Direct medical costs of chronic obstructive pulmonary disease: chronic bronchitis and emphysema

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In this study we aimed to estimate direct medical costs of Chronic Obstructive Pulmonary Disease (COPD) by disease type; chronic bronchitis and emphysema.

This study estimates direct costs in 1996 dollars using a prevalence approach and both aggregate and micro-costing.

A societal perspective is taken using prevalence, and multiple national, state and local data sources are used to estimate health-care utilization and costs.

Chronic bronchitis and emphysema together account for $14.5 billion in annual direct costs. Inpatient costs are greater than outpatient and emergency costs ($8.3 vs. $7.8 billion) and hospital and medication costs account for most resources spent. The high prevalence of chronic bronchitis accounts for its larger total costs ($11.7 billion) compared with emphysema ($2.8 billion). Emphysema, which is more severe, has higher costs per prevalent case ($1341 vs. $816). Hospital stays account for the highest costs, $6.0 billion for chronic bronchitis and $1.9 billion for emphysema. The hospitalization rate, length of stay and average cost per prevalent case are higher for emphysema than for chronic bronchitis. Medication costs are the second highest cost category ($4.4 billion for chronic bronchitis, $0.693 billion for emphysema).

The high hospitalization and low home care costs (0-2% of total) suggest underuse of home care and room to shift from acute to preventive care. More attention to healthcare management of chronic bronchitis and emphysema is suggested, and improving inhaler and anti-smoking compliance might be important targets.

Key words: cost; COPD; chronic bronchitis; emphysema; economics; drugs; home care.

Introduction

Chronic Obstructive Pulmonary Disease (COPD), defines a group of heterogeneous diseases characterized by chronic airway obstruction, usually chronic bronchitis and emphysema (1). It is a major cause of morbidity and mortality in the United States and constitutes a significant cost burden to society which will likely expand if the estimated 45% increase in prevalence since 1982 continues (1). The efficient allocation of resources in treating disease is a major focus of managed care organizations in their disease management process and economic studies can play an important role in resource allocation decisions on a local and national basis. Developers of new technologies for treating or testing for diseases find resource allocation information of specific diseases essential to ensure clinically useful and maximally efficient treatments. Despite the significant cost burden of obstructive lung diseases, there have been few studies of disease specific cost and existing estimates are almost a decade old (2-5). Most cost-of-illness studies examine costs by broad disease categories with the goal of prioritizing government allocation of resources among these broad areas (2,3,6). For example, the cost burden of all respiratory diseases in 1980 was $33 billion, $16-7 of which were direct costs (2). As the delivery of healthcare becomes more locally based within managed care organizations, there is a need for resource allocation decisions based on more specific disease states and costs.

Methods

DESIGN

This study estimates the annual direct medical costs of COPD (specifically chronic bronchitis and emphysema) in 1996 in the United States using a prevalence approach, both aggregate and micro-costing, and a societal perspective.
Prevalence and probabilities were estimated from national data sources and published studies of prevalence and treatment outcome. Estimates were made using International Classification of Disease version 9 (ICD-9) codes 490 and 491 for chronic bronchitis and ICD-9 492 for emphysema (7). These ICD-9 groupings follow those of the national health interview survey which is often used for prevalence estimates and are consistent with the disease classification in the other data sets used. Costs were determined by stages or severity of disease based on American Thoracic Society (ATS) criteria (1). If national estimates were not available, San Francisco area charges were used, deflating charges to cost with a cost to charge ratio (8). These estimates were then inflated to 1996 US dollars using the Consumer Price Index (CPI) inflation rates for medical care (9). If no data were available (for laboratory tests and medications), probabilities were estimated by clinicians from constructed models of resource use. This is standard practice in many disease specific aggregate estimates of cost when other data are unavailable (10–14).

DATA SOURCES

Prevalence and mortality

Prevalence of chronic bronchitis and emphysema was estimated from the 1985 to 1994 National Health Interview Surveys (NHIS) and applied to the 1996 population estimates from the U.S. census reports (15–17) and mortality was estimated from Center for Disease Control (CDC) death certificates (17,18).

Direct costs

Categories of expenditures were inpatient care (hospital stays and hospital inpatient doctor visits), outpatient care (doctor visits, laboratory tests and medications), emergency care and home and long-term care (home healthcare, including equipment and supplies; and nursing home visits).

