ORIGINAL ARTICLE

Health Care Spending on Respiratory Diseases in the United States, 1996–2016

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Abstract

Rationale: Respiratory conditions account for a large proportion of health care spending in the United States. A full characterization of spending across multiple conditions and over time has not been performed.

Objectives: To estimate health care spending in the United States for 11 respiratory conditions from 1996 to 2016, providing detailed trends and an evaluation of factors associated with spending growth.

Methods: We extracted data from the Institute of Health Metrics and Evaluation's Disease Expenditure Project Database, producing annual estimates in spending for 38 age and sex groups, 7 types of care, and 3 payer types. We performed a decomposition analysis to estimate the change in spending associated with changes in each of five factors (population growth, population aging, disease prevalence, service usage, and service price and intensity).

Measurements and Main Results: Total spending across all respiratory conditions in 2016 was $170.8 billion (95% confidence interval [CI], $164.2–179.2 billion), increasing by $71.7 billion (95% CI, $63.2–80.8 billion) from 1996. The respiratory conditions with the highest spending in 2016 were asthma and chronic obstructive pulmonary disease, contributing $35.5 billion (95% CI, $32.4–38.2 billion) and $34.3 billion (95% CI, $31.5–37.3 billion), respectively. Increasing service price and intensity were associated with 81.4% (95% CI, 70.3–93.0%) growth from 1996 to 2016.

Conclusions: U.S. spending on respiratory conditions is high, particularly for chronic conditions like asthma and chronic obstructive pulmonary disease. Our findings suggest that service price and intensity, particularly for pharmaceuticals, should be a key focus of attention for policymakers seeking to reduce health care spending growth.

Keywords: health economics; health policy; health expenditures

Respiratory diseases are among the leading contributors to the burden of disease in the United States (1). Two population-based studies project that the burden of respiratory diseases will only accelerate, driven largely by chronic respiratory diseases (2, 3). Coupled with this high burden is a high amount of health care spending (4). The United States spends more on health care than any other country in the world without better outcomes (5, 6). Spending on respiratory diseases is no exception. However, currently

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Data sharing: Data are available for download at https://ghdx.healthdata.org/ihme_data. Data can be explored interactively at https://vizhub.healthdata.org/dex/.

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At a Glance Commentary

Scientific Knowledge on the Subject: Previous estimates of respiratory disease spending in the United States have been limited to single conditions, such as asthma or chronic obstructive pulmonary disease, with methodologic heterogeneity between studies. Furthermore, most studies focus on short time periods. As a result, comparisons across conditions, between studies, and over time are challenging.

What This Study Adds to the Field: In this study, we produced detailed, disaggregated estimates of spending for 11 respiratory conditions in the United States by demographic group, type of care, and payer type. We described trends over time and conducted a decomposition analysis to identify the association of five factors (population size, population age, disease prevalence, service usage, and service price and intensity) with spending growth. Our findings can help guide future resource allocation and policies set by decision-makers.

available estimates of spending on respiratory diseases, while providing an important starting point, provide an incomplete overview because of limitations. Existing studies are either on the basis of older estimates or are limited to specific diseases, which can lead to double counting of spending when not adjusting for comorbidities (4, 7–10). Among recent efforts to produce better health care spending estimates, the DEX (Disease Expenditure Project) is unique, providing comprehensive estimates of U.S. health care spending from 1996 to 2016 (11). However, no study has used DEX findings to provide a detailed analysis of spending on respiratory disease, such as how this spending varied by demographic group, how it changed over time, and how various factors drove spending growth.

The objective of this study was to provide the most comprehensive description of U.S. health care spending on respiratory diseases to date. We describe spending estimates of 11 different respiratory disease conditions from 1996 to 2016, with further characterization by type of care, payer, and demographics. We also measure the association between five factors and changes in spending over time: population size, population age, disease prevalence, service usage, and service price and intensity. Determining spending patterns and drivers of spending growth is critical to guiding research and health policy priorities for respiratory diseases in the United States.

Methods

We used data from the 2016 DEX produced by the IHME (Institute for Health Metrics and Evaluation). The methods and framework for the DEX project have been provided in detail elsewhere (11, 12). An overview is provided here. DEX was reviewed and approved by the University of Washington institutional review board, but because the data were from a deidentified database, the requirement for informed consent was waived.

Data

DEX estimates 85.2% of all U.S. health care spending from 1996 through 2016. These estimates are disaggregated by 154 health conditions, 7 types of care, 3 payer types, and 38 age and sex groups. Types of care include ambulatory care, inpatient care, prescribed retail pharmaceuticals, nursing care facilities, emergency department care, dental care, and general administration. Dental care was excluded for the purposes of this study as dental care is not typically a part of treatment for respiratory conditions. The goods and services included in each type of care category are defined in detail in the online supplement. Payer-type categories are public insurance (which includes Medicaid, Medicare, Veteran's Affairs, and spending by other Federal and local programs), private insurance, and out-of-pocket spending. The areas of U.S. health care spending that fall outside the scope of DEX estimates are home health care, durable equipment and nondurable medical products (including over-the-counter medications), government public health activities, and investments such as research and development.

