



Attributable Cost of Adult Hospitalized Pneumonia Beyond the Acute Phase

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Abstract

Background While much is known about the cost of community-acquired pneumonia (CAP) during the acute phase of illness, little is known about the potential attributable cost of CAP thereafter.

Objective The aim of this study was to assess long-term attributable costs associated with CAP among adults in US clinical practice.

Methods A retrospective matched cohort design and data from a US private healthcare claims repository were employed. In each month during the study period (2011–2016), adults who were hospitalized for CAP in that month (‘CAP patients’) were matched (1:1, without replacement) on demographic, clinical, and healthcare profiles to adults who did not develop CAP in that month (‘comparison patients’). All-cause healthcare expenditures were tallied for the qualifying CAP hospitalization and during the 30-day period post-discharge (collectively, ‘acute phase’), as well as from the end of the acute phase to the end of the 3-year follow-up period (‘long-term phase’).

Results The study population included 43,975 matched pairs of CAP patients and comparison patients. Expenditures averaged \$33,380 (95% confidence interval [CI] \$32,665–\$34,161) for the CAP hospitalization and \$4568 (95% CI \$4385–\$4749) during the 30-day period thereafter (vs. \$2075 [95% CI \$1989–\$2167] in total for the comparison patients). During the long-term phase, all-cause expenditures averaged \$83,463 (95% CI \$81,318–\$85,784) for CAP patients versus \$51,017 (95% CI \$49,553–\$52,491) for comparison patients, and thus attributable expenditures during this phase totaled \$32,446 (95% CI \$29,847–\$35,075). The majority of attributable CAP expenditures (53% of \$68,319) occurred during the acute phase, while 21%, 14%, and 12% occurred during the first, second, and third years, respectively, after the acute phase.

Conclusions Our findings provide additional evidence that the cost of CAP requiring hospitalization is high, and that the impact of CAP extends well beyond the expected time for resolution of acute inflammatory signs.

1 Introduction

Community-acquired pneumonia (CAP) is an acute infection of the pulmonary parenchyma that is acquired outside of a healthcare setting, and is a leading cause of morbidity and mortality worldwide [1]. According to data from the National Hospital Discharge Survey, 257,000 US adults aged 45–64 years and 621,000 US adults aged \geq 65 years

were admitted to hospital for pneumonia in 2010, and the total cost of pneumonia to the US healthcare system was estimated at \$14 billion in 2008 [2, 3].

The risk of CAP, and corresponding short-term clinical consequences, among US adults have been documented to increase markedly with age, as well as the presence of chronic medical conditions such as chronic obstructive pulmonary disease (COPD), coronary heart disease (CHD), and diabetes [4–6]. Not surprisingly, the short-term economic consequences of CAP among US adults have also been reported to be substantial and to increase with the complexity of the patients’ comorbidity profile [2, 6–11].

However, little is known about the long-term clinical and economic consequences of CAP among US adults, that is, CAP-related consequences beyond the acute phase of illness and over a multi-year period. Available evidence suggests that CAP patients may have prolonged elevated risks of death and exacerbations of underlying conditions (e.g.

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Key Points for Decision Makers

While acute costs of community-acquired pneumonia (CAP) requiring hospitalization (\$35,873) are notably high, attributable downstream (i.e. long-term) costs (\$32,446) are commensurate.

Costs attributable to CAP (acute phase + long-term phase) are highest among patients aged 50–64 years (\$88,002) and those who are at high-risk of CAP-related complications (\$97,914).

Across all age and risk subgroups, acute and long-term attributable costs exceeded \$43,692.

COPD, heart failure), as well as increased medical costs beyond the acute phase [8, 12–15]. However, available evidence is based on data that are now over a decade old, did not differentiate between the short-term versus long-term burden of illness, and/or did not evaluate long-term clinical and economic consequences among US adults on an overall basis as well as within subgroups defined on important characteristics (e.g. age, comorbidity profile). Therefore, a new study was undertaken to assess the long-term attributable costs associated with CAP among adults in US clinical practice.

