



Pre-hospital and emergency department pathways of care for exacerbations of chronic obstructive pulmonary disease (COPD)

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Abstract: Exacerbations are serious complications of chronic obstructive pulmonary disease (COPD) that often require acute care from pre-hospital and emergency department (ED) services. Despite being a frequent cause of emergency presentations, gaps remain in both literature and practice for emergency care pathways of COPD exacerbations. This review seeks to address these gaps and focuses on the literature of pre-hospital and ED systems of care and how these intersect with patients experiencing an exacerbation of COPD. The literature in this area is expanding rapidly; however, more research is required to further understand exacerbations and how they are addressed by emergency medical services worldwide. For the purpose of this review, the pre-hospital domain includes ambulance and other emergency transport services, and encompasses medical interventions delivered prior to arrival at an ED or hospital. The ED domain is defined as the area of a hospital or free-standing centre where patients arrive to receive emergent medical care prior to admission. In many studies there is a significant overlap between these two domains and frequent intersection and collaboration between services. In both of these domains, for the management of COPD exacerbations, several overarching themes have been identified in the literature. These include: the appropriate delivery of oxygen in the emergency setting; strategies to improve the provision of care in accordance with diagnostic and treatment guidelines; strategies to reduce the requirement for emergency presentations; and, technological advances including machine learning which are helping to improve emergency healthcare systems.

Keywords: Chronic obstructive pulmonary disease (COPD); exacerbation; pre-hospital; ambulance; emergency department (ED); systems; pathways

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Introduction

Chronic obstructive pulmonary disease (COPD) is a common, chronic respiratory condition that is both preventable and treatable. COPD causes significant morbidity and mortality, and is frequently placed in the top four leading causes of death worldwide (1). Exacerbations

are acute complications of this disease which significantly affect its trajectory and often require emergency management in both the pre-hospital and emergency department (ED) setting. The literature of exacerbations is expanding rapidly and there are comprehensive national and international guidelines outlining COPD diagnosis, management and prevention including the COPD-X Plan

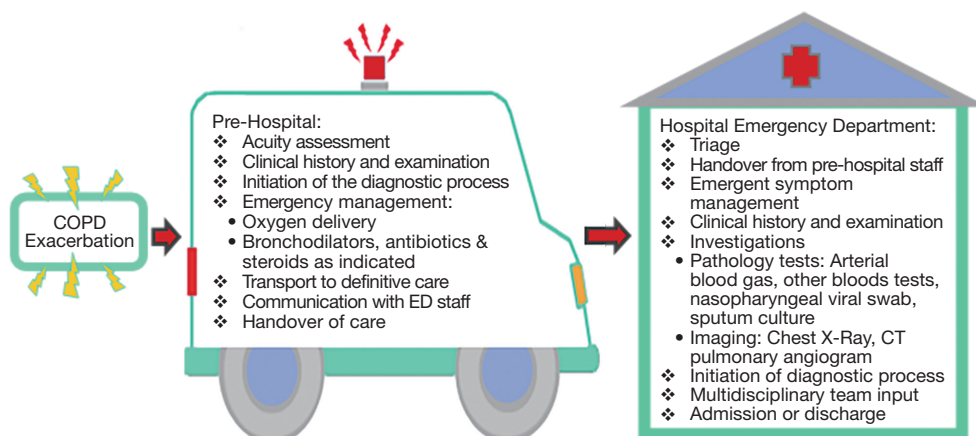


Figure 1 Escalation of care in pre-hospital and emergency systems for COPD exacerbation. COPD, chronic obstructive pulmonary disease.

and the GOLD Report (2,3); however, more research is needed in the area of pre-hospital and emergency systems for COPD exacerbations.

Many patients with COPD require frequent emergency treatment for exacerbations, generating significant healthcare provision from ambulance and ED services (*Figure 1*). A large proportion of these patients access pre-hospital services prior to hospital arrival with an international study involving Australia, New Zealand and South East Asia demonstrating that 65% of COPD patients presenting to EDs engaged ambulance services (4). The requirement for hospital-based services is also significant with Australian data from 2017–2018 demonstrating that COPD was the twelfth most common ED presentation resulting in hospital admission and the fifth most common cause of overnight or longer hospital stays (5,6). From these figures, it is evident that COPD and exacerbations generate significant health burden for patients and contribute to the challenges faced by ambulance and emergency healthcare services.