The DEX method for generating health care spending estimates involved extracting microdata from household surveys, public and private insurance claims databases, and administrative records to obtain national encounter-degree spending and length of stay information. The data sources encompassed 5.9 billion unique insurance claims, 150.4 million emergency and outpatient visits, 1.5 billion inpatient and nursing care facility bed-days, and 5.9 million prescribed retail pharmaceuticals (Table E1 in the online supplement). These data were aggregated and formatted to fit within one data framework so that they all conformed to the same demographic groupings, payer categories, and health conditions. The 154 health condition categories were on the basis of the GBD (Global Burden of Disease) study, using the ICD (International Classification of Disease) 9 and 10 mapping methodology developed by the GBD project (13). Mapping is a process by which the thousands of existing ICD diagnosis codes associated with health data are assigned to a set of specific health conditions. Once the data were formatted accordingly, several data adjustments were made to address data limitations before the final step of scaling the results to the federally produced NHEA (National Health Expenditure Accounts). Because the various microdata sources used do not provide a comprehensive view of health care spending because of bias and incomplete sampling, scaling the microdata estimates to match the NHEA estimates ensured that final DEX estimates did not over or underestimate overall aggregate spending. An additional explanation of the DEX method, including how data adjustments and scaling were performed, is available in the online supplement and published in detail elsewhere (11).

Two specific data adjustments in the DEX method are particularly pertinent to spending on respiratory conditions. First, spending estimates were adjusted for comorbidities using a regression-based technique (11). Second, data on specialty drug spending from the consulting firm IQVIA were collected to refine the estimates of spending on prescribed retail pharmaceuticals. Specialty drugs are used in several respiratory conditions, and specialty drug spending is often missed in datasets that rely on national samples because they are relatively uncommon. The methodology behind these two adjustments is addressed in the online supplement.

For this study, we focused on the 11 respiratory conditions (Table 1) among the 154 total disease conditions reported in the DEX project. The disease condition "other chronic respiratory diseases" is an aggregate

category that includes miscellaneous respiratory diseases such as inhalational exposures and upper airway conditions (such as larynx, nasal, and allergic diseases). The ICD9 and ICD10 code mapping for each of the 11 respiratory conditions is available in Tables E3 and E4. On the basis of the GBD mapping system, certain respiratory conditions with multiorgan involvement, such as cystic fibrosis, sleep disorders, and pulmonary hypertension, were mapped to other organ systems and were not included in this analysis. Similarly, by including tuberculosis as an important respiratory infection, extrapulmonary tuberculosis codes were also included by default because of GBD mapping. In addition, 60 of the 1,372 ICD10 codes mapped to respiratory diseases were misclassified as tracheal, bronchus, and lung cancers instead of other nonrespiratory cancers. Exploration of this misclassification showed that inpatient care for females for tracheal, bronchus, and lung cancers was initially estimated to be $0.4 billion greater than it should have been in 2016 and $0.1 billion greater than it should have been in 2015, with all other categories and years unaffected. The initially overestimated spending on inpatient care of tracheal, bronchus, and lung cancers was adjusted by multiplying through correction factors derived from the underlying data to correct for this misclassification. More detail is provided in the online supplement.

Statistical Analysis

This study describes spending trends and factors associated with changes in respiratory disease spending. The statistical analysis for these evaluations is described here. First, we examined time trends in spending by respiratory condition. Estimates were reported as aggregated spending in 2016 by respiratory disease, age, sex, type of care, and payer. To evaluate changes in spending, the annualized rate of change can be calculated between any two points in time (t_1 and t_2) with the following equation (14, 15):

$$\text{Annualized rate of change} = \left(\left(\frac{Spending_{t_2}}{Spending_{t_1}}\right)^{\left(\frac{1}{t_2-t_1}\right)} - 1\right) \times 100$$

We measured annualized rate of change in spending between 1996 (t_1) and 2016 (t_2).

Second, to determine the factors associated with changes in spending, five factors were evaluated using a decomposition analysis. The decomposition analysis method was first described by Das Gupta and later used to study health care spending by Dieleman and colleagues (12, 16). The five factors were *1*) population growth; *2*) population aging; *3*) disease prevalence; *4*) service usage; and *5*) service price and intensity. These factors were chosen on the basis of prior literature implicating them as potential causes for spending growth in the United States (17–20). Additional details of how all factors were defined and how the decomposition analysis was performed are available in the online supplement.

Third, we conducted a subanalysis to estimate spending attributable to smoking for chronic obstructive pulmonary disease (COPD) and trachea, bronchus, and lung cancers. These two respiratory conditions were selected because of established and strong attributable risks from smoking (21, 22). Attributable spending was calculated using previously described methods and is detailed in the online supplement (23).

Estimation of uncertainty for all analyses was performed by bootstrapping and is described in the online supplement. Statistical analysis was performed using Stata version 13.1 (StataCorp), R version 3.31 (R Foundation), and Excel (Microsoft). All spending was adjusted for inflation before modeling. All estimates are reported in 2016 U.S. dollars.

