Health Economists' Study Group meeting, University of Exeter, January 2013

Costs and benefits of interventions to improve the management of COPD: results of an implementation study

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Abstract

Evidence suggests that a high proportion of patients with chronic obstructive pulmonary disease (COPD) are not receiving optimal primary care. In June 2010 NICE published guidelines for the management of patients with COPD, making wide-ranging recommendations for diagnosing COPD, managing stable COPD and managing COPD exacerbations. The aim of this paper is to present an evaluation of a project designed to improve the quality of care of COPD patients based on the implementation of the NICE COPD guidelines. Four interventions were included: COPD masterclasses; spirometry training; nurse mentorship; and, dashboards reporting comparative data for practices for a range of COPD management and cost indicators. These were delivered to 189 general practices in four PCTs in Outer North East London PCT Cluster between 1 April 2011 and 31 May 2012. The four interventions were calculated to cost £128,000. Data on outcome measures and COPD-related management costs were taken from general practice records linked to secondary care use and cost data. We used a before and after study design with monthly practice level data for the period January 2010 to August 2012, regressing the outcomes measures and cost variables against whether or not practices had

received the interventions plus indicators for seasonality and numbers of COPD patients, as well as practice fixed effects. The interventions improved the management of COPD patients according to NICE COPD guidelines, though not all patients were being managed according to the guidelines by the end of the follow-up period. COPD-related management costs per patient fell as a result of the interventions but costs across all patients were higher as larger numbers of patients were identified as having COPD.

Introduction

Chronic obstructive pulmonary disease (COPD) is an umbrella term used to describe a range of health problems including chronic bronchitis and emphysema. An estimated three million people have COPD in the UK, though over two third of these are undiagnosed.[1] According to data from the *Quality and Outcomes Framework*, the prevalence of diagnosed COPD is 1.6%.[2]

The health burden of COPD is high. It has been estimated that it accounts for around 30,000 deaths each year in the UK.[1],[3]-[6] One in eight (130,000) emergency hospital admissions is for an exacerbation of COPD, making it the second largest cause of emergency admission in the UK;[7] COPD accounts for more than one million bed days each year in the NHS in the UK;[3][5] there is evidence that COPD admissions are seasonal, being more common in Winter months.[8] As a consequence of the health burden, the costs of COPD are high. It has been reported that COPD accounts for around £800 million in health care costs to the NHS each year.[3] More than half of these costs relate to hospital care.[9] The indirect costs are also substantial, accounting for an estimated 24 million lost working days each year,[1][3][9] with the cost of lost productivity being estimated at around £2.7 billion.[2][3]

Evidence suggests that a high proportion of COPD patients are not receiving optimal primary care, and there is considerable variation in the standards of COPD care between general practices. In June 2010 the National Institute for Health and Clinical Excellence (NICE) published updated guidelines for the management of patients with COPD in adults in primary and secondary care.[10] The guidelines made wide-ranging recommendations for diagnosing COPD, managing stable COPD and managing COPD exacerbations. A number of the recommendations were set as priorities for implementation: diagnosis of COPD using

spirometry; encouraging patients with COPD to stop smoking; promoting effective inhaled drug therapy, including appropriate use of short-acting muscarinic antagonists (SAMAs), short-acting beta$_2$ agonists (SABAs)**,** long-acting muscarinic antagonists (LAMAs), long-acting beta$_2$ agonists (LABAs), and LABAs with inhaled corticosteroids (LABA+ICS); provide pulmonary rehabilitation for patients who need it; use of non-invasive ventilation; managing exacerbations through use of medications, self-management advice, non-invasive ventilation and hospital-at-home or assisted-discharge schemes; and, ensuring multidisciplinary working.

A costing report published alongside the guideline and analysing the cost implications of implementing it throughout England calculated that adopting the recommendations would increase prescribing costs by around £51 million each year.[2] It also calculated that these additional costs would result in fewer hospital admissions, producing savings of around £16 million per year; the total incremental costs were computed to be around £36 million per year.

In April 2011 the Outer North East London (ONEL) PCT Cluster (now part of NHS North East London and the City PCT Cluster), the UCL Partners Academic Health Science Partnership (UCLP) and the North East London, North Central London and Essex Health Innovation and Education Cluster (NECLES HIEC) launched the COPD 'Year in the Life' project to improve the quality of care of COPD patients in the four PCTs in ONEL (Barking and Dagenham, Havering, Redbridge, Waltham Forest), comprising a total of 189 general practices. The project was based around the implementation of the NICE COPD guidelines. A series of educational interventions aimed primarily at GPs and practice nurses were developed and delivered alongside comparative data for every practice for a range of COPD management and cost indicators. The educational interventions described and explained the NICE COPD guidelines and provided training on specific aspects of COPD diagnosis and management recommended in the guidelines. These implementation interventions were designed to encourage the adoption of the NICE COPD guidelines and improve the quality of COPD care.

The aim of this paper is to present an evaluation of the 'Year in the Life' project. The objectives are to calculate the costs of the implementation interventions, to analyse the impact of the interventions on meeting recommendations in the NICE guidelines, and to assess the impact on

COPD-related management costs. To achieve the last two objectives we used a before and after study design using monthly practice level data, regressing a series outcome and cost measures against indicators for whether or not practices had received the implementation interventions, plus indicators for seasonality and numbers of COPD patients, as well as practice fixed effects.