2 Materials and Methods

2.1 Study Design and Data Source

This study employed a retrospective matched cohort design and data from a large integrated US private healthcare claims repository—the IBM® MarketScan® Commercial and Medicare Supplemental Databases (‘MarketScan Database’). The Commercial Database contains healthcare claims (i.e. medical [facility and professional service] and outpatient pharmacy claims) information for employees of large self-insured corporations as well as their spouses and dependents, along with data from a few commercial health plans. The Medicare Supplemental Database contains healthcare claims information (including Medicare and employer-sponsored plans) for Medicare-eligible retirees, and includes only plans where both the Medicare-paid amounts and employer-paid amounts are available. Participating plans are located throughout the US, and provide health benefits to > 15 million persons annually.

Data available from each facility and professional service claim include dates and places of service, diagnoses (International Classification of Diseases, Ninth Revision,

Clinical Modification [ICD-9-CM] and International Classification of Diseases, Tenth Revision, Clinical Modification [ICD-10-CM]), procedures performed/services rendered (ICD-9-CM, ICD-10-CM, Healthcare Common Procedure Coding System [HCPCS]), discharge disposition (inpatient facility claims), and quantity of services (professional service claims). Data available for each outpatient pharmacy claim include the drug dispensed, dispensing date, dose, quantity dispensed, and number of therapy days supplied. Medical and pharmacy claims also include amounts paid (i.e. reimbursed) by health plans and patients to healthcare providers for services rendered. Selected demographic and eligibility information is also available.

All data can be arrayed longitudinally to provide a detailed chronology of medical and outpatient pharmacy services used by each plan member over time. The MarketScan Database was de-identified prior to its release to study investigators, and its use for research described herein was thus compliant with the Health Insurance Portability and Accountability Act (HIPAA) Privacy Rule and federal guidance [16].

2.2 Source Population

The source population comprised all persons aged ≥ 18 years who, during the study period (2011–2016), had comprehensive health benefits for 1 or more days. Because the presence of certain conditions could confound study results (e.g. due to systematic differences in unobserved factors between CAP patients and matched counterparts, and their relative importance vis-à-vis cost consequences), persons who had evidence of major organ transplantation (i.e. lung, heart, kidney, liver, or bone marrow) at any time during this period were excluded from the source population (Online Resource 1).

2.3 Study Population

Beginning with January 2011, and on a monthly basis thereafter through the end of the study period (i.e. December 2016), all adults aged ≥ 18 years who were hospitalized for CAP were identified in the source population based on the following criteria:

- Admission to an acute-care hospital for the treatment of CAP;
- Continuous and comprehensive health benefits during the 1-year period prior to the CAP hospitalization; and
- No evidence of pneumonia (irrespective of care setting) during the prior 1-year period, excluding the 30-day period immediately before the qualifying (‘index’) CAP hospitalization.

CAP hospitalizations were identified based on acute-care hospital facility claims with a principal diagnosis of pneumonia (irrespective of secondary diagnoses) or a principal diagnosis of bacteremia or respiratory failure, and a secondary diagnosis of pneumonia (Online Resource 2). To refine the identification of CAP, patients who may have had hospital-acquired pneumonia, based on the presence of a separate hospital admission for any reason during the 7-day period prior to the qualifying hospitalization, were excluded from consideration. Non-invasive CAP hospitalizations (defined as a principal diagnosis of pneumonia, no secondary diagnoses of bacteremia/meningitis) were identified for additional analyses.

Each ‘CAP patient’ in that month was matched to one ‘comparison patient’ from the source population in the same month, irrespective of whether the comparison patient had evidence of CAP in a subsequent month. Matching was implemented for each CAP patient by first identifying all ‘candidate’ comparison patients who, during the 1-year period prior to the CAP hospitalization (i.e. for the CAP patient), had comprehensive health benefits and no evidence of pneumonia, as well as the same age, sex, risk profile, comorbidity profile, and pre-index levels of healthcare utilization. From all such candidates, one candidate was randomly selected for matching and was included in the study population. For each matched pair, the admission date for the CAP hospitalization was designated as their ‘index date’. Once matched, both the CAP patient and the comparison patient were included in the study population and removed from the source population. The same process was repeated for each subsequent calendar month using the pool of patients remaining in the source population after matching in prior months.