Table 1. List of Respiratory Conditions Included for Analysis

Respiratory Condition
Other chronic respiratory diseases
Asthma
Chronic obstructive pulmonary disease
Lower respiratory tract infections
Upper respiratory tract infections
Trachea, bronchus, and lung cancers
Interstitial lung disease and sarcoidosis
Tobacco intervention
Tuberculosis
Pneumoconiosis
Whooping cough

Results

Spending Patterns in 2016

Total health care spending on respiratory conditions was $170.8 billion (95% confidence interval [CI], $164.2–179.2 billion) in 2016. Spending was highest among those aged 65 and older, who accounted for $57.9 billion (95% CI, $54.5–61.8 billion) in total respiratory spending, or 33.9% (95% CI, 32.1–35.7%) of total respiratory spending. Comparing differences by sex, spending was highest among females ($98.2 billion [95% CI, $93.3–104.0 billion]), accounting for 57.5% (95% CI, 55.5–59.6%) of total respiratory spending. Examined by type-of-care services, spending was highest for ambulatory care, accounting for 34.1% (95% CI, 31.6–36.3%), or $58.2 billion (95% CI, $53.2–63.4 billion) of spending, followed by inpatient care (22.7% [95% CI, 21.0–24.84%], $38.8 billion [95% CI, $35.3–42.0 billion]) and pharmaceutical care (18.9% [95% CI, 17.6–20.5%], $32.3 billion [95% CI, $29.9–34.6 billion]). A total of $17.2 billion (95% CI, $16.5–18.1 billion) or 10.1% (95% CI, 9.9–10.2%) was spent on general administration. Examined by payer type, public insurance accounted for the highest percentage of total spending (46.8% [95% CI, 43.5–49.2%], $80.0 billion [95% CI, $75.3–84.0 billion]). Private insurance represented a similar proportion of spending (46.2% [95% CI, 43.9–49.2%], $78.9 billion [95% CI, $73.2–87.4 billion]), followed by out-of-pocket spending (7.0% [95% CI, 6.2–8.0%], $11.9 billion [95% CI, $10.6–13.8 billion]). Figure 1 highlights estimated spending stratified by age group, type of care, and respiratory disease condition. We also include detailed pediatric (age less than 20 yr) spending estimates in Table E5. In addition, estimates and figures reported here can be explored interactively at https://vizhub.healthdata.org/dex/.

Spending by Respiratory Condition in 2016

Conditions with the highest spending were the following categories in descending order: aggregated category of other chronic respiratory diseases, asthma, COPD, lower respiratory tract infections (LRTI), and upper respiratory tract infections (Table 2). Spending on asthma constituted 20.8% (95% CI, 19.2–22.4%) of spending on respiratory diseases, totaling $35.5 billion (95% CI, $32.4–38.2 billion) in 2016, and spending on COPD made up 20.1% (95% CI, 18.6–21.9%) of this spending at $34.3 billion (95% CI, $31.5–37.3 billion). In asthma, the most expensive type of care was prescribed pharmaceuticals, with an estimated $17.0 billion (95% CI, $15.3–18.6 billion) of spending, or 48.0% (95% CI, 43.9–51.7%) of asthma spending. In COPD, spending for pharmaceuticals ($9.8 billion [95% CI,

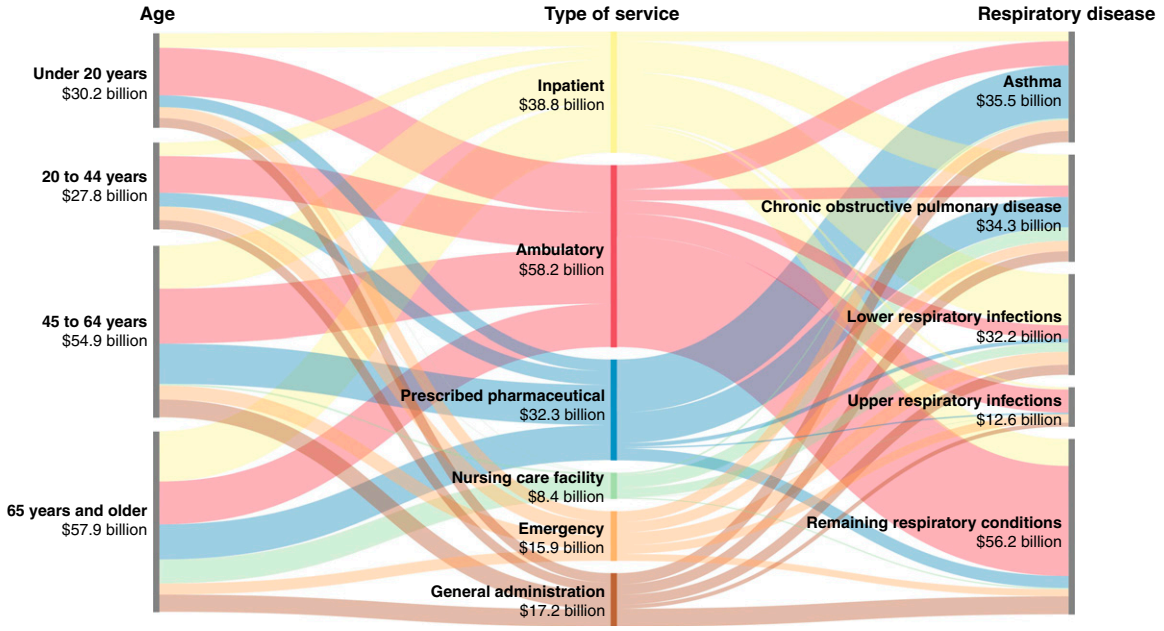

Figure 1. Total respiratory health care spending in the United States by age group, condition, and type of health care, 2016. Reported in 2016 U.S. dollars. Each of the three columns sums to the estimated $170.8 billion of 2016 respiratory spending disaggregated in this study. The width of each line reflects the relative share of the estimated $170.8 billion attributed to that age group, type of service, or respiratory condition.