Methods

Description of interventions

Widespread publicity for the project within ONEL began in December 2010 and a launch event for local GPs was held in December 2010. A series of interventions were then delivered to practices throughout the four PCTs in ONEL during the period April 2011 to May 2012. The interventions were:

Masterclasses: These consisted of a series of four half-day classes held between October 2011 and May 2012 and made available to all GPs in ONEL free of charge. Each class focused on a different topic, covering (1) COPD diagnosis, (2) COPD medicines management, (3) inhaler technique, and (4) differentiating between COPD and asthma. Each class was delivered by a senior hospital consultant with expertise on the topic, supported by a nurse specialist, another senor consultant, and an information consultant who provided brief training on recording COPD data accurately on patient records.

Spirometry training: This consisted of a half-day course, which ran twice, once in November 2011 and once in February 2012, made available to all GPs and practice nurses in ONEL free of charge. Each course provided training accredited by the Association for Respiratory Technology and Physiology (ARTP) on how to perform spirometry for diagnosis of COPD. Each class was delivered by an accredited trainer, who was senior hospital consultant.

Nurse mentorship: The nurse mentorship programme involved a specialist nurse visiting a GP practice, spending 30 minutes with a practice nurse discussing management of COPD patients, and a further three and a half hours running a clinic for COPD patients being shadowed by the practice nurse. The mentor focused mainly on COPD diagnosis, annual reviews for COPD patients, COPD medicines management, inhaler technique, plus brief training on recording COPD data accurately on patient records.

Dashboards: From May 2011 to July 2012 every practice in ONEL received a report by email every two months describing their performance against a number of indicators derived from

recommendations in the NICE COPD guidelines. These indicators focused on the number and proportion of COPD patients registered at each practice who had been diagnosed and managed according to the guidelines. Practices were also provided with information on the number and cost of COPD-related hospitalisations incurred by patients registered with their practice. In addition, practices were also provided with aggregate values for all the variables for the other practices in their PCT, as a means of benchmarking performance and encouraging improvement. These data were extracted via an information system that had been installed previously in every practice across ONEL; the system was also used to derive the outcomes measures and measures of COPD-related management costs (see below).

Note that to receive the masterclass, spirometry training and nurse mentorship interventions practices had to actively participate and as stated below not all 189 practices in ONEL did. The dashboard intervention was delivered to all practices.

The format and content of the interventions were developed by an Education Group and an Informatics Group convened specifically for the project, comprising COPD experts, local GPs and practice nurses, and informatics experts. While the interventions aimed to encourage the adoption of all aspects of the NICE COPD guidelines, they focused in particular on improving the diagnosis of COPD, since accurate diagnosis and assessment of disease severity were felt to be particularly important by local GPs and practice nurses given their impact on optimal disease management.

Measuring the cost of the interventions

We computed the costs of the masterclasses, spirometry training, nurse mentorship and dashboard from an NHS perspective, accounting for staff time and venue hire based on records of the resources used in the preparation and delivery of each intervention. For the masterclasses and spirometry training we included the cost of time of the attendees as well as those who delivered the interventions. We also included staff costs for arranging and co-ordinating the interventions. See Table 1 for details.

Outcome measures

Data used to construct the outcome measures was obtained from the same information system that was used to produce the dashboards. This system, developed by Health Analytics (www.health-analytics.co.uk), was used to extract detailed patient level information on COPD management, linking general practice records and Secondary Users Service Programme (SUS) data. The system extracts raw data from patient records, and puts it into a usable format.

Following input from the Education and Informatics Groups the following outcome measures were constructed:

1. Total COPD patients. This included all patients with COPD recorded on the practice database with a COPD management READ code ("H3…") plus patients not recorded as having COPD on their practice database but who had a COPD-related inpatient admission based on SUS records with a primary diagnosis of COPD (ICD-10 code J40-J44). The NICE COPD guidelines are intended to improve the identification of people with COPD. Hence an increase in the number of people identified as having COPD is interpreted as a positive outcome.
2. Number of recorded COPD patients with 'FEV_1 % predicted' recorded. Given the importance of FEV_1 measurements in the diagnosis and management of COPD an increase in the number of patients with 'FEV_1 % predicted' recorded is a positive outcome.
3. Number of recorded COPD patients who have had spirometry testing and the number who have had spirometry reversibility testing. The NICE COPD guidelines recommend that all diagnoses of COPD should be supported by spirometry testing but that spirometry reversibility testing was not necessary. Hence an increase in spirometry testing but not spirometry reversibility testing was deemed to be a positive outcome.
4. Number of recorded COPD patients with recorded COPD severity. The NICE guidelines state that severity assessment is important in COPD because it has implications for therapy, which affects prognosis. Hence an increase in the number of patients with a severity assessment is a positive outcome.
5. Number of recorded COPD patients with an annual review according to NICE standards. The NICE COPD guidelines state that patients with COPD should be reviewed at least once per year, and that the review should cover a range of issues including clinical assessments, smoking status, adequacy of symptom control, presence of complications, effects of drug

treatment, inhaler technique, and need for referral to specialist services. An increase in the number of patients with an annual review according to these standards is a positive outcome. Note that there is also a less stringent QOF Clinical Domain pertaining to the number of COPD patients who have had a review in the previous 15 months.