Risk profiles were determined based on the presence of selected chronic (at-risk) conditions and immunocompromising (high-risk) conditions, which were identified based on corresponding diagnosis codes, procedure codes, and/or drug codes that were recorded during the 1-year period prior to and including the index date (Online Resources 3 and 4). Healthy persons included those without any of the at-risk or high-risk medical conditions. Comorbidity profiles included CHD, COPD, diabetes, liver disease, malignancy, and renal disease. Levels of healthcare utilization were ascertained during the 1-year period prior to the match month, and included the number of hospitalizations (0, 1, 2, ≥ 3), hospital days (0, 1–5, 6–10, ≥ 11), and ambulatory encounters (0, 1–4, 5–9, ≥ 10).

2.4 Study Measures

All-cause healthcare expenditures were tallied from the index date through the end of the 3-year follow-up period, and were segmented as follows: index CAP hospitalization

(from admission date through discharge date for each CAP patient, and for the same number of days from index date for the corresponding comparison patient); from the end of the index CAP hospitalization through the end of the 30-day period thereafter; and from the end of the 30-day period following CAP hospitalization through the end of the following 1-, 2-, and 3-year periods. The ‘acute phase’ included the index CAP hospitalization and the 30-day post-discharge period, while the ‘long-term phase’ included up to 3 years following the end of the 30-day post-discharge period. Expenditures were tallied on an overall basis using paid amounts on corresponding healthcare claims, and were expressed in 2018 US dollars. Expenditures from earlier years were adjusted using the appropriate component (e.g. hospital and related services) of the Consumer Price Index for All Urban Consumers.

2.5 Statistical Analyses

Total healthcare expenditures among CAP patients and comparison patients were estimated during the period of the qualifying CAP hospitalization and on a monthly basis thereafter (i.e. from hospital discharge) during the 3-year follow-up period. Because it was not possible to differentiate between health plan disenrollment due to death versus other reasons, monthly estimates were derived using data for patients who were enrolled at the beginning of the corresponding month of follow-up, and cumulative expenditures were tallied by summing monthly estimates over the period of interest. By using this approach and censoring patients at the beginning of the month in which they were lost to follow-up, study findings reflect attributable expenditures, assuming generalizability across changing populations of hospitalized CAP and comparison patients and implicitly that patients are tracked throughout the follow-up period. Ninety-five percent confidence intervals (CIs) were derived for each estimate using non-parametric bootstrapping techniques.

Analyses were conducted considering all CAP patients, subgroups defined by age and risk profile (i.e. healthy, at-risk, and high-risk), and non-invasive CAP patients. To evaluate the robustness of our findings, we replicated the matching process creating an additional three independent samples of matched comparison patients and estimated attributable expenditures for CAP during the acute and long-term phases in each matched sample.

3 Results

3.1 Patient Characteristics

A total of 43,975 hospitalized CAP patients were identified in the source population, and all hospitalized CAP patients

were matched to a corresponding comparison patient on age, sex, risk profile, comorbidity profile, and pre-index levels of healthcare utilization. Less than 1% of patients in the source population had evidence of a major organ transplantation and were thus excluded from consideration. Among all hospitalized CAP patients and their matched counterparts, 56% were aged ≥ 65 years and 39% were aged ≥ 75 years; 53% of patients were female (Table 1). Most patients were healthy (38%) or at-risk (40%); 25% had CHD, 15% had COPD, and 27% had diabetes.

3.2 Healthcare Expenditures

All-cause healthcare expenditures for the CAP hospitalization totaled \$33,380 (95% CI \$32,665–\$34,161), on average, and \$698 (95% CI \$650–\$747) for comparison patients over the same period (Table 2). With corresponding expenditures averaging \$4568 (95% CI \$4385–\$4749) and \$1377 (95% CI \$1310–\$1453) during the 30-day period thereafter, expenditures during the acute phase totaled \$37,948 (95% CI \$37,209–\$38,780) for CAP patients versus \$2075 (95% CI \$1989–\$2167) for comparison patients; thus, attributable expenditures during the acute phase were \$35,873 (95% CI \$35,132–\$36,702).