Inpatient care

Hospital discharges were determined from the 1993 National Hospital Discharge Survey (NHDS) (19). All first-listed diagnosis stays (those determined at discharge to be responsible for the hospital admission) and any of six secondary diagnoses listed on the discharge abstract for chronic bronchitis and emphysema were included to ensure that COPD patients admitted for diagnoses other than COPD, such as infections which are attributable to COPD, are accounted for. For example, first listed diagnoses were only 43% of all diagnoses for chronic bronchitis and only 15% of all diagnoses for emphysema patients hospitalized. Including only first listed diagnoses would seriously undercount hospital costs.

Hospital costs were obtained from charges in the Healthcare Cost and Utilization Project (HCUP-3) (20). These charges were then reduced to costs using the Medicare cost to charge ratio of 0.45. Hospital physician visits were calculated using estimates based on the average hospital length of stay for each disease. Costs for these visits were obtained from the national Medicare physician fee estimates in 1996 for an initial visit, a discharge visit, and one standard visit per day during the remaining hospitalization (21).

Outpatient care

All outpatient care was estimated based on the distribution of prevalence by disease severity assuming 68–73% mild, 19% moderate and 8–13% severe disease (1). The annual proportion of ambulatory physician visits included both office-based visits from the 1993 National Ambulatory Medical Care Survey (NAMCS) and hospital outpatient visits obtained from the National Hospital Ambulatory Medical Care Survey: Outpatient Department (NHAMC-OP) (22,23). Costs were estimated using the average national Medicare fee schedule for initial and return physician visits.

The types of laboratory tests were estimated by disease severity and included spirometry, pulse oximetry, chest radiology and, for severe disease, arterial blood gases (1). The frequency of each laboratory intervention was estimated from the Canadian Thoracic Society Workshop Group (8,24,25) and costs for each procedure were estimated from a major medical center in San Francisco. There were no other sources of data on laboratory tests so these estimates are intended as a conservative estimate of average laboratory test use in the COPD population and although they represent only 3.4% of total costs, should be further validated. Sensitivity analyses were done on selected probabilities and cost estimates as well as to test assumptions about severity and compliance levels.

While several studies have estimated COPD costs (2,4,5) no public use data are available on detailed medication costs by disease. Annual drug costs were calculated by disease severity using a micro-costing approach and average wholesale price (26,27). Expert clinicians and literature assessment of the recommended standards of drug treatment for COPD by disease severity were used to model a medication resource use profile of average practice (1,24,28–32 (Table 3). The proportion of patients in each severity category differed for chronic bronchitis and emphysema patients respectively (mild: 73%, 68%; moderate: 19%, 19%; and severe: 8%, 13%). The utilization of drug treatment included vaccines, bronchodilators, antibiotics and steroids. Inhaler use was reduced by 50% based on compliance results from the Lung Health Study (33). Multidose Inhalers (MDIs) were the only delivery mode included because of their predominant use in the outpatient setting. Mucoytic agents were not included in the drug treatment costs because they are not frequently utilized in the U.S. We assumed that patients use bronchodilator therapy throughout the course of their disease, with theophylline added to the regimens for a proportion of patients with moderate and severe disease and oral
prednisone added to a proportion of those with severe disease (Table 3). Studies suggest that only 20–30% of patients with COPD improve when given chronic oral steroid therapy and that there is yet no definitive way of identifying the patients prior to treatment who will benefit from this regimen. Furthermore, the side effect profiles of steroids must be weighed against their potential benefit (34–36). Because of these limitations, the use of prednisone was applied to only one-fifth of the patients in the severe disease category, and only for acute exacerbation (Table 3). In addition, there may be a role for inhaled steroids in the management of COPD. Inhaled steroids are currently being evaluated and are sometimes used in clinical practice (1,34–36). We therefore included inhaled corticosteroids for 20% of patients in all severity categories used intermittently (50% of the time annually). To further validate our medication use profile we looked at the number of prescriptions written for emphysema and chronic bronchitis from the Scott and Levin Physicians Drug and Diagnosis Audit (PDDA) which provides information on prescriptions written in a staged sampling of about 3400 physicians and is then weighted to the population (37).

**Emergency care**

The National Ambulatory Medical Care Survey: Emergency Department (NAMCS:ED) 1993 was used to determine utilization of emergency room visits. Estimates were too low to be reliable for patients with emphysema, so the emergency use rate for chronic bronchitis was used (38). Costs per visit were calculated based on estimates of patient severity and by the intensity of care by three levels of care (35% were level 1 intensity costs, 30% level 2 and 35% level 3) from a large medical center in California.