6. Number of COPD-related inpatient admissions among patients not recorded as having COPD on their practice database but who had a COPD-related inpatient admission based on a primary diagnosis of ICD-10 code J40-J44. As noted, the NICE COPD guidelines are intended to improve the identification of people with COPD, especially those with more severe disease who are more likely to require hospitalisation. Hence a decrease in this number is a positive outcome.

Measures 2-5 were based on the relevant COPD management READ codes recorded in the patient records; they were obtained for 'recorded COPD patients', recorded on the practice database with a COPD management READ code.

The measures were aggregated to the practice level and extracted for each practice on a monthly basis on the first day of each month over the period January 2010 to August 2012.

Measuring COPD-related management costs

In addition to the outcome measures, data were extracted and used to calculate the cost of COPD-related management. The following variables were used:

1. Cost of COPD-related GP visits. We extracted data on the numbers of GP consultations with a COPD management READ code. These were costed using a unit cost value of £36 per consultation based on Curtis[11], assuming that all consultations took place in the practice.
2. Cost of COPD-related practice nurse visits. We also extracted data on the numbers of practice nurse consultations, calculated as the total number of consultations with a COPD management READ code minus the number of GP consultations. These were costed using a unit cost value of £13 per consultation based on Curtis.[11] Again, we assumed that all consultations took place in the practice.
3. Cost of COPD-related primary care contacts (GP and practice nurse visits). These were calculated as the sum of 1 and 2.

4. Cost of COPD-related medications. We extracted data on the number of recorded COPD patients who were prescribed the following six types of medication each month: ICS; SABA; SAMA; LABA; LABA+ICS; LAMA. These were then costed using the mean cost of each medication type based on the current prescribing patterns and costs for COPD in primary care reported by NICE.[2] This accounted for the use of different drug preparations within each type, which were weighted by the proportion of patients treated using that preparation. We assumed that each prescription was for one month of drug therapy and applied monthly unit costs. These were: ICS £2.85; SABA £2.42; SAMA £2.30; £29.67; LABA+ICS £40.72; and, LAMA £32.94.
5. Cost of COPD-related primary care contacts and medications. These were calculated as the sum of 3 and 4.
6. Cost of COPD-related hospitalisations. These were based on the numbers of all inpatient, outpatient and A&E attendances with a primary diagnosis of ICD-10 code J40-J44 among the patients registered with each practice, based on the SUS data. This included hospitalisations among patients who were recorded as having COPD on the practice database and also among those not recorded as having COPD. The data were costed using provider specific reference costs for each type of activity. These calculations were undertaken internally within the information system and not by the researchers.
7. Total COPD-related management cost. These were calculated as the sum of 5 and 6.

Based on the NICE costing report,[2] we expect that if NICE COPD guideline were implemented the changes in prescribing patterns would increase the costs of COPD-related medications. We also expect the improvements in the management of COPD patients would reduce hospitalisation costs.

As with the outcome measures, these variables were computed at the practice level on a monthly basis, covering the duration of each month. For reporting purposes, costs reported as being incurred on the first of each month (e.g., 1 January 2012) pertain to the whole of that month (e.g., January 2012).

Analytical approach

We calculated the costs of each implementation intervention using the methods described above. We analysed the outcome measures and COPD-related management costs in two ways. First, we summed the monthly practice level data across all 189 practices in the four PCTs in ONEL to compute monthly values for the whole PCT cluster. These data are unadjusted and presented graphically using locally weighted scatterplot smoothing. Second, we ran a series of regression models where the units of observation were practice/months. We regressed each of the outcome measures and COPD-related management cost variables in each practice/month against "During" and "After" indicators for whether or not the implementation interventions were or had been delivered ("Before" was the omitted category) and 11 indicators for calendar month. The interventions were delivered between 1 April 2011 and 31 May 2012, and the data were available for the period 1 January 2010 to 30 August 2012. Hence we defined three periods: "Before", 1 January 2010 to 31 March 2011; "During", 1 April 2011 to 31 May 2012; and, "After", 1 June 2012 to 30 August 2012. We controlled for calendar month because there is evidence that COPD exacerbations are seasonal (they are more common in the Winter months) and the three time periods cover different seasons. We ran two versions of each model, with and without controlling for the total number of COPD patients in each practice/month. Given that the NICE COPD guidelines are intended, among other things, to improve the identification of people with COPD and there is a high proportion of undiagnosed disease we expect the total numbers of COPD patients to increase over time if the implementation interventions are effective. As a consequence all else equal we would expect the values of the outcomes and costs to increase over time. Controlling for the total number of COPD patients gives estimates of the outcome measures and costs as if the total number of COPD patients had remained constant. For every outcome measure and cost variable we run fixed effects (within estimator) linear models, controlling for practice fixed effects. The data were available for all 189 practices within ONEL only. Each of the individual implementation interventions was run over a specific duration and with the exception of the dashboard intervention not all practices received the interventions, and those that did receive them did not necessarily receive them at the same time. We used a before and after study design where the before and after periods were the same for every practice because while there was differential uptake and timing of some of the interventions the widespread publicity for the project and the dashboard intervention were delivered to all practices at the same time. The upshot is that the use of an adjusted before and after study design was not possible.