For the purposes of this review, a search was undertaken of the scientific literature from the last ten years in Medline and Embase using a search term with variations of the key words. Studies generated from this search were then assessed with the aim to appraise pre-hospital and ED systems for COPD care. Those of significant relevance and interest were selected for inclusion in this review (*Table 1*).

Prehospital themes

Nationally and internationally, a number of studies have focused on pre-hospital emergency systems and their

intersection with patients experiencing an exacerbation of COPD. Studies involving paramedic and emergency prehospital services have identified three main themes: the accuracy of diagnosis for patients with respiratory distress; appropriate delivery of oxygen to COPD patients; and strategies to reduce COPD patient's requirement for prehospital services.

Prehospital & ED diagnostic accuracy

The accurate and timely differentiation of COPD exacerbations from other illnesses is important due to the frequency of emergency presentations for respiratory distress as well as the specific requirements for optimal COPD management. However, in the pre-hospital setting, differentiation of respiratory distress can be difficult owing to its wide variety of aetiologies. A recent Australian retrospective study by Williams *et al.* found that paramedics had difficulty differentiating between COPD, asthma and other conditions presenting with breathlessness, and correctly identified only 57% of COPD patients (7). Interestingly, they found that for patients coded by paramedics as having 'shortness of breath', 21% had cardiac failure (7). These findings were corroborated by a US study which found that of all emergency medical service encounters coded for respiratory distress, 30% had a discharge diagnosis unrelated to intrinsic respiratory disease (8). These studies demonstrate the complex nature of respiratory distress, a symptom which can be caused by multiple different organ systems.

Furthermore, Williams *et al.* also demonstrated the complex and acute nature of patients seeking ambulance

Table 1 Table of included studies and details

Study	Study type	Study size	Main findings
Pre-hospital studies			
Austin <i>et al.</i> [2010]	RCT	N=405	Significant difference in mortality (RR 0.42, 95% CI: 0.20–0.89; P=0.02) between high flow and titrated flow O ₂ . Patients receiving titrated O ₂ were significantly less likely to suffer respiratory acidosis (P=0.01)
Susanto & Thomas [2015]	Retrospective audit	N=150	FiO ₂ >0.28 given in 54 prehospital patients and 35 patients in ED. Clinical recognition of COPD as the cause is poor and consequently high flow O ₂ often utilised in the preliminary treatment of patients with COPD
Wijesinghe <i>et al.</i> [2011]	Retrospective cohort + audit	N=250	High flow O ₂ associated with elevated mortality rate; assisted ventilation or respiratory failure. 75% of patients had oxygen saturations in excess of the target range (88–92%) on ED presentation
Williams <i>et al.</i> [2015]	Retrospective cohort	N=2,571	COPD correctly identified pre-hospital in only 57% of patients
Lindvig <i>et al.</i> [2010]	Retrospective cohort	N=537	Physician-led prehospital system in Denmark. 88.5% of patients admitted to hospital & of these, 92.9% received confirmed diagnosis of COPD. 29.8% were discharged from ED within 24 hr of admission but 9.3% were re-admitted within 48 hr
Huertas <i>et al.</i> [2017]	Prospective cohort	N=150	Respiratory day hospital attendance effective in reducing re-hospitalisations
Hensel <i>et al.</i> [2019]	Prospective cohort	N=99	Differences between baseline and hospital admission values of all endpoints showed significantly better improvement in NIV groups compared to the control group (P<0.001)
Willmore <i>et al.</i> [2015]	Before-and-after cohort	N=341	Despite the robust in-hospital data supporting its use, we could not find benefit from CPAP in our prehospital setting with respect to morbidity, mortality, and length of stay. EMS must exercise caution in making the decision to invest in the equipment and training required to implement pre-hospital CPAP
Emergency department studies			
Considine <i>et al.</i> [2012]	Retrospective cohort	N=273	Patients with COPD exacerbation requiring O ₂ had higher incidence of ambulance transport (P<0.0001); were considered higher acuity (Triage cat 2 P<0.006); were more likely to use home O ₂ (P<0.001); had increased work of breathing on ED arrival (P<0.001); higher median heart rate (P=0.001) and respiratory rate (P<0.001). Significant proportion of hypoxaemic patients (O ₂ <90%) did not receive O ₂ on arrival at ED
Chow <i>et al.</i> [2016]	Retrospective cohort	N=378	SPO ₂ in the target range at 30 min was higher in the controlled O ₂ group (32% vs. 16%; 95% CI: 7–24%) and mortality lower (2.7% vs. 5.8%)
Kelly <i>et al.</i> [2016]	Observational sub-study of a prospective interrupted time-series cohort	N=415	91% existing COPD diagnosis. 80% received bronchodilators; 66% systemic corticosteroids; 75% of those with pH <7.3 received NIV
Alrahib <i>et al.</i> [2012]	Retrospective cohort	N=369	Patients with 2 or more exacerbations per year experienced a 58% reduction in hospital admissions and a 43% reduction in ED/LUC visits following home tele-monitoring
Newham <i>et al.</i> [2017]	Systematic review and meta-analysis	66 clinical trials	Patients who received self-management interventions had significantly fewer ED visits than those who didn't
Hurst <i>et al.</i> [2010]	Clinical audit	N=74	45% reduction in admission and 37% reduction in bed days (P=0.002) in patients who used a 24 hr telephone support service
Baker <i>et al.</i> [2013]	Retrospective matched cohort	N=1,767	No relationship between the program and ED use or number of hospital days for patients who were hospitalised