During the long-term phase, all-cause expenditures averaged \$83,463 (95% CI \$81,318–\$85,784) for CAP patients versus \$51,017 (95% CI \$49,553–\$52,491) for comparison patients; thus, attributable expenditures during this phase totaled \$32,446 (95% CI \$29,847–\$35,075). In total, including the acute and long-term phases, corresponding average expenditures totaled \$121,410 (95% CI \$118,983–\$123,969) for CAP patients, versus \$53,092 (95% CI \$51,616–\$54,579) for comparison patients, yielding attributable expenditures of \$68,319 (95% CI \$65,454–\$71,142). The majority of attributable CAP expenditures (53% of \$68,319) occurred during the acute phase, while 21%, 14%, and 12% occurred during the first, second, and third years, respectively, after the acute phase. Cumulative and monthly healthcare expenditures attributable to CAP over the 3-year follow-up period are presented in Figs. 1 and 2. In sensitivity analyses evaluating healthcare expenditures in each of three additional matched samples, expenditures attributable to CAP during the acute and long-term phases were comparable ($\pm 3\%$) with base-case estimates.

Within subgroups defined by age, attributable expenditures ranged from \$26,644 (95% CI \$25,572–\$27,744) for persons aged ≥ 85 years, to \$46,048 (95% CI \$44,339–\$47,986) for persons aged 50–64 years during the acute phase; from \$20,407 (95% CI \$14,627–\$26,079) for persons aged ≥ 85 years, to \$41,954 (95% CI \$36,702–\$47,222) for persons aged 50–64 years during the long-term phase; and from \$47,051 (95% CI \$41,078–\$53,063) for persons aged ≥ 85 years, to \$88,002

(95% CI \$82,424–\$93,916) for persons aged 50–64 years in total (i.e. including the acute and long-term phases). With subgroups defined by risk profile, attributable expenditures ranged from \$34,690 (95% CI \$33,386–\$35,993) for healthy persons, to \$39,924 (95% CI \$38,069–\$41,863) for high-risk persons during the acute phase; from \$24,767 (95% CI \$22,412–\$27,277) for healthy persons, to \$57,989 (95% CI \$47,937–\$68,025) for high-risk persons during the long-term phase; and from \$59,456 (95% CI \$56,723–\$62,526) for healthy persons, to \$97,914 (95% CI \$87,138–\$108,144) for high-risk persons in total. Results for CAP subgroups defined on age and risk profile, as well as for non-invasive CAP patients, are reported in Online Resources 5 and 6.

4 Discussion

Using a retrospective matched cohort design and data from a large healthcare claims repository, we evaluated expenditures for CAP requiring hospitalization, during the acute phase and up to 3 years thereafter, among all adults as well as by age and risk profile. The findings from our study suggest that all-cause expenditures—considering the acute as well as long-term phases—are markedly higher among CAP patients versus matched counterparts. Attributable expenditures for CAP during the acute phase (including the qualifying event) totalled \$35,873, while during the long-term phase (i.e. the 3-year period beginning 30 days post-discharge), these expenditures totalled \$32,446. We note that while attributable expenditures during the acute and long-term phases were comparable, 46% of long-term attributable expenditures occurred during the first year of that follow-up period and 54% occurred over the subsequent 2-year period. We also note that our estimates of attributable CAP expenditures are higher than those reported previously, which may be explained, at least in part, by differences in study designs and study populations.

In the 2012 study by Polsky and colleagues, which employed commercial claims data (2003–2007) and considered all CAP patients irrespective of care setting, mean ‘excess’ healthcare expenditures during the 1-year follow-up period (including the qualifying CAP episode) totalled \$14,429 among CAP patients versus matched comparison patients [8]. Across subgroups defined on comorbidities (asthma, diabetes, COPD, congestive heart failure [CHF]), excess expenditures ranged from \$13,307 (asthma) to \$34,436 (CHF). In the 2012 study by Thomas and colleagues, which utilized Medicare claims data (2005–2007) and limited attention to hospitalized CAP patients, mean excess healthcare expenditures during the 2-year follow-up period (including the qualifying CAP episode) totalled \$16,133 among CAP patients versus matched comparison patients [14].

