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Hyperglycaemia is associated with poor outcomes in people admitted to hospital with acute exacerbations of chronic obstructive pulmonary disease

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ABSTRACT

Background Hyperglycaemia is associated with poor outcomes from pneumonia, myocardial infarction and stroke, but the effect of blood glucose on outcomes from acute exacerbations of chronic obstructive pulmonary disease (AECOPD) has not been established. Recent UK guidelines do not comment on measurement or control of blood glucose in AECOPD. We therefore determined the relationship between blood glucose concentrations, length of stay and mortality in people admitted with AECOPD.

Methods Data was retrieved from electronic records for patients admitted with "AECOPD with Lower Respiratory Tract Infection" in 2001-2. Patients were divided by blood glucose quartile (Group 1, <6mmol.L^{-1} (n=69); Group 2, 6.0-6.9mmol.L^{-1} (n=69); Group 3, 7.0-8.9mmol.L^{-1} (n=75); and Group 4, >9.0mmol.L^{-1} (n=71)).

Results. Relative risk (RR) of death or long in-patient stay was significantly increased in Group 3 (RR 1.46 [95% C.I.:1.05-2.02] (p=0.02) and Group 4 (RR 1.97 [95% C.I.:1.33-2.92] (p<0.0001), compared to Group 1. For each 1mmol.L^{-1} increase in blood glucose the absolute risk of adverse outcomes increased by 15% [95% C.I.:4-27%] (p=0.006). The risk of adverse outcomes increased with increasing hyperglycaemia, independent of age, gender, prior diagnosis of diabetes and COPD severity. Isolation of multiple pathogens and *Staphylococcus aureus* from sputum also increased with increasing blood glucose.

Conclusion. Increasing blood glucose concentrations were associated with adverse clinical outcomes in people with AECOPD. Tight control of blood glucose reduced mortality in people on intensive care or following myocardial infarction. A prospective study is now required to determine whether control of blood glucose can also improve outcomes from AECOPD.

INTRODUCTION

Around 1.5 million people in the United Kingdom suffer from chronic obstructive pulmonary disease (COPD) [1] and exacerbations of this condition have major impact on personal and public health. Acute exacerbations of COPD (AECOPD) contribute to more than 100,000 hospital admissions, 1 million in-patient bed days and 30,000 deaths annually in England and Wales [2]. In this context strategies to reduce mortality and length of stay from AECOPD are urgently required. Previous studies have shown that in-hospital mortality from AECOPD is predicted largely by fixed factors such as older age [3] [4], male gender, co-morbidity and higher income [4], but also by arterial pH [3]. It is not known whether hyperglycaemia, which is remediable, predicts outcomes of hospitalisation for AECOPD.

Hyperglycaemia is of interest as it is associated with poor outcomes from acute hospital admission for other conditions. In a study of 2,030 adults admitted to general hospital wards, newly-discovered hyperglycaemia (admission or fasting blood glucose >7mmol.L^{-1} or two random blood glucose measurements >11.1mmol.L^{-1}) was associated with higher in-hospital mortality (16%) than established diabetes mellitus (3%) or normal blood glucose (1.7%) [5]. Furthermore hospital stay was longer and intensive care unit admission was more frequent in those with new hyperglycaemia. In 2,471 patients with community-acquired pneumonia, those with admission blood glucose >11mmol.L^{-1} had increased risk of death and in-hospital complications compared to those with blood glucose ≤11mmol.L^{-1} [6]. Risk of in-hospital complications increased by 3% for each 1mmol.L^{-1} increase in blood glucose. Hyperglycaemia has also been associated with adverse outcomes from acute myocardial infarction [7], ischaemic or haemorrhagic stroke [8], surgery [9] and trauma [10].

Diabetes mellitus and acute hyperglycaemia are common in people with COPD. In the general population women with COPD had an 1.8-fold increased risk of developing type 2 diabetes compared to those without COPD [11]. A prior diagnosis of diabetes mellitus was recorded in 14-15% people admitted to hospital with AECOPD [12][13]. Treatment of AECOPD with oral glucocorticoids was associated with an increased risk of developing hyperglycaemia (odds ratio 5.48 [95% confidence intervals: 1.58-18.96]) [14]. People with AECOPD and diabetes treated with insulin had longer in-patient stay and more frequent isolation of gram-negative bacteria from sputum than those without diabetes [14]. Admission hyperglycaemia (>11mmol.L^{-1}) predicted failure of non-invasive ventilation and infectious pulmonary complications in people admitted to intensive care with acute respiratory failure caused by severe AECOPD [15].