$8.6–11.3 billion]) and inpatient care ($9.9 billion [95% CI, $8.2–11.7 billion]) were similar. Together, these two types of care were 57.3% (95% CI, 54.2–60.4%) of total COPD spending. COPD spending was concentrated among adults aged 45 years and older (96.4% [95% CI, 95.9–96.8%) and predominantly paid for by public funders (69.8% [95% CI, 63.2–77.4%]). In contrast, asthma spending was more evenly distributed across the lifespan, and most spending was by private payers (51.5% [95% CI, 47.1–55.3%]). Table 2 provides a full list of spending estimates for each respiratory condition in 2016, and Table E6 provides spending per case for each respiratory condition for patient-degree estimates.

Changes in Spending, 1996–2016

Spending on respiratory diseases increased by $71.7 billion (95% CI, $63.2–80.8 billion) between 1996 and 2016, representing an annualized growth rate of 2.7% (95% CI, 2.4–3.1%). Of the demographic groups evaluated, patients aged 45–64 had the largest increase in spending ($29.3 billion [95% CI, $25.5–33.2 billion]) and the highest annualized rate of spending growth (3.9% [95% CI, 3.4–4.3%]). Among the types of care analyzed, emergency care spending growth outpaced other categories, increasing at 6.2% annually (95% CI, 5.6–6.8%) and by $11.1 billion (95% CI, $10.0–12.1 billion). However, ambulatory care and prescribed pharmaceuticals both contributed to higher absolute increases in spending over time. Ambulatory care increased by $25.2 billion (95% CI, $19.7–30.4 billion) and at an annualized rate of 2.9% (95% CI, 2.4–3.4%). Prescribed pharmaceutical spending increased by $15.1 billion (95% CI, $12.7–17.8 billion) and at an annualized rate of 3.2% (95% CI, 2.8–3.7%). The conditions with the largest increases included spending on tobacco intervention (5.8%; 95% CI, 4.4–7.0%), pneumoconiosis (5.4%; 95% CI, −0.4 to 8.6%), asthma (4.4%; 95% CI, 3.9–4.9%), and COPD (4.0%; 95% CI, 3.3–4.7%). Table 2 provides a full list of annualized spending growth rates by condition. Among all respiratory conditions, asthma and COPD were the individual conditions that contributed the largest absolute increases in spending between 1996 and 2016, with a $20.6 billion (95% CI, $17.8–23.3 billion) increase and an $18.6 billion (95% CI, $15.4–21.9 billion) increase, respectively. Figure 2 demonstrates trends in spending for select respiratory conditions, subcategorized by type of care. Comparing changes in spending between payer types, spending increased the most for public payers (3.8%; 95% CI, 3.4–4.3%) from 1996 to 2016, followed by private payers (2.4%; 95% CI, 1.8–2.9%). Out-of-pocket spending decreased slightly (−0.4%; 95% CI, −1.1 to 0.4%) (Table E7).

Factors Associated with Changes in Spending Over Time, 1996–2016

Across all the respiratory conditions included in the decomposition analysis, we observed increasing service price and intensity as the factor associated with the largest change in spending, accounting for an 81.4% (95% CI, 70.3–93.0%), or $50.4 billion (95% CI, $44.5–56.7 billion) increase in 2016 compared with 1996. The association between the factors studied and changes in spending varied by condition and type of care (Figure 3). Spending on prescribed retail pharmaceuticals accounted for the majority of the spending increase in both asthma and COPD. This increase was associated with rising pharmaceutical prices, alone responsible for a 76.0% (95% CI, 67.4–85.1%), or a $10.3 billion (95% CI, $9.0–11.6 billion), increase in spending on asthma, and a 37.8% (95% CI, 29.8–46.2%), or $4.6 billion (95% CI, $3.7–5.4 billion), of additional spending for COPD. The increase in spending on LRTI was concentrated on inpatient and emergency care, which in turn was strongly associated with increasing price and service intensity. For example, increasing spending per bed-day treating LRTI was associated with 27.1% (95% CI, 13.6–44.4%), or $5.6 billion (95% CI, $2.9–9.1 billion), higher spending, largely

Table 2. Total Respiratory Health Care Spending in the United States by Condition for 2016