Table 1 Characteristics of CAP patients and matched comparison patients

	CAP patients and matched counterparts, <i>n</i> (%)		Standard difference*
	CAP patients (<i>n</i> = 43,975)	Comparison patients (<i>n</i> = 43,975)	
Patient characteristics			
Age (year)			
18–49	6827 (15.5)	6827 (15.5)	–
50–64	12,704 (28.9)	12,704 (28.9)	–
65–74	7153 (16.3)	7153 (16.3)	–
≥ 75	17,291 (39.3)	17,291 (39.3)	–
Sex			
Female	23,177 (52.7)	23,177 (52.7)	–
Male	20,798 (47.3)	20,798 (47.3)	–
Risk profile			
Healthy	16,637 (37.8)	16,637 (37.8)	–
At-risk	17,652 (40.1)	17,652 (40.1)	–
Alcoholism	249 (0.6)	291 (0.7)	<0.1
Asthma	2971 (6.8)	2531 (5.8)	< 0.1
Chronic heart disease (CHD)	10,972 (25.0)	10,972 (25.0)	–
Chronic lung disease	2302 (5.2)	1191 (2.7)	0.13
COPD	6593 (15.0)	6593 (15.0)	–
Diabetes	11,664 (26.5)	11,664 (26.5)	–
Liver disease	416 (0.9)	416 (0.9)	–
Smokers	2323 (5.3)	2191 (5.0)	< 0.1
High-risk	9686 (22.0)	9686 (22.0)	–
Chronic renal failure	2781 (6.3)	2781 (6.3)	–
Cochlear	0 (0.0)	0 (0.0)	<0.1
Congenital immunodeficiency	174 (0.4)	113 (0.3)	< 0.1
Disease of white blood cells	426 (1.0)	257 (0.6)	< 0.1
Functional/anatomical asplenia	7 (0.0)	15 (0.0)	< 0.1
HIV	111 (0.3)	106 (0.2)	< 0.1
Malignant neoplasms	7202 (16.4)	7202 (16.4)	–
Nephrotic syndrome	39 (0.1)	25 (0.1)	< 0.1
Hospitalizations in prior year			
Mean (SD)	0.3 (0.7)	0.3 (0.7)	< 0.1
0	34,614 (78.7)	34,614 (78.7)	–
1	7166 (16.3)	7166 (16.3)	–
2	1491 (3.4)	1491 (3.4)	–
≥ 3	704 (1.6)	704 (1.6)	–
Hospital days in prior year			
Mean (SD)	1.5 (6.2)	1.4 (5.5)	< 0.1
0	34,755 (79.0)	34,755 (79.0)	–
1–4	5208 (11.8)	5208 (11.8)	–
5–9	2399 (5.5)	2399 (5.5)	–
≥ 10	1613 (3.7)	1613 (3.7)	–
Ambulatory encounters in prior year			
Mean (SD)	22.5 (20.8)	21.9 (20.4)	< 0.1
0	1272 (2.9)	1272 (2.9)	–
1–4	5328 (12.1)	5328 (12.1)	–
5–9	6862 (15.6)	6862 (15.6)	–
≥ 10	30,513 (69.4)	30,513 (69.4)	–

CAP community-acquired pneumonia

*The adequacy of the matching procedure was evaluated by comparing standardized differences in baseline characteristics (i.e., those not considered in the matching process) between CAP patients and comparison patients; a standardized difference < 0.1 was assumed to indicate a negligible difference

Table 2 Healthcare expenditures during 3-year period from beginning of CAP hospitalization