Hyperglycaemia is thus associated with poor outcome from a wide range of acute illnesses, including community-acquired pneumonia, and is common in people with AECOPD. However the relationship between blood glucose and clinical outcomes in AECOPD has not been fully established. Furthermore, recently published national UK guidelines [2] do not comment on whether blood glucose should be measured or controlled in the management of AECOPD. We therefore performed a retrospective pilot study to determine the relationship between blood glucose concentrations and clinical outcomes in people admitted with AECOPD. The rationale for the retrospective design was to establish whether hyperglycaemia was associated with poor outcomes from AECOPD before investing in a large scale prospective study to determine whether tight control of blood glucose could improve the prognosis of AECOPD.

METHODS

Participants. ICD-10 codes were used to identify people admitted to St George's Hospital in 2001 and 2002 with a discharge diagnosis of 'Acute Exacerbation of COPD with Lower Respiratory Tract Infection', code J44.0. A single admission for people admitted once and the first admission for people admitted 2 or more times were included in the study. Information was obtained for each person using electronic patient records. This was not considered by the Local Research Ethics Committee to require ethical approval.

Demographics. Individual ages and genders were noted. Lung function records were searched to retrieve FEV_1, FVC and FEV_1/FVC % from up to 2 years before or after hospital admission. These spirometric measurements were used to confirm the diagnosis and determine the severity of COPD using GOLD criteria [16].

Blood glucose. Blood glucose measurements taken on admission and during hospital stay were obtained for each participant from electronic patient records where available. Where more than one blood glucose measurement was made for an individual, the highest value was included in the analysis. Participants were divided into 4 groups by blood glucose quartiles. ICD-10 codes E10-14 were used to identify people with a discharge diagnosis of diabetes mellitus.

Clinical outcomes. Admission and discharge dates or dates of death, if death occurred in hospital, were retrieved and used to calculate length of stay and in-patient mortality. A composite adverse outcome was defined as death or length of stay longer than the median length of stay for analysis.

Sputum culture. Sputum microbiology results were retrieved for each individual where available and bacteria isolated were recorded.

Analysis. Normally distributed values are given as mean (standard deviation, SD) and were compared between 2 groups using unpaired t tests and between more than 2 groups using analysis of variance. Non-normally distributed values are expressed as median (interquartile range, IQR) and were compared between 2 groups using Mann-Whitney U testing and between more than 2 groups using Kruskal-Wallis testing. Categorical results are given as absolute numbers and percentages and compared between groups using χ^2 analysis. Logistic regression was used to estimate the change in risk of outcomes per $1mmol.L^{-1}$ change in blood glucose, adjusted for age, gender, prior diagnosis of diabetes mellitus and FEV1 % predicted. $P<0.05$ was considered significant. Software used for the analysis was Statistical Package for the Social Sciences Version 11.5.

RESULTS

Demographics.

433 admissions with 'Acute Exacerbation of COPD with Lower Respiratory Tract Infection' encoded J44.0 were identified. A single admission for 291 people admitted once and the first admission for 57 people admitted 2 or more times were included in the analysis (n=348, 195 (56%) male, age 74.4 (SD 10.4 years). Spirometry was available for 119/348 (34%) people, of whom 105 (88%) met criteria for diagnosis of GOLD stage 1 COPD or worse.

Blood glucose measurements

Blood glucose was measured at admission for 252/348 (72%) people and at or during admission for 284/348 (82%) people (figure 1). Where more than one blood glucose measurement was made for an individual, the highest value was included in the analysis. In 193 (68%) people admission blood glucose was used for analysis. Blood glucose was >6.1mmol.L^{-1} in 204 (72%) and >11.1mmol.L-1 in 32 (11%) people tested. Median blood glucose concentration was 7.0mmol.L^{-1} (IQR 6.0 – 9.0 mmol.L^{-1}). Participants were divided into 4 groups by blood glucose quartiles: Group 1, blood glucose <6.0mmol.L^{-1}; Group 2, blood glucose 6.0-6.9mmol.L^{-1}; Group 3, blood glucose 7.0-8.9mmol.L^{-1}; and Group 4, blood glucose >9.0mmol.L^{-1} (table 1). 15/284 (5.3%) people had a diagnosis of diabetes recorded on their discharge summary.