Respiratory Spending Condition	Respiratory Spending, 2016 $billion (95% CI)		Annualized Rate of Change, 1996–2016% (95% CI)		Proportion of Spending across Age Groups, Type of Payer, and Type of Care (%)												
					Aggregate Age Group, yr				Type of Payer			Type of Care					
					<20	20–44	45–64	65+	Public	Private	Out-of-pocket	Inpatient	Ambulatory	Nursing Care Facility	Prescribed Pharmaceuticals	Emergency	General Administration
All respiratory diseases	170.8	(164.2 to 179.2)	2.7	(2.4 to 3.1)	17.7	16.3	32.1	33.9	46.8	46.2	7.0	22.7	34.1	4.9	18.9	9.3	10.1
Other chronic respiratory diseases	45.0	(39.4 to 50.1)	2.7	(2.0 to 3.4)	22.6	24.0	33.7	19.7	26.9	65.0	8.1	4.9	72.3	0.2	8.0	4.3	10.3
Asthma	35.5	(32.4 to 38.2)	4.4	(3.9 to 4.9)	22.1	20.9	36.0	21.1	41.4	51.5	7.1	8.6	21.9	1.5	48.0	9.9	10.1
Chronic obstructive pulmonary disease	34.3	(31.5 to 37.3)	4.0	(3.3 to 4.7)	0.6	3.0	32.8	63.6	69.8	24.2	6.0	28.8	10.6	12.7	28.5	9.7	9.7
Lower respiratory tract infections	32.2	(28.7 to 35.9)	1.2	(0.5 to 1.8)	17.0	14.7	28.5	39.8	56.0	37.6	6.4	51.2	12.8	9.3	3.9	12.9	9.9
Upper respiratory tract infections	12.6	(11.3 to 13.9)	1.6	(0.9 to 2.4)	50.2	21.7	17.3	10.9	37.0	54.3	8.7	6.3	58.1	0.3	3.6	21.7	10.0
Trachea, bronchus, and lung cancers	6.6	(5.7 to 7.5)	0.5	(−0.4 to 1.4)	0.5	5.1	35.3	59.1	63.4	32.8	3.8	57.5	23.6	2.8	3.0	1.8	11.3
Interstitial lung disease and sarcoidosis	2.1	(1.8 to 2.5)	2.5	(4.4 to 7.0)	1.5	9.5	42.1	47.0	57.4	38.4	4.2	62.8	24.4	2.4	0.2	0.1	10.1
Tobacco intervention	1.9	(1.5 to 2.3)	5.8	(4.4 to 7.0)	2.2	24.7	50.9	22.2	48.5	43.5	8.0	55.5	22.3	2.7	0.9	8.8	9.9
Tuberculosis	0.5	(0.4 to 0.6)	−0.9	(−1.6 to 0.6)	14.9	29.6	28.4	27.2	53.4	33.2	13.5	47.7	39.2	3.6	0.5	0.0	9.1
Pneumoconiosis	0.2	(0.1 to 0.3)	5.4	(−0.4 to 8.6)	1.7	2.6	17.8	78.0	63.6	32.0	4.4	12.3	76.4	1.0	0.2	0.0	10.0
Whooping cough	0.03	(0.02 to 0.04)	−2.1	(−3.9 to 0.4)	84.6	9.5	5.9	0.0	60.2	37.1	2.7	82.6	0.0	0.0	0.0	7.2	10.3

Definition of abbreviation: CI = confidence interval.

outweighing the cost savings associated with fewer bed-days per incident case, a 28.5% (95% CI, 19.0–44.1%), or $5.9 billion (95% CI, $3.6–9.7 billion) decrease.

We observed decreased service usage across all respiratory conditions included in the decomposition analysis. For inpatient care, fewer bed-days per prevalent or incident case of respiratory disease was associated with a 57.2% (95% CI, 49.3–66.6%), or $17.2 billion (95% CI, $14.1–21.2 billion), decrease in spending from 1996 to 2016. For ambulatory care, fewer visits per prevalent or incident case were associated with a 65.9% (95% CI, 48.5–84.2%), or $11.8 billion (95% CI, $8.8–15.0 billion), decrease in ambulatory spending on respiratory conditions. These savings were offset by increasing service price and intensity. We did not observe a decrease in service usage for prescribed retail pharmaceuticals (Figure 3). Detailed results of the decomposition analysis are available in Table E9.

Spending Attributable to Smoking

In 2016, $15.3 billion (95% CI, $14.0–16.6 billion) of the $34.3 billion (95% CI, $31.5–37.3 billion) spent on COPD was attributed to smoking. For trachea, bronchus, and lung cancers, $4.5 billion (95% CI, $3.9–5.2 billion) of the $6.6 billion (95% CI, $5.7–7.5 billion) spent was attributable to smoking (Table E10).

Discussion

U.S. health care spending on respiratory diseases totaled $170.8 billion in 2016 and grew by 2.7% annually between 1996 and 2016. This spending represents 6.3% of total U.S. health care spending in 2016 (11). The growth rate of spending on respiratory diseases is less than the total U.S. health care spending growth rate, estimated at 4.0% (11). Spending was highest for asthma, COPD, and the aggregate category of other chronic respiratory diseases. Spending by public payers increased more rapidly than by private payers.