Results

Each masterclass was attended by a mean number of 40 GPs. Forty four GPs and 44 practice nurses attended the spirometry training course. The nurse mentorship programme ran in 80 practices. The total cost of the implementation interventions across all participating practices was £128,000 (Table 1). The masterclasses accounted for the largest proportion of the total cost (28%) followed by the nurse mentorship programme (25%), the spirometry training (24%) and the dashboards (3%). Co-ordinating the activities accounted for 20% of the total cost.

The total number of COPD patients across ONEL increased throughout the period from 11,203 (mean 59 patients per practice) in January 2010 to 13,291 (mean 70 patients per practice) in August 2012 (Figure 1). Controlling for seasonal trends and practice fixed effects, there were significantly more COPD patients per month on average "During" (around five patients more per practice) and "After" (around eight patients more) compared with "Before" (Table 2).

The number of recorded COPD patients with 'FEV_1 % predicted' recorded increased linearly over time (Figure 2). The number of patients with spirometry testing increased throughout the period, at higher rate during the second half (Figure 3). Spirometry reversibility testing increased throughout the period, at a lower rate during the second half (Figure 4). The number of recorded COPD patients with recorded COPD severity increased throughout the period, at higher rate during the second half (Figure 5); this trend was also observed for the number of recorded COPD patients with annual review using NICE standards, though the numbers are relatively low at under 1,500 (Figure 6). The number COPD-related inpatient admissions among patients not recorded as having COPD on the GP COPD register declined, especially during the second half of the period (Figure 7).

The coefficients in Table 2 are consistent with Figures 1-7. They suggest that the numbers of patients with 'FEV_1 % predicted' recorded, spirometry testing, spirometry reversibility testing, recorded COPD severity, and an annual review according to NICE standards were significantly higher on average "During" and "After" compared with "Before". These positive coefficients were obtained irrespective of whether or not the total number of COPD patients was controlled

for. The coefficients were higher when the number of COPD patients was not controlled for, suggesting that, holding the number of COPD patients constant, the likelihood of a positive outcome was higher in the "After" period and the total numbers with a positive outcome was even higher when the number of COPD patients was allowed to increase. The number of COPD-related inpatient admissions among patients not recorded as having COPD on the GP COPD register was significantly lower in the "During" and "After" periods compared with the "Before" period. Hence, the interventions improved the management of COPD patients according to NICE COPD guidelines, though as evidenced by Figure 1-7 not all patients were being managed according to the guidelines by the end of the follow-up period.

In terms of COPD management costs, Figures 8 to 11 show that the cost of primary care contacts increased over most of the period but then started to decline towards the end (Figure 8). The cost of COPD medications increased over the period but at a decreasing rate towards the end (Figure 9). The cost of COPD-related hospital contacts increased over most of the period and then declined towards the end (Figure 10) as did the total COPD-related management costs (Figure 11), which are affected in the most part by the hospital costs.

The regression results in Table 3 show that, controlling for the number of COPD patients, the cost of COPD-related GP visits was significantly higher in the "During" and "After" periods compared with the "Before" period. The cost of practice nurse visits increased during the "During" period compared with the "Before" period and then declined in the "After" period. The summed costs of the primary care contacts followed the same trend as for GP visits. The cost of COPD medications was significantly higher in the "During" and "After" periods compared with the "Before" period, as was the overall cost of COPD-related primary care contacts and medications. The cost of COPD-related hospitalisations was higher during the "During" period and then lower in the "After" period; this trend was also seen with respect to total COPD-related management costs. With respect to the coefficients for the latter, these indicate that holding the number of COPD patients constant the total monthly cost per practice was around £759 lower in the period after the implementation interventions compared with before.

Once the total number of COPD patients was not controlled for total monthly costs were higher in the "After" period compared with the "Before" period for GP visits, primary care contacts, medications, hospital contacts and total costs. They were lower for practice nurse visits.

In terms of the total COPD-related management costs, combining the results with and without controlling for total COPD patients, the findings suggest that the cost per patient declined in the "After" period compared with the "Before" period, but that the total cost increased as a result of more patients having been identified with COPD.

Two additional points are worth bearing in mind with respect to the results in Table 3. First, because we used linear regression models the coefficients for each of the cost components are additive. Second, we can use our figures to produce estimates of the total costs of COPD management. For example, using the last month of data across all of ONEL there were 13,291 patients with COPD, and the cost of COPD-related GP visits, practice nurse visits, medications, hospital contacts and total costs were £241,524, £35,561, £276,356, £2,582,015 and £3,135,463, respectively. This represents an annual total cost of £2,831 per COPD patient of which 8% is accounted for by GP visits, 1% by practice nurse visits, 9% by medications, and 82% by hospital contacts.