**Home and institutional care**

Home healthcare visits were determined using the National Home and Hospice Care Survey (NHHCS) and the medical equipment, supplies and services used were obtained from a 1990 report to the Senate Committee on Aging and updated to 1996 (39,40). The medical equipment used in the home included oxygen, a walker, a hospital bed, a bedside commode and over-bed table.

The proportion of patients admitted to nursing homes for the primary diagnoses of chronic bronchitis or emphysema were obtained from the National Nursing Home Survey (NNHS) for 1995 and updated to 1996 prices (41). Medicare charges per day (reduced to costs) were used to obtain total and per patient costs (42).

**Results**

**PREVALENCE AND MORTALITY**

The age and gender specific prevalence rates of chronic bronchitis (54/1000) and emphysema (7.8/1000) were used with age and sex specific census data to estimate the 1996 prevalence of 14.3 million cases of chronic bronchitis and 2.1 million cases of emphysema (8,9). The chronic bronchitis prevalence rate per thousand has increased from 49.7 in 1985 to 54 in 1994 (Fig. 1), while the prevalence rate for emphysema has decreased slightly from 8.9 to 7.8 cases

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**Prevalence per 1000 Persons**

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>490, 491</td>
<td>Chronic Bronchitis</td>
<td>49.7</td>
<td>48.1</td>
<td>48.8</td>
<td>49.4</td>
<td>49.2</td>
<td>51.1</td>
<td>52.4</td>
<td>53.7</td>
<td>54.3</td>
<td>54</td>
</tr>
<tr>
<td>492</td>
<td>Emphysema</td>
<td>8.9</td>
<td>8.5</td>
<td>8.2</td>
<td>7.9</td>
<td>8.2</td>
<td>8.2</td>
<td>7.9</td>
<td>7.6</td>
<td>7.6</td>
<td>7.8</td>
</tr>
<tr>
<td>Total</td>
<td>Total</td>
<td>58.6</td>
<td>56.6</td>
<td>57</td>
<td>57.3</td>
<td>57.4</td>
<td>59.3</td>
<td>60.3</td>
<td>6.3</td>
<td>61.9</td>
<td>61.8</td>
</tr>
</tbody>
</table>


**Fig 1. Prevalence of chronic bronchitis and emphysema (Number per 1000 persons).** •: chronic bronchitis; ■: emphysema; ▲: total.
per thousand in that same time period. Taken together, the prevalence of COPD is 16.4 million with a slight increase in prevalence rate from 1985–1994, from 58.6 to 61.8 per thousand persons, probably reflecting the general aging of the population. The prevalence trends over time are the same by gender except for emphysema where the prevalence rate shows a slightly downward rate in males and a slightly upward rate in females. These effects may be due to changes in smoking habits of males (decreasing) and females (increasing) since 1960 (17,18).

In 1996 there were an estimated 119 340 deaths (7.3 per 100 000 population) attributable as the underlying cause to chronic bronchitis and emphysema, 2980 deaths from chronic bronchitis (1.1/100 000) and substantially more, 116 360, from emphysema (6.2/100 000) (8,17). Although the prevalence of chronic bronchitis is far greater than that of emphysema, the latter disease exacts a greater annual mortality. NCHS estimates of mortality from COPD are somewhat higher (165 000 for 1996) than reported here, but differ from ours in the exact diagnoses included (15).

Deaths from the Monthly Vital Statistics Report where the ICD-9’s match ours closely report annual deaths (101 690) close to ours for 1996 (4).

**DIRECT MEDICAL COSTS**

The annual direct medical costs of COPD is $14.5 billion in 1996 dollars (Table 1). Total inpatient costs are $8.3 billion (57% of total costs) while outpatient and emergency care costs are $5.8 billion (40% of total costs), and home and institutional care is only $0.34 billion. The largest costs are for inpatient hospital stays ($7.8 billion) which are 54% of total costs and medications ($5.1 billion) which are 35% of the total costs. Laboratory costs account for only 3.4% and outpatient physician visits account for only 1.7% of total costs. Unlike the high emergency costs for asthma, the costs of emergency room care are only 0.2% of the total costs for COPD. Surprisingly, the costs of home healthcare and nursing home care also account for only a small proportion of total direct medical costs (2.3%).