Our study contributes to the existing literature by providing a comprehensive overview of respiratory disease spending in the United States, with detailed spending trends over a 21-year period. For common conditions such as COPD and asthma, in which there are existing economic estimates in the literature, our estimates are not

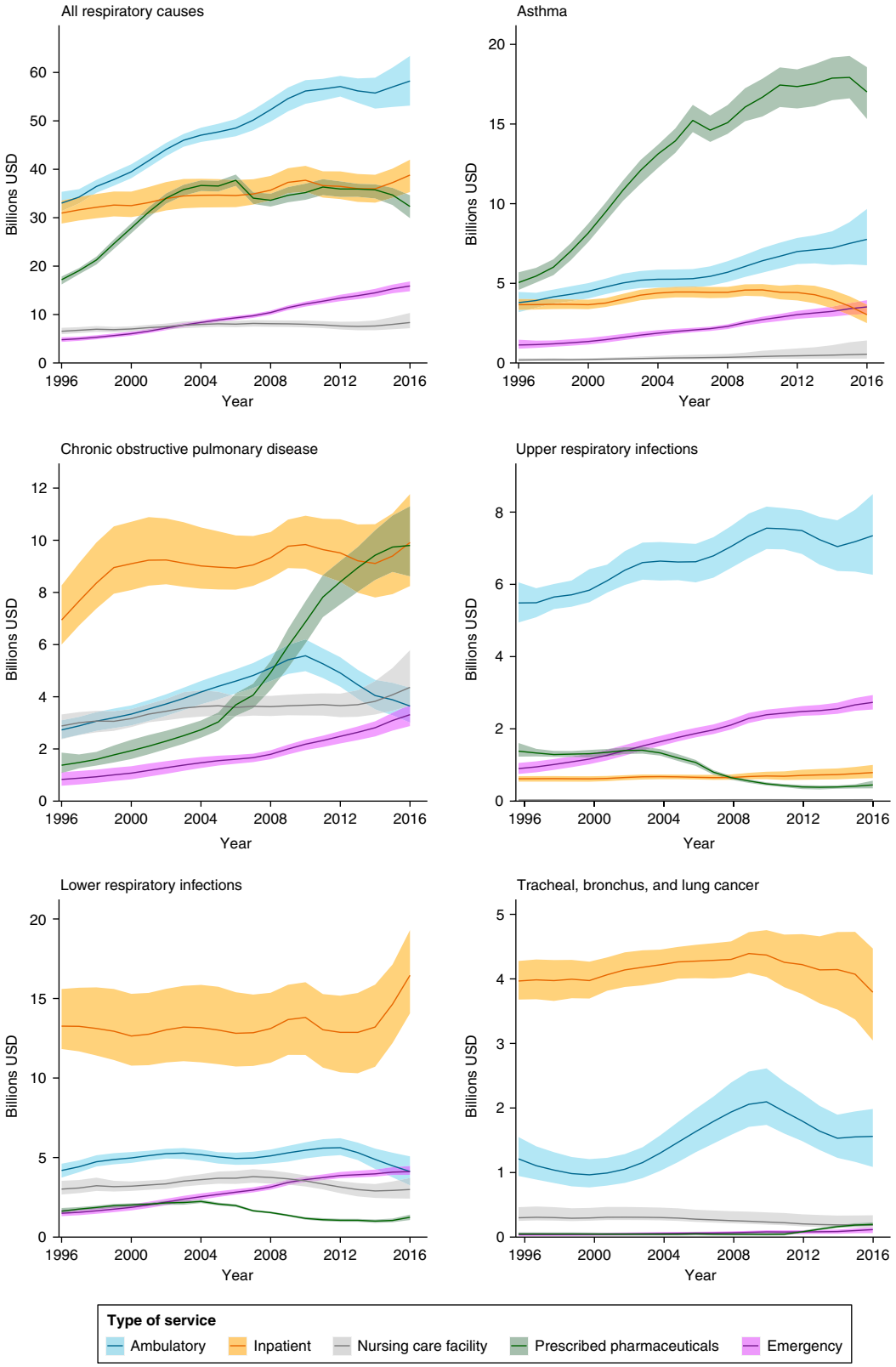

Figure 2. Total health care spending in the United States across time for all respiratory conditions and the five respiratory conditions with the greatest absolute increases in annual spending from 1996 to 2016. Reported in 2016 U.S. dollars. Each panel shows spending changes over time for a respiratory condition, disaggregated by type of care. Each colored line within a panel represents the mean estimate for a given type of care. Shaded areas indicate uncertainty intervals.