Discussion

The aim of this paper was to present an evaluation of the COPD 'Year in the Life' project. The objectives were to calculate the costs of a series of interventions to encourage the implementation of NICE guidelines, to analyse the impact of these interventions on meeting recommendations in the guidelines, and to assess the impact on COPD-related management costs. While not negligible the implementation interventions incurred a relatively modest cost of around £130,000. During this period there were around 13,000 COPD patients, therefore the cost per patient was around £10, noting that the interventions may affect the management of additional COPD patients in the future. Our analysis suggests that the interventions improved the management of COPD patients according to NICE COPD guidelines, with respect to diagnosis of COPD, spirometry testing, COPD severity recording and annual reviews. However, not all patients were being managed according to the guidelines by the end of the follow-up period. Our

findings also suggest that COPD-related management costs per patient fell as a result of the interventions but that costs across all patients were higher as larger numbers of patients are identified as having COPD and managed appropriately.

A limitation of the present study is that the duration of the "After" period is relatively short. Further follow-up is needed to accurately measure the impact of the interventions over a longer time frame. For example, in Figures 8, 10 and 11, other than for medications costs, the COPD management costs are declining by the end of the follow up period. Further research, with a longer time horizon, is needed to ascertain if this downward trend continues into the future. In terms of outcomes, not all patients were being managed according to the guidelines by the end of the follow-up period, though the trends were favourable. COPD guidelines are not implemented instantaneously, even with the use of interventions to encourage their adoption. Another limitation is that we used an unadjusted before and after study design. Due to the nature of the project and the interventions and the availability of data it was not possible to use an adjusted design to control for other factors that might have affected COPD management and costs during the period.

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http://www.pssru.ac.uk/project-pages/unit-costs/2011/index.php

Figure 1. Total number of COPD patients

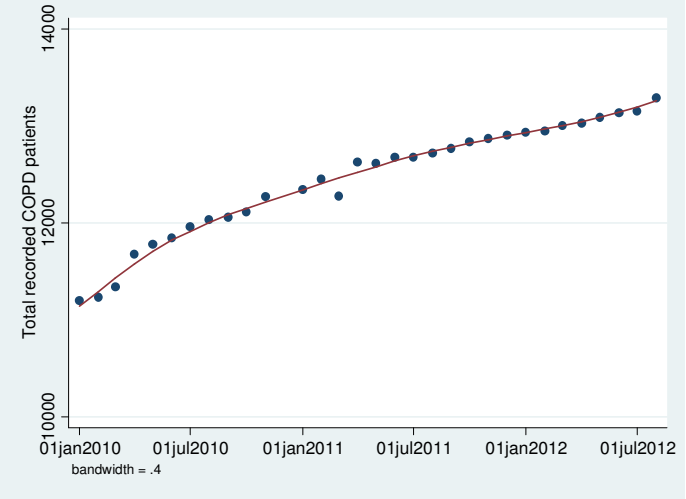

Figure 2. Number of recorded COPD patients with 'FEV1 % predicted' recorded

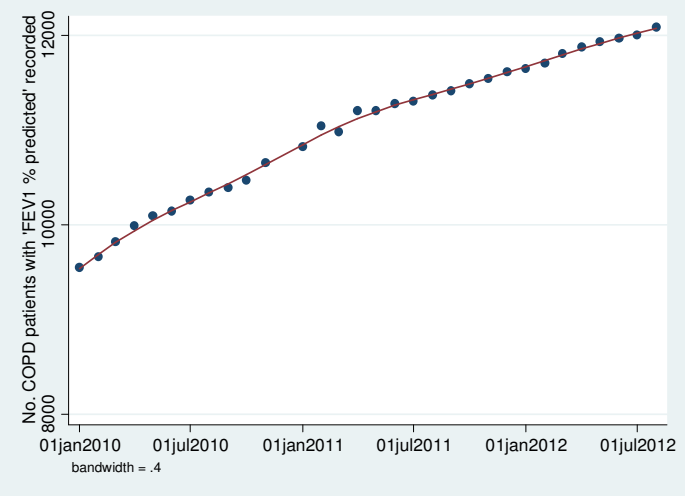

Figure 3. Number of recorded COPD patients who have had spirometry testing

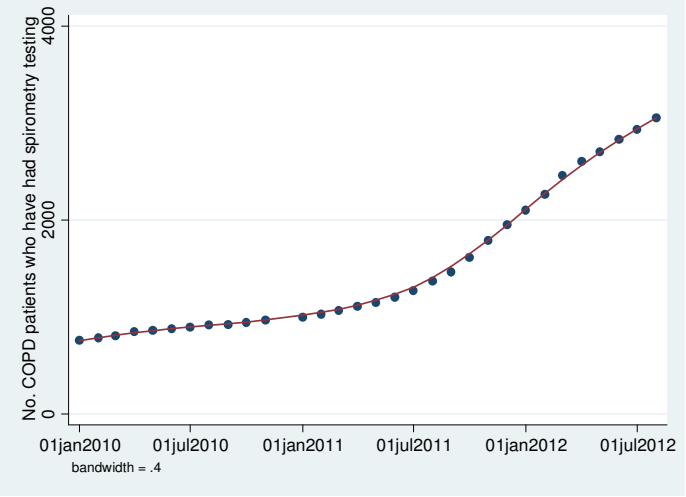

Figure 4. Number of recorded COPD patients who have had spirometry reversibility testing