Relationship between blood glucose and adverse outcomes

Composite adverse outcomes. Median length of stay was 9 (IQR 5-17) days. 154 (44%) people were judged to have had a good clinical outcome from their AECOPD (survival and length of stay $\leq$9 days). 194 (56%) people were judged to have had an adverse clinical outcome (death or length of stay >9days).

The proportion of participants in each blood glucose quartile who had an adverse clinical outcome are shown in table 1. The relative risk of an adverse outcome was 1.30 [95% Confidence Intervals (C.I.) 0.93-1.82] in Group 2, 1.46 [95% C.I. 1.05-2.02] in Group 3 and 1.97 [95% C.I. 1.33-2.92] in Group 4, compared to participants in Group 1 (lowest blood glucose quartile). The absolute risk of an adverse outcome increased by 15% [95% C.I: 4-27%] per 1mmol.L^{-1} increase in blood glucose (p=0.006) after adjustment for age, gender and prior diagnosis of diabetes mellitus.

In the subgroup of 193 people who had admission blood glucose used for analysis, the relative risk of an adverse outcome was 1.69 [95% C.I. 1.08-2.64] in Group 2, 1.53 [95% C.I. 1.01-2.34] in Group 3 and 1.98 [95% C.I. 1.33-2.96] in Group 4, compared to participants in Group 1. In this subgroup, in whom admission blood glucose was used for analysis, the absolute risk of adverse outcomes increased by 31% [95% C.I: 11-55%] per 1mmol.L^{-1} increase in blood glucose (p=0.002) after adjustment for age, gender and prior diagnosis of diabetes mellitus.

Mortality. The proportion of participants in each group who died is shown in table 1. Blood glucose was 7.7 (SD 2.8) mmol.L^{-1} in patients who survived (n=227) and 9.1 (SD 4.7) mmol.L^{-1} in patients who died during admission (n=57, p=0.004). The relative risk of death was 1.22 [95% C.I. 0.70-2.12] in Group 2, 2.10 [95% C.I. 0.82-5.20] in Group 3 and 3.42 [95% C.I. 1.40-8.36] in Group 4, compared to participants in Group 1. The risk of death increased by 10% [95% C.I: 0-22%] per 1mmol.L^{-1} increase in blood glucose (p=0.055) after adjustment for age, gender and prior diagnosis of diabetes mellitus.

Table 1. Demographic information, clinical outcomes and sputum culture results in participants divided into groups by blood glucose quartiles

Group	1	2	3	4	P value
Demographics					
Blood glucose ($mmol.L^{-1}$)	<6.0	6.0-6.9	7.0-8.9	>9.0	
Number of participants	69	69	75	71	
Age (Years, SD)	73.1 (10.7)	72.9 (11.1)	76.7 (8.6)	75.0 (10.5)	0.087
Gender (M:F)	43:26	39:30	43:32	42:29	0.743
Pre-existing diagnosis of diabetes (n(%))	1 (1.4%)	1 (1.4%)	3 (4%)	10 (14.1%)	0.002
Clinical outcomes					
Composite adverse outcomes (n (%))	28 (41%)	37 (54%)	45 (60%)	51 (72%)	0.0001
Mortality (n (%))	8 (12%)	11 (16%)	16 (21%)	22 (31%)	0.003
Length of stay (days, IQR)	7 (4-14)	9 (5-16)	10 (6-22)	12 (5-21)	0.087
Sputum culture results					
At least one pathogen (n (%))	14 (56%)	17 (61%)	19 (66%)	22 (73%)	0.154
Multiple pathogens (n (%))	3 (12%)	5 (18%)	8 (28%)	10 (33%)	0.031
Staphylococcus aureus (n (%))	1 (4%)	3 (11%)	8 (28%)	8 (27%)	0.011
Yeasts (n (%))	0 (0%)	3 (11%)	2 (7%)	5 (17%)	0.065

Age is given as mean (standard deviation), relative risk is given as risk [95% Confidence Intervals] and length of stay is given as median (interquartile range). Logistic regression was used for analysis of univariate relationships between glucose (divided by quartiles into 4 exposure levels) and categorial variables. Analysis of variance was used to compare age between the 4 groups and Kruskal-Wallis testing used to compare length of stay (not normally distributed) between the groups.