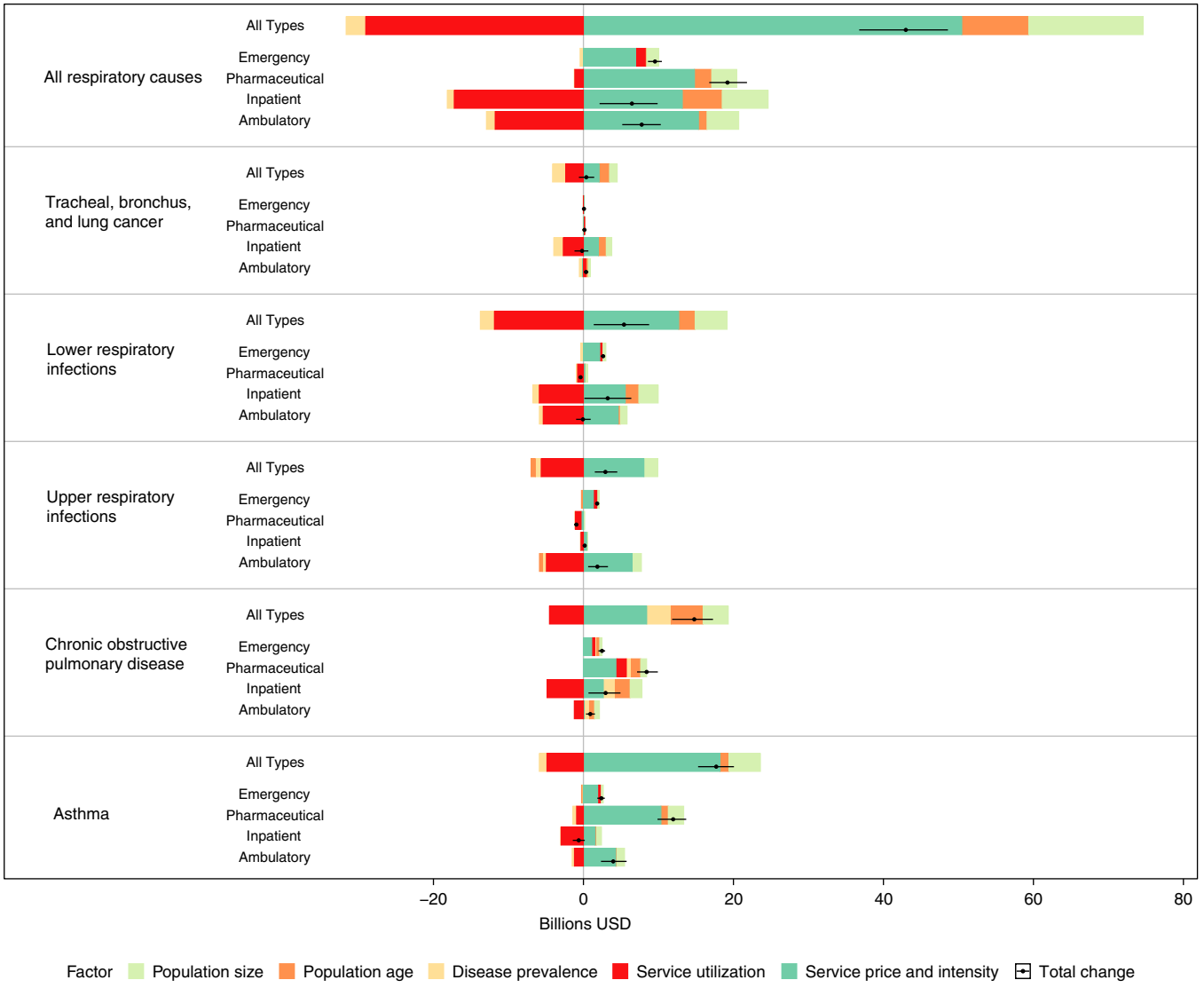

Figure 3. Five-factor decomposition of changes in total spending from 1996 to 2016 for all respiratory conditions and the five respiratory conditions with the most spending in 2016. Reported in 2016 U.S. dollars. Each color corresponds to one of five factors and reflects the amount of spending change associated with that factor. Colored bars to the left of the vertical line (no change) indicate factors associated with decreased spending; to the right of the line, factors associated with increased spending within that type of care. Within each type of care, the sum of the five colored bars equals the total spending change, 1996 through 2016, indicated with a black marker. Error bars indicate uncertainty intervals of the total spending change.

directly comparable to other published work because of differences in measurement (spending vs. costs), methodology (e.g., comorbidity adjustment), and the breadth of data sources used in our study (8, 9, 24, 25). Despite these differences, estimates in our study are similar in magnitude to other published estimates. For example, a 2015 study estimated that direct medical costs for COPD in 2010 were $32.1 billion (9).

Over the 21-year period evaluated, a notable pattern that emerged is the increase in respiratory spending on prescribed pharmaceuticals. Spending in this category grew at an annualized rate of 3.2% and increased by a total of $11.1 billion. More striking is that among the two conditions with the highest spending (COPD and asthma), pharmaceutical care accounted for both the highest annualized growth rate and the largest absolute increase in spending. The growth in pharmaceutical spending for asthma and COPD also appears to remain constant throughout the study period. This growth likely offset reductions in pharmaceutical spending in other conditions, leading to relatively stable aggregate pharmaceutical spending across all respiratory conditions in the latter half of the study period, from 2004 to 2016. Our decomposition analysis suggests that price was most strongly associated with spending increases on pharmaceuticals. Price increases can likely be attributed to inhalers, which became more expensive over time with minimal clinical

innovation, driven by extended patent protections on new delivery devices, new combination inhalers, and the 2008 change from chlorofluorocarbon to hydrofluoroalkane propellants (26–29). Asthma care has also benefited from new biologic medications with high drug prices, but these medications are unlikely to be a key driver of spending compared with inhalers as they are used in a minority of cases (30). Interestingly, increased spending was not seen in interstitial lung disease or tracheal, bronchus, and lung cancers, for which there are new high-cost medications available (e.g., antifibrotics for interstitial lung disease and immune checkpoint inhibitors for cancer) (31, 32). Because these new medications were approved around 2014–2015, there was likely insufficient drug adoption to be reflected in our study period (33). We expect that including these newer medications in future iterations of DEX will lead to significant increases in pharmaceutical spending.