COPD, chronic obstructive pulmonary disease; ED, emergency department; NIV, non-invasive ventilation.

assistance for respiratory distress, identifying that these patients were significantly unwell, were older, had more comorbidities, and required more complex management, resulting in higher rates of admission than similar patients who did not present by ambulance (9). Consequently, the findings of these studies highlight the difficulties faced by paramedics when managing patients in respiratory distress and the diagnostic and treatment challenges involved with the management of COPD exacerbation in the pre-hospital setting.

Internationally, medical specialist support has proven effective in improving pre-hospital diagnostic accuracy and patient hospitalisation. Utilising physicians specialising in anaesthesiology on mobile emergency care units (MECUs) in Denmark allowed for on-site treatment and release of less ill patients. Of the 469 (88.5%) patients admitted to hospital, correct diagnosis of COPD exacerbations was confirmed in 436 (92.9%) (10). Consultation at a respiratory Day Hospital (DH) care facility in Barcelona, Spain showed that 71% of patients with severe COPD and with two admissions or more in the previous year reduced their annual number of admissions to one or zero, and this reduction was maintained over time (11).

Strategies such as telehealth initiatives and self-management interventions have successfully reduced both ED presentations (12,13) and hospital admissions (12,14,15). Initiatives such as this are likely to assist in reducing ambulance presentations for COPD exacerbations. However, it is worthy of note that there are methodological limitations in many of the studies, including a reliance on retrospective cohorts designs with relatively small sample sizes. No large studies utilising the linked data sets spanning the prehospital, ED and admitted inpatient experience of this patient group have been able to be identified.

Prehospital & ED oxygen use

Pre-hospital delivery of oxygen is a frequent topic in the literature as a consequence of the known link between excessive high-flow oxygen and hypercapnic respiratory failure in patients with exacerbations of COPD. A landmark randomised controlled trial in Australia demonstrated that in the pre-hospital environment titrated oxygen treatment significantly reduced mortality, hypercapnia, and respiratory acidosis compared with high flow oxygen in acute exacerbations of COPD (16). Studies such as this have informed guidelines including the Queensland Ambulance Service Clinical Guidelines and the COPD-X which both

recommend aiming for oxygen saturations of 88–92% in the emergency setting (2,17).

Despite this, studies show that patients are still frequently given incorrect oxygen flows in the pre-hospital setting with associated poorer clinical outcomes (18,19). Appropriate oxygen administration has also been shown to be an issue in the ED setting, with some patients not receiving oxygen when it was in fact required (20) despite studies demonstrating that the delivery of controlled oxygen in the ED assists with achieving target oxygen saturations and improves patient outcomes (21). To reduce the risk of complications in COPD patients, implementation of education programs and strategies to improve adherence to guidelines have been shown to be beneficial (22,23). Additionally, delivery of oxygen to COPD patients once they arrive at definitive care is also a significant emergency health service issue.