When the COPD costs are analysed separately by disease type, the higher disease prevalence of chronic bronchitis and the greater relative severity of emphysema become evident (Table 1). The annual direct medical cost of chronic bronchitis is $11.7 billion, 4.2 times more than the total costs for emphysema ($2.8 billion) which is 7 times less prevalent. The average costs per prevalent case for...
emphysema are higher ($1341) than for chronic bronchitis ($816); 64% more, demonstrating the greater severity of emphysema compared with chronic bronchitis.

**Inpatient costs**

Hospitalization stay costs were the highest cost category, $7.8 billion overall, $6.0 billion for chronic bronchitis and $1.9 billion for emphysema (Table 1). However, the average hospitalization costs per admission are higher for emphysema ($13498) than for those with chronic bronchitis ($10127). The hospitalization rate and length of stay (14.3 vs. 8.2 and 7.9 vs. 6.9 respectively) and the average cost per prevalent case ($961 vs. $441) are higher for emphysema than for chronic bronchitis (Table 2).

**Outpatient costs**

There are only 12 million physician visits annually for patients with COPD cited as the main reason for the visit (1.5 visits per prevalent case). The annual population average is 5.4 visits per person for all causes (16.31). Chronic bronchitis patients have visit costs 22 times that of emphysema patients ($240. million vs. $11 million) (Table 1). The average physician visit costs per prevalent case are also higher for chronic bronchitis than emphysema patients ($17 vs. $6) due to an annual visit rate of only 26/100 patients with emphysema. It may be that with the greater intensity of emphysema, some physician visits are being substituted with hospital visits or home care in these patients. It also may be that COPD patients who visit their physician are not coded with COPD as a reason for the visit and therefore visits may be under-counted in the NAMCS data base. However, physician visit costs are a small part of the total costs and are varied in the sensitivity analysis as discussed below.

Medication costs were the second highest cost category, $4.4 billion for chronic bronchitis and $0.693 billion for emphysema patients (Table 1). The literature does not differentiate between drugs used by patients with chronic bronchitis and emphysema and therefore we use the same drugs in our resource use profile for both diseases but vary the proportion of patients in each severity category to obtain different drug use and costs by disease. The annual cost per prevalent case for COPD is $309 (Tables 1 and 3). Costs by disease severity demonstrate that the majority of total outpatient medication costs are for those 68-73% of patients with mild disease ($2075 million). The 19% of patients with moderate disease and 8-13% with severe disease account for costs of $1809 million and $1098 million in total medication costs. The per patient increases in costs as disease severity increases are more than three times larger from mild to moderate disease and increase 1-34 times from moderate to severe disease. This is primarily because the major cost drivers are the frequency of the use of the ipratropium and albuterol inhalers. Mild patients were given only intermittent use of inhalers, to reflect use about 50% of the time annually. The addition of theophylline and prednisone which are added for treating acute disease, were introduced into the market much earlier and do not add much extra cost. Inhalers account for 84% of total medication costs for COPD despite being included in the model at only a 50% compliance rate, while other drugs plus vaccines account for only 16% of costs. Inhalers account for 100% of total medication costs for mild disease, 86% for moderate disease and 82% for severe disease. The cost of inhaled steroids amounts to only a small amount of overall COPD drug costs (3.4% or $170 million).

Outpatient laboratory costs accounted for only $.496 million, $471 million for chronic bronchitis, and $23 million for emphysema. Those with severe disease account for 50% of the visits and for about 53% of total laboratory test costs in chronic bronchitis and only 48% in emphysema patients (Table 1).

**Emergency care**

Emergency visit costs are also quite low, only 135,583 visits and $28.8 million for chronic bronchitis patients and 18,623 visits and $4.0 million for emphysema patients. The overall visit rate for COPD patients is only 0.9%.

**Home and institutional care**

Home health costs and nursing home costs account for only 1.8% of total costs. Annually, about 21,000 chronic bronchitis (69%) and 9500 emphysema patients have some

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**Table 2. Hospital inpatient utilization and costs by disease 1996, base case**