Another major trend observed in the decomposition analysis from 1996 to 2016 is that spending associated with inpatient and ambulatory service usage decreased across all respiratory conditions. There are several possible reasons for the observed decrease. First, changes in health care delivery such as higher enrollment in capitated payment insurance plans (34, 35), the implementation of health policy innovations such as accountable care organizations and value-based purchasing (36, 37), and provider market consolidation (38) all may exert negative pressure on usage. Second, clinical advances may have led to decreased usage in certain respiratory conditions. For example, for LRTI, new medications (e.g., oseltamivir) (39), new pneumococcal vaccines (e.g., 13-valent pneumococcal vaccine) (40), and increased vaccination rates over time may have contributed to decreased service usage (41).

Although spending associated with service usage decreased, spending because of changes in service price and intensity increased for inpatient and ambulatory care. Our findings are consistent with established evidence that high prices are an important driver of high U.S. health care spending (5, 42). Multiple health care market forces likely explain the rise in service price and intensity, such as provider market consolidation (43), increased patient complexity (44), adoption of new medical technologies (45), and changes in coding practice (46, 47). Importantly, while an aging population is sometimes characterized in the popular media as a major trend affecting spending growth (48), in respiratory conditions, our decomposition analysis suggests that this plays a minor role compared with service price and intensity.

Finally, we estimated that administrative costs account for 10% of total expenditure. This estimate is consistent with other estimates of U.S. health care administrative costs, such as the 8% estimated by Papanicolas and colleagues (5). These authors also estimated that other high-income countries only spend 1–3% of health care expenditures on administrative activity. Improving administrative efficiency in the fragmented U.S. health care system is needed to reduce health care spending or redistribute resources to improve patient care more directly.

Our study has important policy implications. First, to decrease spending growth, policymakers must continue to focus on health care prices for both pharmaceuticals and health care services. Pharmaceuticals warrant particular attention as the category that underwent the largest relative spending increase because of price. Negotiating lower prices and leveraging the purchasing power of large payers such as Medicare is one proposed approach (49, 50). Second, our study suggests that service usage and service price and intensity should be targeted simultaneously when designing policy interventions to reduce spending growth. We observed that lower service usage between 1996 and 2016 was counterbalanced by higher service price and intensity. As such, policies that aim to contain health care costs by targeting usage alone, such as the Hospital Readmission Reduction Program, are unlikely to achieve spending reductions. Most likely, a multifaceted approach is necessary. Third, our subanalysis on spending attributable to smoking provides supporting economic evidence that continued efforts to reduce existing tobacco use and prevent new uptake of tobacco remain critical to reducing respiratory disease spending.

This study has significant strengths. These include a regression-based comorbidity adjustment to avoid double counting of spending, multiple data sources as inputs, and detailed subcategorization of spending by payer, type of care, age, and sex (10). Despite these strengths, there are several limitations. First, although many data sources were used in this study, the estimates presented are ultimately limited by the quality of the underlying inputs. Although many of the included surveys and datasets have national reach, they are not nationally representative because of the fragmentation of the U.S. health care system and exclude certain portions of the U.S. population. Second, additional subcategorization of spending that could further guide health policy and priorities, such as geography and race, was not possible in this study. Third, the reliance on administrative data precludes easy measurement of disease severity. As such, we are unable to draw conclusions on the relationship between the severity of illness and spending for any given respiratory condition.

There are two main limitations that relate specifically to respiratory conditions. First, spending on durable medical equipment (DME) was not included in our estimates. Given that DME, such as oxygen, nebulizers, and home positive airway pressure devices, contribute significantly to respiratory care costs, our estimates are likely an underestimation (51, 52). We intend to include DME spending in future iterations of DEX. However, to provide an estimate of the potential magnitude of DME spending, we performed a back-of-the-envelope calculation of home oxygen spending in COPD, which suggests that around $1 billion could have been spent on this type of DME in 2016 among those aged 65 and older. The assumptions used for the back-of-the-envelope calculation are explained in the online supplement. Second, there were limitations in our ICD 9 and 10 mapping. As outlined in the methods section, some diseases considered respiratory conditions were mapped to other nonrespiratory conditions on the basis of the ICD 9 and 10 mapping methodology developed by the GBD study and adapted for the DEX project (13). Some conditions, such as cystic fibrosis and pulmonary hypertension, are resource-intensive to treat and have groundbreaking but expensive medications available for treatment. Excluding these conditions leads to an underestimation of respiratory disease spending in the United States. We also

suspect that evolving and heterogenous ICD coding practices for lung cancer screening, a test that can result in significant downstream spending, means that the effects of this expanding screening practice may be only partially mapped to the respiratory conditions and ICD codes we evaluated (53, 54). This effect would again underestimate spending.

Conclusions

Health care spending in the United States on respiratory conditions increased significantly from 1996 to 2016. The spending increase was most associated with higher service price and intensity, which supports policy reforms targeting prices as an important approach to containing spending growth. ■

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