Clinical outcomes in people who did and did not have blood glucose measured
64 (18%) people did not have blood glucose measured during admission. Outcomes were compared between people who did and did not have blood glucose measurement made to determine whether missing values may have confounded the results. The risk of an adverse outcome was similar in those who did not have glucose measured (52%) to those who did (57%, p=0.456). Mortality (No measurement: 11%, Measurement: 20%, p=0.088) and length of stay (No measurement: 9 (IQR 4-12) days, Measurement: 9 (IQR 5-18) days, p=0.064) were slightly but not significantly lower in people who did not have blood glucose measured.

Clinical outcomes in people who did and did not have spirometry measured
Spirometry was measured in 119 people, 105 (88%) of whom met criteria for diagnosis of GOLD stage 1 COPD or worse [16]. 24/105 (23%) people had mild COPD (FEV_1% predicted 61 (SD 11)%), 53/105 (50%) had moderate COPD (FEV_1% predicted 38 (SD 6)%) and 28/105 (27%) had severe COPD (FEV_1% predicted 24 (SD 5)%). Spirometry was abnormal in the 14 people who did not meet GOLD criteria for COPD (FEV_1% predicted 58 (SD 19)%, FEV_1/FVC ratio 80 (SD 9)%). In 88 people with spirometry who also had blood glucose measurements available, blood glucose quartiles were significantly related to adverse outcome on univariate logistic regression (unadjusted odds ratio (OR) 1.51 [95% C.I: 1.02-2.23]). This relationship persisted after adjustment for age and gender (adjusted OR 1.70 [95% C.I: 1.10-2.65]) and after further adjustment for FEV_1 % predicted (adjusted OR 1.76 [95% C.I: 1.12-2.76]). On multivariate analysis FEV_1 % predicted was not a significant determinant of adverse outcome (adjusted OR 1.02 [95% C.I: 0.99-1.06].

Relationship between blood glucose concentrations and sputum culture results
112 (32%) people who had blood glucose measured at some point during admission also had sputum culture results available. There was no difference in the frequency of isolation of *Streptococcus pneumoniae, Haemophilus influenzae, Moraxella catarrhalis* and *Pseudomonas aeruginosa* from sputum between the glucose quartile groups. However multiple pathogens and *Staphylococcus aureus* were isolated significantly more often from sputum from participants in the higher blood glucose quartiles (table 1).

DISCUSSION

We have shown that increasing blood glucose concentrations are associated with adverse clinical outcomes in people admitted to hospital with a physician diagnosis of AECOPD. People with higher blood glucose concentrations were more likely to die or have in-patient stay longer than the median than those with lower blood glucose concentrations, independent of age, gender and prior diagnosis of diabetes. In the subgroup of patients who had COPD confirmed by spirometry, blood glucose quartile independently predicted adverse clinical outcomes, whereas underlying COPD severity did not. Our results show that the association between acute hyperglycaemia, increased mortality and longer in-patient stay previously described for other conditions [5][6][7][8][9][17][18] is also seen in patients with AECOPD. These findings add hyperglycaemia to previously known risk factors for in-hospital mortality from AECOPD, namely arterial pH [3], older age [3,4], male gender, co-morbidity and higher income [4]. Further studies are now required to determine whether control of blood glucose can influence outcomes from AECOPD.

In this study we determined the association between blood glucose and outcomes by dividing patients into quartiles determined by blood glucose concentrations. The risk of adverse outcomes was significantly increased in Groups 3 and 4 (higher blood glucose), compared to Group 1 (lowest blood glucose). This implies that random blood glucose at concentrations $\geq$7mmol.L^{-1} is detrimental in AECOPD and has implications when setting targets for blood glucose control. Studies of other conditions have also attempted to define blood glucose concentrations that determine clinical outcomes. Blood glucose >11.1mmol.L^{-1} was associated with longer in-patient stay and increased mortality for general hospital admission [5] and increased mortality and in-hospital complications from community-acquired pneumonia [6]. Control of blood glucose to $\leq$11.0mmol.L^{-1} reduced mortality by 29% following myocardial infarction [19]. Other studies confirmed our findings that lower blood glucose concentrations (6.0-11.1mmol.L^{-1}) were associated with poor outcomes, including increased mortality and poor functional recovery from stroke [8] and increased mortality and infection on a cardiothoracic intensive care unit (CICU) [20]. Tight control of blood glucose to 4.4-6.1mmol.L^{-1} in the CICU patients reduced mortality, septicaemia and prolonged antibiotic therapy compared to conventional therapy (blood glucose 10-11.1mmol.L^{-1}) [20].