<table>
<thead>
<tr>
<th>Disease</th>
<th>No. of discharges (in thousands)¹</th>
<th>Days of care (in thousands)²</th>
<th>Length of stay (in days)¹</th>
<th>Hospitalization rate (in %)</th>
<th>Total MD visit costs (in thousands)³</th>
<th>Total cost including MD visits (in billions)²</th>
<th>Cost per prevalent case (in $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>COPD</td>
<td>1465</td>
<td>10333</td>
<td>7.06</td>
<td>8.93%</td>
<td>471</td>
<td>8.3</td>
<td>507</td>
</tr>
<tr>
<td>Chronic</td>
<td>1168</td>
<td>8142</td>
<td>6.97</td>
<td>8.15%</td>
<td>363</td>
<td>6.3</td>
<td>441</td>
</tr>
<tr>
<td>Bronchitis</td>
<td>296</td>
<td>2396</td>
<td>7.92</td>
<td>14.3%</td>
<td>107</td>
<td>2.0</td>
<td>961</td>
</tr>
</tbody>
</table>

¹ National Hospital Discharge Survey, 1993. Updated to 1996; ² Based on first-listed diagnosis; ³ Physicians Fees. Practice Management Information Corporation, (PMIC) 1996; ⁴ Numbers don’t add up due to rounding.
home care and the total home care costs are $184 million and $79 million respectively. The average cost per prevalent case for home care across all patients is only $13 for chronic bronchitis and is about three times higher ($38) for emphysema. This suggests a low usage of home care by these patients, only 0.2% for COPD overall. Only 18 per 10,000 patients with COPD have home care annually, 14 per 10,000 for chronic bronchitis patients and more (44 per 10,000) for emphysema patients.

Twenty-three thousand patients enter nursing homes annually for chronic bronchitis (16 admits/10,000 patients), and about 7000 enter due to emphysema (31 admits/10,000 patients), resulting in costs of $56 million and $17 million respectively.

When the costs for chronic bronchitis are analysed separately, the percentage of costs attributable to inpatient hospital costs decreases from 57% for all COPD to 54%, and increases to 71% for emphysema alone. Correspondingly, total outpatient costs increase from 40% for all COPD to 44% for chronic bronchitis alone and decrease to only 26% for emphysema alone. As chronic bronchitis is a chronic disease of moderate severity when compared to emphysema, it follows that the outpatient costs are greater. Medication costs are 35% of total costs for COPD, 37% for chronic bronchitis and only 25% for emphysema. Home health costs for emphysema comprise 2.8% of emphysema costs and 1.6% of chronic bronchitis costs as compared to 1.4% for home health costs for both diseases combined. The relative increase in proportion of hospital inpatient costs and home care costs for emphysema reflect the more severe nature of this disease.

### SENSITIVITY ANALYSES

We conducted sensitivity analyses on selected utilization and cost parameters to account for uncertainties. We estimated minimum and maximum case estimates using all the lowest and highest parameter estimates together to present the most extreme range (Table 4). We varied estimates using two methods. Firstly, sampling errors using standard error of estimates were calculated for national data set estimates when available. Secondly, for non-sampling errors, published ranges or clinically meaningful

### TABLE 3. COPD medication costs by drug and severity of disease (23,28–32,46,47)

<table>
<thead>
<tr>
<th>No. Pts. (in millions)</th>
<th>Total Costs Per Year (in millions) ($)</th>
<th>Cost Per Patient ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Vaccines</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Influenza Vaccine x 1</td>
<td>16.4</td>
<td>47.8</td>
</tr>
<tr>
<td>Pneumococcal Vaccine x 1</td>
<td>16.4</td>
<td>33.6</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>81.4</td>
</tr>
<tr>
<td>B. Mild Disease (68–73% of Total)</td>
<td>11.9</td>
<td>1026.6</td>
</tr>
<tr>
<td>Ipratropium MDI (12 puffs/day)</td>
<td>11.9</td>
<td>659.9</td>
</tr>
<tr>
<td>Albuterol MDI Prn, (6 puffs/day)</td>
<td>11.9</td>
<td>298.3</td>
</tr>
<tr>
<td>MDI Spacer x 1</td>
<td>2.4</td>
<td>90.2</td>
</tr>
<tr>
<td>Beclomethasone, dble str., ¼ of pts.</td>
<td>11.9</td>
<td>2075</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Moderate Disease (19% of Total)</td>
<td>3.1</td>
<td>808.6</td>
</tr>
<tr>
<td>Ipratropium MDI (12 puffs/day)</td>
<td>3.1</td>
<td>693.0</td>
</tr>
<tr>
<td>Albuterol MDI (12 puffs/day)</td>
<td>3.1</td>
<td>78.3</td>
</tr>
<tr>
<td>MDI Spacer</td>
<td>0.8</td>
<td>170.8</td>
</tr>
<tr>
<td>Theophylline (300 mg BID) ¼ of pts.</td>
<td>1.6</td>
<td>11.0</td>
</tr>
<tr>
<td>10 day course of antibiotics ¼ of pts.</td>
<td>0.6</td>
<td>47.4</td>
</tr>
<tr>
<td>Beclomethasone, dble str. ¼ of pts.</td>
<td>3.1</td>
<td>1809.1</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Severe Disease (8–13% of Total)</td>
<td>1.4</td>
<td>551.0</td>
</tr>
<tr>
<td>Ipratropium MDI (18 puffs/day)</td>
<td>1.4</td>
<td>314.8</td>
</tr>
<tr>
<td>Albuterol MDI (12 puffs/day)</td>
<td>1.4</td>
<td>35.6</td>
</tr>
<tr>
<td>MDI Spacer</td>
<td>0.7</td>
<td>155.2</td>
</tr>
<tr>
<td>Theophylline (300 mg BID) ¼ of pts</td>
<td>0.7</td>
<td>9.0</td>
</tr>
<tr>
<td>10 day course of antibiotics ¼ of pts</td>
<td>0.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Prednisone 40 mg taper ¼ pts</td>
<td>0.3</td>
<td>32.3</td>
</tr>
<tr>
<td>Beclomethasone, dble str. ¼ of pts</td>
<td>1.4</td>
<td>1098</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>5064</td>
</tr>
</tbody>
</table>