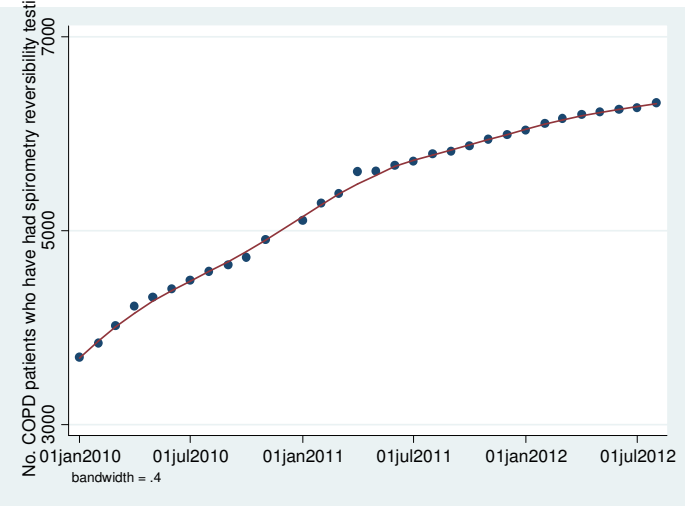

Figure 5. Number of recorded COPD patients with recorded COPD severity

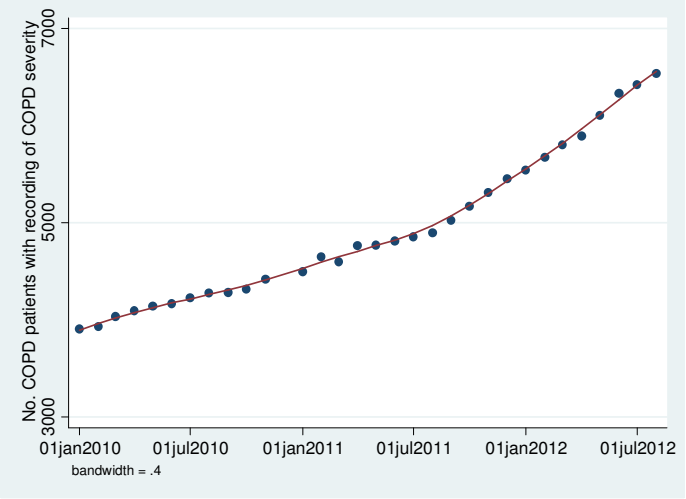

Figure 6. Number of recorded COPD patients with annual review using NICE standards

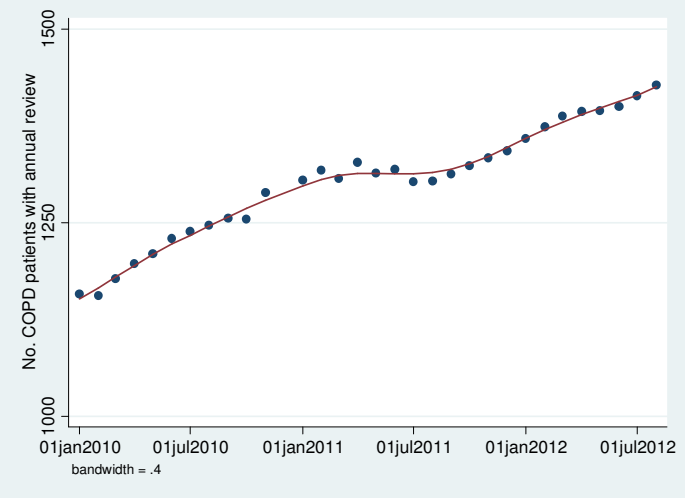

Figure 7. Number of COPD-related inpatient admissions among patients not recorded as having COPD on the GP COPD register

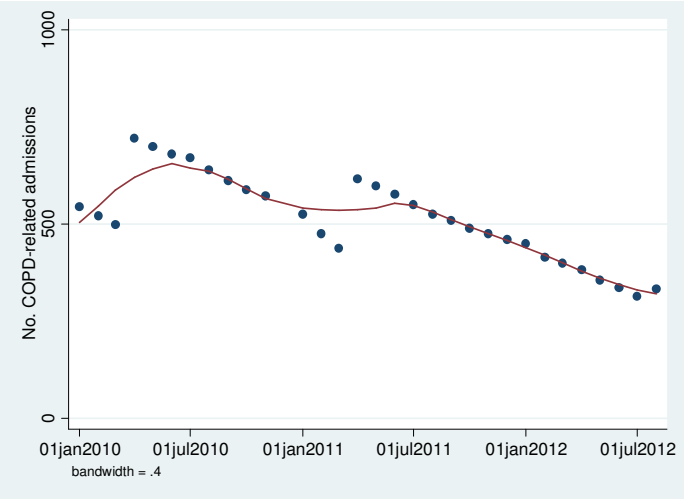

Figure 8. Cost of COPD-related primary care contacts (GP and practice nurse visits)