Finally, the use of non-invasive ventilation (NIV) is increasing in the pre-hospital setting for respiratory and cardiac presentations. Generally, as in the ED setting, the escalation to NIV for patients with an exacerbation of COPD would require an accurate diagnosis, the exclusion of pneumothorax and availability of suitable equipment and trained staff. Currently there are only a handful of studies that have focused on the efficacy of pre-hospital NIV and initial findings have been mixed. A recent study in Germany demonstrated that NIV applied by emergency physicians in the pre-hospital setting rapidly normalised disturbed vital functions in patients with COPD exacerbation and cardiac pulmonary oedema (24). Consequently the authors suggested that NIV should be considered as a first line intervention, however, they acknowledge that future studies are required in this area. Alternatively, an older Canadian study found no benefit from pre-hospital NIV with respect to morbidity, mortality and LOS for patients with either cardiac pulmonary oedema or COPD exacerbation (25). Therefore, the use of NIV in the pre-hospital setting remains a promising innovation, however further evidence is required before it is recommended as a standard practice.

ED themes

Epidemiology and outcomes

The AANZDEM study reported much about the epidemiological profiles of patients attending EDs with COPD exacerbations in Asia, Australia and New Zealand (4). The median age of COPD patients was found to be

73 years with 60% being male. The overwhelming majority of patients, 91%, had a pre-existing diagnosis and most, 65%, arrived by ambulance. Over three out of every four, 78%, were admitted to hospital, including 7% to intensive care. Diagnostic accuracy was high with 88% having a correlating final hospital diagnosis. Concerns overall were raised over evidence-based treatment compliance. In-hospital mortality was 4% and median length of stay was four days (4).

For patients with COPD exacerbations, studies have found that abnormal physiological and measured parameters are associated with in hospital death and adverse outcomes. These parameters have been shown to include: abnormal arterial pH, oxygen saturations and PaCO₂ on arterial blood gas; abnormal blood pressure; tachycardia over 110/minute; haemoglobin less than 100 g/L; urea greater than or equal to 12 mmol/L prior intubation; and being too ill to do a walk test (26,27). Despite these factors Soltani *et al.* found no clear identifying features between admitted and discharged patients on the whole (26). This may imply that it is easier for emergency clinicians to identify very unwell COPD patients but more difficult to make disposition decisions otherwise.

Stiell *et al.* reported that of 74 (7.8%) patients with a subsequent serious adverse event, 36 (49%) had not been admitted after the initial emergency visit (27). This raises a concern that it may not be easy to identify patients that may have an adverse event and/or some patients are inappropriately being discharged. Soltani *et al.* found mortality after discharge was associated with a history of myocardial infarction, nursing home residence and longstanding severity of COPD (26).

Systems of emergency care for COPD patients

Many studies have examined the systems of care encountered by patients seeking emergency management for COPD exacerbations. Particular focuses include: patient experiences of emergency services; alternative patient flow models; strategies for improving patient care; and increasing staff adherence to guidelines.

Firstly, an interesting qualitative study in the UK involved the analysis of patient, carer and staff interviews to explore patient decision-making processes surrounding presentation for emergency healthcare (28). This study included 15 patients with COPD who had emergency hospital admissions and revealed the complex process of navigating emergency care systems from a patient perspective. The study demonstrated that patients with

advanced COPD often attempt to self-manage as their symptoms deteriorate, with the aim to avoid emergency presentation. However, at a certain point in the trajectory of the exacerbation, the patient's symptoms often deteriorated to a point where they were compelled to make the decision to seek emergent care. This process of decision-making was guided by the patient's perception of their dyspnoea and was found to involve significant uncertainty and anxiety. Findings such as these illuminate the patient experience and should inform clinical practice and the future design of emergency healthcare systems.

Researchers have investigated strategies for improving these emergency systems with the goal to streamline patient care. A large single site study in New York examined the efficacy of an observation unit in the ED and found that there was a 13% reduction in hospital admission, as well as a significant reduction in ED length of stay, following its implementation (29). Whilst many EDs now include observation units, also known as short stay or rapid evaluation and treatment units, this study is one of the first to focus exclusively on patients with COPD exacerbations in these units.