TOTAL MEDICATION COSTS 5064 309
ranges when those were not available, were used to vary parameters for the low and high cases.

NHIS data on prevalence are derived from a population sample and therefore are subject to sampling error, as well as to non-sampling error. We calculated approximate standard errors (se) of the prevalence rates of 0.879 and 95% confidence intervals between 52 and 56 per 1000 for chronic bronchitis and SE of 0.334 and 95% confidence intervals between 7.15 and 8.45 per 1000 for emphysema. This results in a range of 1996 prevalence between 13.8 to 14.8 billion for chronic bronchitis and between 1.9 to 2.2 billion for emphysema. Changes in prevalence caused a range in total costs from ($14.1–$15.2 billion).

**Inpatient care**

Hospitalization rates will vary depending on estimates of the reason for the hospital admission between a minimum where only first-listed diagnosis as reason for hospitalization is selected, to a maximum when all admissions with any listed diagnoses attributable to COPD are included. Therefore we varied the number of NHIS hospital visits included from the all-listed diagnoses data of the NHIS from 25–75% of the diagnoses, which changed the hospitalization rate from 6.98–10.89% for COPD but more than doubled the rate for emphysema patients (8.9%–19.7%). Costs of total hospitalization ranged from $6.6–10.4 billion for COPD; $5.1–7.4 billion for chronic bronchitis, and from $1.2–2.7 billion for emphysema (Table 4).

**Outpatient care**

Physician visits can also be affected by reason for visits and thus were varied by increasing and decreasing the number of visits by 25%. This change caused only a ±1% change in total outpatient care costs from the base case (Table 4).

Changes in laboratory costs also had only a small effect on total costs. We varied both the total number of visits and the proportions of patient severity upon which we estimated the number and extent of laboratory tests. The range in total laboratory test costs was from $364 million to $969 million for COPD.

Medication costs were already conservatively estimated and thus the base case was also used for the low case estimates. We varied the severity proportions from 8–16% in the severe category of chronic bronchitis and from 13–26% for emphysema at the expense of those with mild disease. This resulted in an increase in intensity of medication use and costs; from $5.1–5.9 billion ($4.4–5.1 billion for chronic bronchitis and from $693–855 million for emphysema patients). Emergency department visits were varied also by changing the proportion of disease severity. These changes were small and varied emergency visit costs from $26.9–35.5 million.

**Home health and nursing home care**

We varied the lengths of time patients received home healthcare visits using the low and high ranges provided in the data for home care visits. This caused a change in home care costs per episode from $218–290. The total annual cost per patient receiving home health care ranges from $7100–9500, while the average cost per patient based on disease prevalence ranges was low, from $13–18. The standard error for nursing home visits was 995 with a 95% confidence interval between 31,432 and 28,070 visits. Because undercoding due to comorbidities is also a source of error in nursing home costs, we varied them at a greater rate than this sampling error variance. Nursing home costs were varied by 25% in both directions and varied from $54.2–90.4 million for both diseases. Table 4 summarizes the effects of all the sensitivity analyses in a low and high case. There is a 14–24% change from the base case to the low and high cases, respectively.