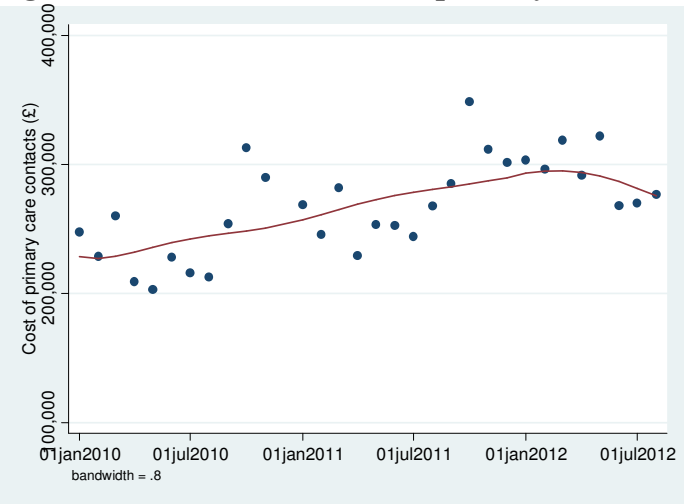

Figure 9. Cost of COPD-related medications

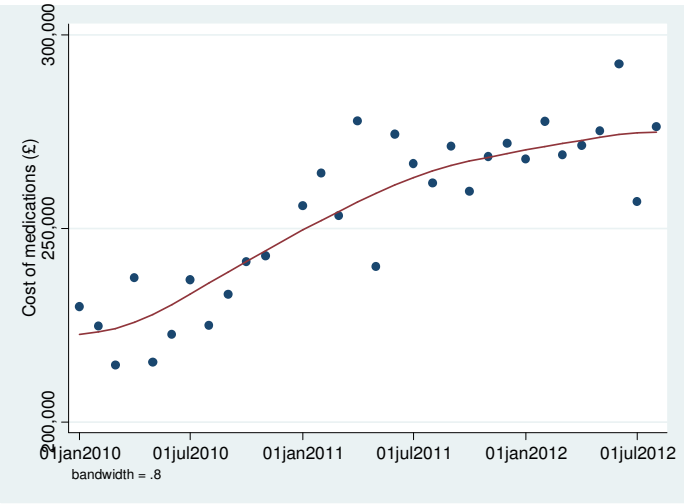

Figure 10. Cost of COPD-related hospital contacts

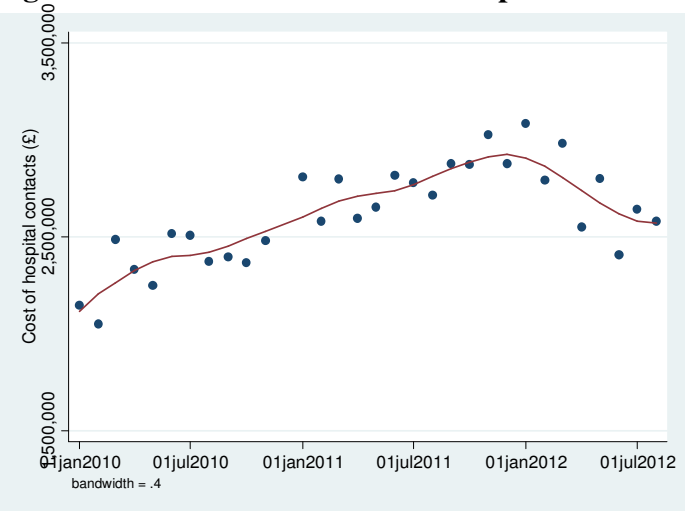

Figure 11. Total COPD-related management costs

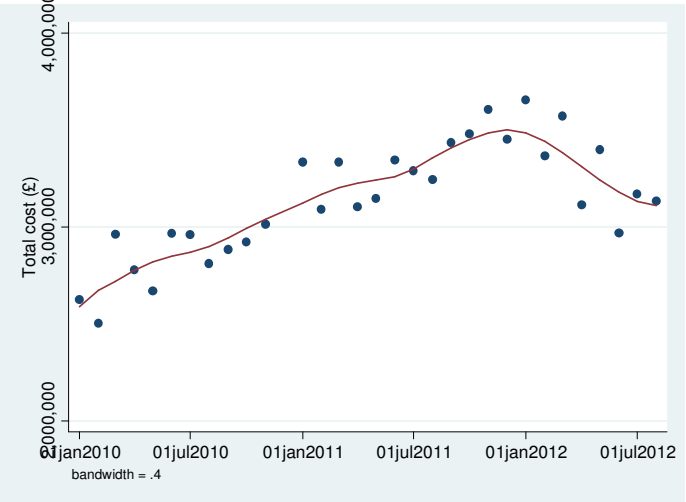

Table 1. Cost of implementation interventions

Cost component	Cost (£)	Notes
Co-ordination		
Undertaken by AfC Band 8, point 33	26,095	Annual salary (£38,851)* 1.24 to account for 10% employers contribution to NI + 14% employers contribution to superannuation; 50% FTE for 13 months
Masterclasses		
Venue hire	1,200	
Professor/Senior Consultant	2,592	4 sessions * 4 hours per session *£162 per hour based on Curtis,[11] p.203 (cost of Consultant (medical) per hour)
Nurse specialist	1,616	4 hours per session * 4 sessions *£101 per hour based on Curtis,[11] p.147 (cost of Nurse advanced per hour in surgery)
+1 hour Professor/Senior Consultant	648	4 sessions * 1 hours per session *£162 per hour based on Curtis,[11] p.203 (cost of Consultant (medical) per hour)
+1 hour Information Consultant	648	4 sessions * 1 hours per session *£162 per hour based on Curtis[11], p.203 (cost of Consultant (medical) per hour)
Total number of GP attendees (43 + 50 + 71 + 75) = 239	28,919	1 session each * 239 GPs *£121 per hour based on Curtis,[11] p.149 (cost of GP per hour of GMS activity)
Sub-total	35,623	
Spirometry training		
Venue hire	600	2 sessions at £300 each
Professor/Senior Consultant	1,296	2 sessions * 4 hours per session *£162 per hour based on Curtis,[11] p.203 (cost of Consultant (medical) per hour)
44 GPs	21,296	1 session each * 4 hours per session *£121 per hour based on Curtis,[11] p.149 (cost of GP per hour of GMS activity)
44 practice nurses	6,864	1 session each * 4 hours per session *£39 per hour based on Curtis,[11] p.146 (cost of Nurse (GP practice) per hour)
Sub-total	30,056	
Nurse mentorship		
Nurse mentor	32,320	4 hours per session * 80 sessions *£101 per hour based on Curtis,[11] p.147 (cost of Nurse advanced per hour in surgery)
Dashboard		
Prepared and circulated by AfC Band 8, point 33 (in addition to co-ordination activities)	3,733	Annual salary (£38,851) * 1.24 to account for 10% employers contribution to NI + 14% employers contribution to superannuation; assume work 41.3 weeks and 5 days per week; each output takes 2 days to prepare; 8 outputs in total
Total	127,827	

Table 2. Association between implementation of NICE guidelines and outcomes

	Model	"During"	"After"	Total COPD patients
Total COPD patients	1	5.171***	7.784***	
Number of recorded COPD patients with 'FEV_1 % predicted' recorded	2	2.040***	3.304***	0.916***
	3	6.774***	10.430***	
Number of recorded COPD patients who have had spirometry testing	2	2.981***	9.631***	0.371***