Potential mechanisms

Our study demonstrates an association between elevated blood glucose concentrations and poor clinical outcomes in AECOPD, but does not explain this relationship. Blood glucose is increased in acute illness due to a combination of metabolic effects such as elevated plasma catecholamines and glucocorticoid hormone concentrations and increased peripheral insulin resistance [21]. Elevated blood glucose concentrations in AECOPD could therefore simply be a marker for more severe illness, which in turn results in adverse clinical outcomes. Blood glucose concentrations also rise with corticosteroid treatment for AECOPD [14], hence elevated blood glucose concentrations could reflect administration of steroids at larger doses or for longer in people who are more unwell, who have poor clinical outcomes. However treatment studies have demonstrated that reduction in blood glucose concentrations improved clinical outcomes, at least in people on intensive care [20] or following myocardial infarction [19]. Regression analysis suggested that control of blood glucose levels, rather than insulin dose, was responsible for the clinical benefits observed [22]. These findings imply that elevated glucose concentrations could have a direct detrimental effect on outcomes.

Hyperglycaemia could have adverse effects in acute illness through cellular glucose overload and oxidative stress. In acute illness, cytokines, hormones and hypoxia upregulate expression

and membrane localisation of glucose transporters in many cell types [23]. Cellular glucose overload results in increased glucose metabolism, in turn increasing superoxide and peroxynitrite production which may impair mitochondrial activity [23]. In support of this, ultrastructural abnormalities were observed in hepatic mitochondria obtained at liver biopsy from ICU patients with hyperglycaemia, whereas virtually no mitochondrial abnormalities were detected in patients where normoglycaemia was maintained therapeutically [24]. Mitochondrial toxicity of glucose in diverse cells could account for the broad spectrum of organ and tissue dysfunction associated with hyperglycaemia in acute illness [20].

Hyperglycaemia could also cause adverse outcomes from AECOPD by predisposing to infection through systemic or local effects on host immunity or bacterial growth. In the present study we found that participants in higher blood glucose groups were more likely to have more than one type of organism or *Staphylococcus aureus* isolated from sputum than those in lower blood glucose groups. Systemic immune defects in people with diabetes are well documented and include decreased neutrophil and macrophage chemotaxis, phagocytosis and killing and impairment in complement and cytokine responses to infection [25]. Our group has recently shown that local glucose concentrations in human airway secretions are normally extremely low [26]. However when blood glucose is elevated above a threshold of 6.7-9.7mmol.L^{-1}, glucose becomes detectable in airway secretions at concentrations of 1-11mmol.L^{-1} [26][27]. People intubated on intensive care who had glucose in bronchial aspirates were more likely than those without glucose in bronchial aspirates to have respiratory pathogens detected in aspirates, particularly methicillin resistant *Staphylococcus aureus* [28]. Glucose in airway secretions could predispose to respiratory infection by promoting bacterial growth or interfering with local innate immunity.

Strengths and weaknesses of study

We studied the relationship between blood glucose concentration and clinical outcomes using a retrospective study. This had the advantage of allowing efficient collection and analysis of data from a large number of patients with AECOPD in whom the clinical outcome was already established. Our retrospective study had a number of limitations, some of which we were able to address during study design and analysis.

We identified people for inclusion in this study using the ICD 10 code J44.0, "Acute Exacerbation of COPD with Lower Respiratory Tract Infection". ICD 10 codes refer to the International Classification of Diseases, and disease codes are allocated by clinical clerks on the basis of summaries for hospital in-patients written by junior hospital doctors at the time of patient death or discharge. As this system is therefore imprecise we chose to select patients with ICD 10 code J44.0. We felt that this code required a positive diagnosis of COPD exacerbation rather than other codes, such as ICD J44.1 (COPD with acute exacerbation unspecified) which were more likely to have been used as a default code. In this retrospective study we did not have participants' smoking histories to support COPD diagnosis or Chest X-Ray results to exclude pneumonia. However we were able to obtain results of spirometry for 34% people, which confirmed the diagnosis of GOLD stage 1 COPD or worse in 88% and was abnormal in the remaining 12%. In this subgroup, ICD J44.0 therefore did accurately identify people with COPD. It is not clear whether this implies that J44.0 was used accurately for the whole group irrespective of lung function, or that availability of spirometry ensured correct diagnosis of COPD . However blood glucose was an independent predictor of poor clinical outcome in both the whole group with physician-diagnosed AECOPD and the subgroup with COPD confirmed by spirometry, implying that our findings are applicable to both patient groups. Of note, in people with COPD confirmed by spirometry, hyperglycaemia