Delivering patient management as a 'bundle of care', based on clinical guidelines, is another recent initiative aimed at improving emergency care and patient outcomes. An Australian study investigated the efficacy of this model, examining the compliance of two metropolitan EDs with the delivery of bundle elements (30). The bundle of care elements included investigations and interventions such as chest X-rays, controlled oxygen delivery, bronchodilators and other required management based on clinical guidelines. The study found that compliance with the overall bundle was 49% and varied with severity, with 83% of patients classified as severe receiving the complete bundle. Interestingly the study found no difference in mean length of stay for admitted patients, in-hospital mortality or 30 day readmission by bundle compliance in the ED, indicating that other factors such as disease severity and pre-hospital and ward treatment likely have significant influence on these parameters.

Finally, a study from the UK investigated the efficacy of a proforma for junior doctors in the ED for improving care for COPD patients (31). The researchers found that following implementation of a physical checklist, doctors were able to more accurately categorise the type of respiratory failure (4% compared to 89%) and appropriately deliver controlled oxygen (47% prior compared to 92%). Additionally, rates of repeat arterial blood gases and referral

Table 2 Recommended pre-hospital and ED care for COPD exacerbations based on the COPD-X Plan, the Queensland Ambulance Service Clinical Guidelines and the Thoracic Society of Australia and New Zealand (TSANZ) Acute Oxygen Guidelines (2,17,32)

Variable	Pre-hospital	Emergency department
Initial assessment	Paramedic review: DRS ABCDE (danger, response, send for help, airway, breathing, circulation, disability and exposure); monitor observations including respiratory rate and oxygen saturation (SpO ₂); primary and secondary surveys with assessment of respiratory distress	ED triage: DRS ABCDE; monitor observations including respiratory rate and SpO ₂ ; primary and secondary surveys with assessment of respiratory distress
Confirm of COPD exacerbation and severity	Initiation of diagnostic process: history and examination; COPD action plan	Progression of diagnostic process: history and examination; COPD action plan; detailed medical records including prior spirometry, admissions and medication lists; pathology (blood tests, venous blood gas; sputum culture and microscopy; nasopharyngeal viral swab, etc.; consider arterial blood gas; measurement if SpO ₂ <92%; hypercapnia risk, critically ill; patient, unreliable pulse oximetry; or deteriorating SpO ₂ with increasing FiO ₂ *); imaging (CXR, CT, echocardiogram etc.); peak flows; spirometry
Acute management	Oxygen delivery: delivery of controlled oxygen aiming SpO ₂ saturations 88-92% for patients with known COPD; continuous pulse oximetry; escalation of oxygen delivery and respiratory support devices: nasal prongs → venturi mask → intubation. Available treatment: bronchodilators; oral corticosteroids	Oxygen delivery: delivery of controlled oxygen aiming SpO ₂ saturations 88-92% for patients with known COPD; escalation of oxygen delivery and respiratory support devices: nasal prongs → NIV → intubation. Available treatment: bronchodilators; oral corticosteroids; antibiotics
Escalation of care	Transport to ED: pre-Notify ED if indicated	Referral for admission

*, the authors note that use of venous or arterial blood gas measurements in acute COPD presentations is currently an area of clinical practice that is debated and undergoing change. These recommendations are derived from the TSANZ acute oxygen guidelines. COPD, chronic obstructive pulmonary disease; ED, emergency department; NIV, non-invasive ventilation.

for NIV were also improved indicating that a proforma or checklists in the ED enhanced the delivery of optimal COPD care. *Table 2* offers some general recommendations regarding the acute management of COPD exacerbations based on the literature and recent pre-hospital and emergency guidelines.

Therefore, it is clear from these studies involving emergency care systems, that there is great potential for improvement in both the delivery of emergency care, as well as the experiences and outcomes for patients with COPD exacerbations. More research is required in this area to further elucidate patient experiences as well as to identify strategies to improve emergency care pathways.

Prevention of presentations and readmission

In considering admission to hospital versus short stay versus discharge and prevention of presentations, it is important to consider data from Bartels *et al.* regarding readmission after discharge (33). Readmission rates in the ED group (n=240)

were significantly higher than that in the hospitalized group (n=271) for both 30- (0.54 vs. 0.20, P=0.0001) and 90-day (1.29 vs. 0.51, P=0.0001) ED readmissions. Furthermore, the time to first readmission was significantly shorter in the ED group than in the hospitalized group (24.1±22 vs. 31.8±27.8 days; P=0.05). Cardiovascular comorbidities (P=0.00001), substance abuse disorder (P=0.001), and mental illness (P=0.001) were the strongest predictors of readmission in the ED group. Age (P=0.01), forced expiratory volume in 1 second (P=0.001), and cardiovascular comorbidities (P=0.05) were the best predictors for both 30- and 90-day COPD readmission rates in the ED group (33). Therefore, if COPD patients are reluctant to come to the ED, come to the ED as a last resort and have a higher readmission rate if discharged, it may be that only a small minority of patients are suitable for discharge from the ED.