### Table 4. Sensitivity ranges: total direct costs—1996

<table>
<thead>
<tr>
<th></th>
<th>Base case (costs in millions)</th>
<th>Low case (costs in millions)</th>
<th>High case (costs in millions)</th>
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<tr>
<td>Total hospital inpatient costs</td>
<td>8312</td>
<td>6630</td>
<td>10,419</td>
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<tr>
<td>Hospital stays</td>
<td>7841</td>
<td>6270</td>
<td>9856</td>
</tr>
<tr>
<td>Physicians visits</td>
<td>471</td>
<td>360</td>
<td>563</td>
</tr>
<tr>
<td>Total outpatient care costs</td>
<td>5812</td>
<td>5617</td>
<td>7198</td>
</tr>
<tr>
<td>Physicians visits</td>
<td>252</td>
<td>189</td>
<td>315</td>
</tr>
<tr>
<td>Labs</td>
<td>496</td>
<td>364</td>
<td>968.6</td>
</tr>
<tr>
<td>Medications</td>
<td>5064</td>
<td>5064</td>
<td>5914</td>
</tr>
<tr>
<td>Total emergency care costs</td>
<td>32.8</td>
<td>26.9</td>
<td>35.5</td>
</tr>
<tr>
<td>Total home health costs</td>
<td>263</td>
<td>218</td>
<td>290</td>
</tr>
<tr>
<td>Total nursing home costs</td>
<td>72.3</td>
<td>54.2</td>
<td>90.4</td>
</tr>
<tr>
<td>Total direct costs</td>
<td>$14,492</td>
<td>$12,546</td>
<td>$18,032</td>
</tr>
</tbody>
</table>

COPD: ICD-9 #490, #491, #492
Discussion

This study demonstrates that chronic bronchitis and emphysema are a significant cost burden to society, which together accounted for $14.5 billion in direct costs in 1996. Rice estimated that the costs of all respiratory diseases in 1980 accounted for $16.7 billion in direct costs ($43 billion in costs when inflated to 1996), so these two diseases account for 34% of this total (2). Another study of COPD costs estimated $9.6 billion in direct care expenditures in 1991 ($12.6 billion in 1996 costs) (5). Our costs are higher due primarily to increasing disease prevalence, a more detailed estimate of drug costs, and also the inclusion of a wider range of causes for admission in determining hospital costs. The major categories of cost are hospital stay costs ($7.4 billion) which are 54% of total costs and medications ($5.1 billion) which are 40% of the total costs. This demonstrates both the long chronicity of these diseases, whose major treatment is with medications, as well as the severity of the disease in its later stages which leads to hospitalizations with respiratory failure, pneumonia, pneumothorax and cor pulmonale.

The disease specific cost calculations demonstrate the wide variation in costs between chronic bronchitis and emphysema. The higher total costs of chronic bronchitis are due primarily to its higher prevalence, while the higher per patient costs of emphysema, especially for hospitalization and home care, demonstrate the greater severity of this disease. These differences are lost when costs are calculated for respiratory diseases as a whole, as has been done in most of the cost literature. Disease specific cost studies are valuable for understanding where the major cost burden lies for each disease.

This paper demonstrates the predominance of hospitalizations and medications in the care of COPD patients. Medications were the second largest cost category, yet the high costs of medications for COPD treatment has not been demonstrated previously with most studies of cost not providing detailed estimates of drug cost. The medication estimates made in this paper were based on resource use profiles of drug use by disease severity and type of drug. Aggregate data on actual drug use should be examined to validate our estimates, but available national data are too old (NMES) or incomplete (NAMCS). To validate our medication profiles, we examined the Scott and Levin PDDA physician audit data on prescriptions written for diagnoses of emphysema and chronic bronchitis. The PDDA data are very similar to the IMS Corporations National Disease Therapeutic Index (NDTI) data but are collected slightly more frequently and have a refill variable. These data do not provide information on the time a person is on each drug for each prescription and thus are not directly comparable to our model. However, it appears that the relative use of the major drug categories were similar to our model. The Scott and Levin data indicated that there may be less drug use overall than our data demonstrate because, for example, there were only 1,270,000 prescriptions annually for emphysema drugs. If this prescription number is applied to our prevalence data for emphysema (2.1 million), then there is just over one prescription annually for every two people with the disease. This seems quite low. As with much of the existing prescription based drug data bases, these data are limited due to differences in ICD-9 definitions (using only first diagnosis for physician visit, for example, will miss many prescriptions written for these patients with a related diagnosis and emphysema). Further, the Scott and Levin data consist of only physician visit prescriptions which could exclude refills, use of mail order pharmacies, and visits to other physicians. All of these potential limitations may cause these types of data to seriously under-count drugs, especially for chronic diseases. Therefore, modeled data such as ours may be a better estimate of average actual drug utilization per patient. We recommend that more attention be paid to medication cost estimates in general, in cost of illness studies. Much of the high drug cost burden for elderly patients on Medicare may fall on the patients themselves since Medicare generally does not cover drugs. Until drug data bases are more widely available, micro-costing estimates could be made based on resource use profiles such as those provided here, especially for diseases where drugs are the major focus of treatment. These estimates can then be validated for parts of the population with single institution patient surveys or managed care data bases, when available.

