered by organizational barriers, such as availability of high-acuity beds, and inappropriate prescription of antibiotics may not have decreased due to firmly held physician and/or patient disagreements with guideline recommendations (38).

We also demonstrated a significant reduction in mean hospital LOS from 6.5 to 4.1 days (a reduction of 2.4 days) with order sets. Our baseline LOS of 6.5 days was consistent with the 6.0 days reported by Wong et al (40), and the four to eight day range reported in studies reviewed by Lodewijckx et al (18). Our baseline one-month readmission rate of 20.3% was also comparable with the 18.8% and 22.6% reported in large Canadian (41) and American (42) cohorts, respectively. We also noted a trend toward decreased one-month readmissions with order sets. Furthermore, patients admitted in the order set period had more severe disease than those in the pre-order set period (Table 1), which would have biased against both of these findings. We hypothesize that reductions in LOS may have been driven not only by improvements in pharmacotherapy (Table 3), but also by improved engagement of allied health team members through increases in early consultations to members such as physiotherapists and social workers (Table 2), which may have led to numerous valuable services, including earlier mobilization and earlier initiation of discharge planning, respectively (27).

The use of preformatted order sets as a knowledge translation tool in COPD has not previously been described. However, previous studies have examined the effects of care pathways in AECOPD. Although no study has reported outcomes of an electronic pathway, paper-based AECOPD pathways have been shown to reduce patient anxiety (43), test ordering, medication prescription and LOS (44). Care pathways

are different than admission order sets in that they include care recommendations for the entire length of stay, usually include more comprehensive care elements such as patient education (43) and, as such, represent a more complex intervention (45). Given this complexity, it would be challenging to integrate all features of a clinical pathway into a point-of-care CPOE system (45) to leverage this technology for broad implementation (as simple admission order sets can). These factors are likely why pathways have often shown poor uptake in actual practice (46). Our results suggest that similar benefits may be achievable with simple admission order sets.

Our evaluation of the effect of order sets is limited by several factors and our results will require confirmation in a randomized controlled trial. Although we are unaware of confounders, such as hospital-based COPD education or quality initiatives, or new COPD guidelines released during the study period, our pre/post design is susceptible to unmeasured confounders. Also, as above, patients seen in the order set period had more severe disease than those seen in the pre-order set period. Although this would bias against the observed improvements in health care utilization, it may have biased clinicians to make more considered care choices, resulting in the observed improvements in guideline-congruent practices. The present study was also conducted at a single teaching centre, and a confirmatory multisite study, including nonacademic sites, will be required. Order set uptake was poor but, as noted, it was superior to that reported in previous studies, and this would bias against the observed improvements. There may also have been a halo effect whereby the educational effects of the order set accounted for improvements in care even in cases for which it was not directly used (23). Use of evidence-based strategies to improve uptake may result in even larger improvements than those observed in our study. We should also note that we specifically measured uptake of the AECOPD order set, whereas a 'general medical admission' order set was also available during the order set period and may alternatively have been used for AECOPD patients, contributing to the observed improvements in some overlapping practices (eg, deep venous thrombosis prophylaxis). This is also why we were unable to perform a subgroup analysis based on order set usage (an 'as treated' analysis). Finally, our study used both paper- and CPOE-based order sets. Although the content of the order sets was identical, it is possible that these two media have different effects. However, previous studies have demonstrated similar improvements in specific elements of care addressed with paper (24,25,47) and CPOE-based (34,38) order sets. Although the use of CPOE itself may have had an impact on care independent of the order set, our CPOE system did not provide any decision support except for medication interaction and allergy warnings, which would not be expected to improve the outcomes that we observed to improve (48).

SUMMARY

We have demonstrated important care gaps in multiple aspects of inpatient AECOPD care, and our findings suggest that evidence-based order sets may be an effective aknowledge translation intervention in this context. A future randomized controlled trial should evaluate the impact of preformatted AECOPD order sets on patient-level outcomes such as satisfaction, quality of life, morbidity and mortality, as well as cost-effectiveness. Any future study should use evidence-based methods to augment order set usage, which would be expected to drive even greater improvements in care. This intervention appears to address care gaps resulting from lapses in clinician recall and deficiencies in knowledge, whereas gaps with more complex barriers will require other tailored interventions. Simple preformatted order sets may be readily integrated into the diverse electronic health record platforms that currently exist across different hospitals; however, as technology improves and CPOE systems gain ubiquity, future AECOPD order set interventions should also explore more interactive, patient-specific real-time electronic decision support.

AUTHOR CONTRIBUTIONS: SG and AK had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis, including and especially any adverse effects. SG, AK, ET and TA contributed substantially to the study design, data analysis and interpretation, and the writing of the manuscript.

DISCLOSURES: Dr Gupta is supported by the University of Toronto and the Li Ka Shing Knowledge Institute of St Michael's Hospital. The authors have no other financial disclosures or conflicts of interest to declare.

NOTATION OF PREVIOUS PUBLICATION/PRESENTATION: Clinical outcomes following implementation of an evidence-based order set for inpatient COPD exacerbation management. Canadian Respiratory Conference, Quebec City, Quebec, April 11 to 13, 2013.

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