was a stronger predictor of adverse outcomes from acute exacerbations than severity of COPD.

In this retrospective study we used random blood glucose measurements, taken at admission (68%) or during in-patient stay (32%), to determine hyperglycaemia and we were unable to standardise the timing of blood glucose measurements. In-patient measurements may have differed from admission measurements due to corticosteroid therapy which could elevate blood glucose [14] or due to resolution of the stress response to acute illness which could lower blood glucose [21]. Due to the retrospective study design we were unable to explore the effect of these potential confounders on the relationship between blood glucose quartiles and clinical outcomes. However we were able to confirm the relationship between blood glucose quartiles and adverse outcomes in the subgroup of people whose admission blood glucose was used for analysis, in whom measurement timing was more standardised. This subgroup analysis does not completely exclude the confounding effects of corticosteroids as we were not able to determine whether participants were taking steroids before admission. Further investigation of the important confounding effects of steroid therapy will require a prospective study. An additional limitation of this study was lack of information about time spent by each individual within different bands of hyperglycaemia and this too requires prospective investigation.

Blood glucose measurements were obtained from electronic records and were not available for 18% people, reducing the numbers of people included in the analysis. Mortality and length of stay were slightly but not significantly lower in those who did not have blood glucose measured, suggesting that this group may not have had blood glucose measurement as they were less unwell. Alternatively blood glucose measurements may have been omitted due to lack of requirement for blood glucose measurement in AECOPD guidelines [2][29], or performed by near-patient testing which was not recorded electronically. Use of retrospective data also meant that only 32% people had sputum culture results available, which limited the analysis of the relationship between blood glucose and sputum culture results.

Previous studies have shown that in-hospital mortality from AECOPD is predicted largely by fixed factors such as older age [3,4], male gender, co-morbidity and higher income [4], as well as by arterial pH [3]. In our study we were able to demonstrate that the relationship between hyperglycaemia and poor outcome was independent of age, gender, underlying severity of COPD and a prior diagnosis of diabetes mellitus. Use of ICD10 codes may have underestimated the prevalence of diabetes mellitus as 5.3% people in our study, but 14-15% people admitted to hospital with AECOPD in other studies [12][13] had diabetes. Due to retrospective data collection we were also unable to include the effects of other important covariates, particularly pH [3] and other co-morbidities [4] in our model.

Implications

We have shown that the absolute risk of an adverse outcome (death or hospital stay longer than 9 days) following admission for AECOPD is significantly increased if random blood glucose is $\geq$7mmol.L^{-1}. A prospective study is now required to determine whether clinical outcomes from AECOPD can be improved by tight control of blood glucose. Studies of the effect of controlling blood glucose to physiological concentrations on outcomes have to date been performed on intensive care units, where close monitoring can ensure effective blood glucose control without hypoglycaemia. Protocols now need to be developed for safe and effective blood glucose control to physiological concentrations on general hospital wards. Blood glucose control to 7.2mmol.L^{-1} in a heterogeneous population of critically ill adult

patients, reduced hospital mortality by 29% and ICU length of stay by 11% [30]. If blood glucose control has similar impact on patient outcomes from AECOPD, this could significantly reduce the 1 million in-patient bed days and 30,000 deaths annually attributable to COPD.

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Authorship
All authors listed contributed to:
1. Conception and design, or acquisition of data, or analysis and interpretation of data and
2. Drafting the article or revising it critically for important intellectual content and
3. Final approval of the version to be published

Competing interests
None of the authors has competing interests with this study
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FIGURE LEGENDS

Figure 1. A histogram of the highest blood glucose concentration recorded during in-patient stay for each of 284/348 (82%) people with AECOPD.

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