Hospitalizations are the highest category of cost. Better treatments and or disease management programs may be able to reduce these hospitalizations as the high cost of hospitalization combined with the low use of home care suggests a potential to shift costs out of the hospital to the home with better patient management. The low use of home care is surprising in a disease where rehabilitation programs and healthy lifestyle are an important part of treatment and where drug compliance is low. It has been demonstrated that home care can reduce the initial LOS of inpatients greater than 65 years old by 3-4 days and clinic visits by 6-2 days per patient (5). Increasing home care or other outpatient treatment programs may improve drug compliance, help decrease smoking and promote respiratory and physical fitness. Although the low use of home healthcare may be a problem with diagnosis coding, it may also signify that more attention could be paid to disease management in the home in an effort to improve patients clinical condition and reduce the need for hospitalizations.

This study has several limitations, primarily due to biases inherent in the use of secondary data bases and the use of modeling. Prevalences derived from the NHIS data base are subject to response bias to the extent that patients under- or over-report symptoms in response to open ended questions, or the frequency with which coders miscode diseases into appropriate ICD-9s. A study which estimates probabilities of response bias in the NHIS demonstrated that elderly tend to underestimate their illness and that the chronic diseases were generally under coded (16).

Comorbidities also pose a significant problem in making estimates of chronic disease costs from secondary data bases. It is standard practice to make some adjustment downward to account for multiple diseases but the factor of adjustment for each disease has not been determined. In this study, we attempted to adjust for comorbidities by
careful selection of patients from the data sets and definitions for inclusion. This will maximize our accuracy but also omits other respiratory ICD-9s which may have a component of chronic bronchitis.

We were also limited in estimating disease specific costs in some cases where the sample size was too low to provide reliable estimates and in cases where there was data only for COPD resource use, which was then assumed to apply to both chronic bronchitis and emphysema. Finally, there were some areas for which there were no reliable data available to us. We attempted to include these categories of resource use, by combining information from expert clinicians (for medications) and proportional estimates available for either COPD as a whole or by using chronic bronchitis estimates for emphysema (for home health and nursing home care) to better reflect population based estimates. Although we recognize that medication resource use models are estimates and do not represent all patients, we do not intend this as a recommended treatment. Instead we tried to capture average treatment patterns currently in use. We used sensitivity analysis to estimate both lower and higher estimates of all variables to partially account for these uncertainties. We have presented a conservative estimate of costs and our sensitivity ranges can further bound the case base estimates.

In conclusion, chronic bronchitis and emphysema pose a significant cost burden to society. Hospitalizations and medication costs account for most of the costs. Per patient costs demonstrate the higher disease severity of emphysema patients and the higher volume related costs associated with chronic bronchitis. This paper provides a method for estimating drug costs based on a micro-costing approach using a medication resource use profile which may be preferable to the secondary data sources used in most other cost of illness studies which estimate costs based on non-disease specific sales figures or incomplete physician office based prescription estimates. Models are frequently used to make estimates in cost studies when other data are unavailable (10–14). The low rates of home care may be a signal that these patients are not receiving enough preventative care. Much attention has been focused by clinicians in managed care organizations on the treatment of asthma to increase quality of care and decrease costly emergency visits and hospital admissions (43–45). The same attention has not been focused on COPD. We suggest the initiation of disease management protocols which would focus on COPD chronic disease management in the home; including smoking cessation programs, and medication assessment and compliance programs. As has been seen with asthma, such interventions may shift care and costs of COPD from the hospital to home.

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