Machine learning to predict COPD exacerbation outcomes

Clinical guidelines recommend indications for patients

Table 3 Foci and gaps in the literature of emergency care pathways for COPD exacerbations

Literature foci	Literature gaps
Pre hospital	
Diagnostic difficulties	Delivery of bronchodilators and other medications in the pre-hospital setting
Oxygen delivery	Efficacy of different ambulance team structures (i.e., doctors in pre-hospital setting)
Strategies to reduce emergency presentations	Methods for handover of care to ED staff
	Qualitative research examining patients expectations and experiences of pre-hospital care
Emergency department	
Epidemiology and outcomes	Handover from pre-hospital staff
ED adherence to diagnostic and treatment guidelines	Linkage of the pathway from pre-hospital to ED to discharge or hospital admission
Alternative ED units and care facilities	Diagnostic accuracy and difficulties
Machine learning	Intersection between ED and admitting wards
	ED referral practices and post-discharge follow-up

COPD, chronic obstructive pulmonary disease; ED, emergency department.

with severe COPD exacerbations to seek emergency care (2). However, more accurate prediction of prognosis of exacerbation episodes would enhance the delivery of health services for patients with COPD. One such predictive approach is machine learning, which is use of a computational, artificial intelligence algorithm for predicting patterns from data.

Techniques of machine learning are being increasingly applied to health care (34), including emergency management of COPD. A US study developed models to triage patients presenting to ED with a possible COPD exacerbation, by generating hypothetical patient cases, and then developing prediction algorithms based on clinical variables (35). The models were then compared to clinical gestalt in a validation process. The top performing machine learning algorithm was found to be more accurate in identifying exacerbations and predicting the correct ED triage category, than the consensus opinion of a panel of respiratory physicians in this study.

Machine learning can also more accurately triage patients with COPD or asthma who present to an ED. In a US study using data from the 2007–2015 National Hospital and Ambulatory Medical Care Survey, machine learning was applied to routinely-collected triage data (demographics, arrival mode, respiratory symptoms, vital signs, comorbidities), in order to predict outcomes after ED presentation, especially disposition from ED (36). Amongst

3,206 ED visits for patients with acute presentations for asthma (58% of cohort) or COPD (42% of cohort), 4% had critical care outcomes (ICU or death) and 26% needed hospital admission. Application of machine learning models increased the accuracy of predicting critical care outcomes or hospitalisation, compared to the Emergency Severity Index, a routinely used, five-level triage tool based on patient acuity and resources needed for care. For example, the C-statistic (or discriminative ability, representing the predictive accuracy and equivalent to area under the curve for a binary outcome) was improved at 0.83 for hospitalization for one of the machine learning models (random forest), compared to 0.64 for the Emergency Severity Index.

Collectively, these two studies demonstrate that machine learning has the potential to improve the prediction of clinical outcomes in patients presenting to ED with COPD exacerbations.

Conclusions

In conclusion, patients with COPD exacerbations frequently present to pre-hospital emergency services and EDs requiring acute management of their condition. This review has surveyed the literature surrounding these systems of care and identified a number of important themes (*Table 3*). In the pre-hospital domain, these themes included the appropriate delivery of oxygen to COPD

patients, the accuracy of diagnosis for patients with respiratory distress, and strategies to reduce requirements for prehospital services for COPD patients. In the ED domain, many studies have focused on the themes of epidemiology and outcomes of COPD patients requiring ED care, care pathways, and finally, machine learning to improve prediction of clinical outcomes. Collectively, the surveyed literature demonstrates that systems and pathways of emergency care for exacerbations of COPD are complex and significant. More research is required to further elucidate these complexities and identify strategies for improvement, and, by extension, improve the experiences and outcomes of patients with exacerbations of COPD.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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