	3	4.902***	12.522***	
Number of recorded COPD patients who have had spirometry reversibility testing	2	4.301***	5.515***	0.607***
	3	7.440***	10.238***	
Number of recorded COPD patients with recorded COPD severity	2	2.993***	9.101***	0.526***
	3	5.713***	13.195***	
Number of recorded COPD patients with an annual review according to NICE standards	2	0.042	0.289**	0.102***
	3	0.568***	1.081***	
Number of COPD-related inpatient admissions among patients not recorded as having COPD	2	-0.688***	-1.892***	0.012
	3	-0.627***	-1.800***	

Notes

*** $p<0.001$, ** $p<0.05$, * $p<0.01$.

In every model there are 5936 practice/month observations and 189 practices.

All figures are coefficients showing numbers per practice per month.

Model 1: regressing Total recorded COPD patients against indicators for "During" and "After" implementation (both 1=yes, 0 otherwise) with "Before" as the omitted category, and 11 indicators for calendar month.

Model 2: regressing the variable of interest against indicators for "During" and "After" implementation (both 1=yes, 0 otherwise) with "Before" as the omitted category, 11 indicators for calendar month and Total recorded COPD patients.

Model 3: regressing the variable of interest against indicators for "During" and "After" implementation (both 1=yes, 0 otherwise) with "Before" as the omitted category, and 11 indicators for calendar month.

Table 3. Association between implementation of NICE guidelines and COPD-related NHS costs

	Model	"During"	"After"	Total COPD patients
Cost of COPD-related GP visits	1	69***	159***	23***
	2	188***	338***	
Cost of COPD-related practice nurse visits	1	43***	-45***	3***
	2	59***	-20**	
Cost of COPD-related primary care contacts (GP and practice nurse visits)	1	112***	114***	26***
	2	248***	319***	
Cost of COPD-related medications	1	82***	102***	20***
	2	184***	255***	
Cost of COPD-related primary care contacts and medications	1	194***	216***	46***
	2	432***	574***	
Cost of COPD-related hospital contacts	1	1077***	-975**	229***
	2	2261***	808**	
Total COPD-related management cost	1	1271***	-759*	275***
	2	2693***	1382***	

Notes

*** $p<0.001$, ** $p<0.05$, * $p<0.01$.

In every model there are 5936 practice/month observations and 189 practices.

All figures are coefficients showing costs (£) per practice per month.

Model 1: regressing the cost variable of interest against indicators for "During" and "After" implementation (both 1=yes, 0 otherwise) with "Before" as the omitted category, 11 indicators for calendar month and Total recorded COPD patients.

Model 2: regressing the cost variable of interest against indicators for "During" and "After" implementation (both 1=yes, 0 otherwise) with "Before" as the omitted category, and 11 indicators for calendar month.