	Acute Phase: Mean (95% CI) All-Cause Expenditures (\$)					
	Index CAP Hospitalization		From End of Index CAP Hospitalization Through End of 30-Day Follow-Up Period		From Index CAP Hospitalization Through End of 30-Day Follow-Up Period	
	CAP Patients (N=43,975)	Comparison Patients (N=43,975)	CAP Patients (N=43,975)	Comparison Patients (N=43,975)	CAP Patients (N=43,975)	Comparison Patients (N=43,975)
All Patients	33,380 (32,665-34,161)	698 (650-747)	4568 (4385-4749)	1377 (1310-1453)	37,948 (37,209-38,780)	2075 (1989-2167)
Patients by Age (yrs)						
18-49	36,370 (34,427-38,509)	400 (337-475)	4448 (3969-5002)	793 (691-912)	40,817 (38,810-43,048)	1193 (1056-1348)
50-64	42,460 (40,903-44,245)	870 (757-990)	5909 (5494-6375)	1451 (1333-1585)	48,369 (46,665-50,237)	2321 (2143-2530)
65-74	33,191 (31,409-35,341)	794 (649-948)	4417 (3970-4937)	1577 (1396-1785)	37,608 (35,684-39,825)	2370 (2134-2631)
75-84	26,290 (25,290-27,346)	714 (624-821)	3775 (3517-4010)	1692 (1494-1928)	30,065 (29,002-31,141)	2406 (2184-2672)
≥85	24,849 (23,850-25,894)	578 (493-676)	3599 (3344-3877)	1225 (1118-1345)	28,447 (27,388-29,588)	1803 (1652-1972)
Patients by Risk Profile						
Healthy	32,051 (30,860-33,270)	245 (206-287)	3428 (3190-3700)	545 (471-644)	35,479 (34,199-36,763)	789 (703-902)
At-Risk	32,576 (31,546-33,651)	626 (560-697)	4094 (3817-4379)	1279 (1178-1387)	36,670 (35,522-37,864)	1905 (1784-2048)
High-Risk	37,128 (35,356-38,900)	1607 (1447-1,808)	7388 (6910-7892)	2986 (2796-3184)	44,516 (42,683-46,472)	4592 (4309-4892)
	Long-Term Phase: Mean (95% CI) All-Cause Expenditures (\$)					
	From End of 30-Day Follow-Up Period Through End of 1-Year Follow-Up Period		From End of 30-Day Follow-Up Period Through End of 3-Year Follow-Up Period		Acute Phase + Long-Term Phase: Mean (95% CI) All-Cause Expenditures (\$)*	
	CAP Patients (N=43,975)	Comparison Patients (N=43,975)	CAP Patients (N=43,975)	Comparison Patients (N=43,975)	CAP Patients (N=43,975)	Comparison Patients (N=43,975)
All Patients	30,086 (29,284-30,855)	15,805 (15,342-16,305)	83,463 (81,318-85,784)	51,017 (49,553-52,491)	121,410 (118,983-123,969)	53,092 (51,616-54,579)
Patients by Age (yrs)						
18-49	22,115 (20,617-23,943)	8233 (7599-8980)	58,984 (55,128-63,078)	25,152 (23,176-27,241)	99,801 (95,205-104,585)	26,345 (24,269-28,511)
50-64	34,993 (33,322-36,568)	15,099 (14,241-15,995)	90,300 (86,137-94,415)	48,346 (45,277-51,734)	138,669 (133,885-143,294)	50,667 (47,598-54,054)
65-74	32,939 (30,976-35,207)	19,174 (17,541-20,858)	96,798 (91,053-102,893)	59,967 (55,210-64,971)	134,406 (128,171-141,157)	62,337 (57,521-67,463)
75-84	30,956 (29,345-32,513)	18,231 (17,236-19,273)	87,899 (83,811-92,381)	60,625 (57,620-63,747)	117,964 (113,478-122,552)	63,031 (59,950-66,211)
≥85	25,452 (24,118-26,854)	17,511 (16,664-18,424)	77,499 (72,980-82,613)	57,092 (54,437-60,300)	105,947 (101,109-111,487)	58,895 (56,151-62,067)
Patients by Risk Profile						
Healthy	17,425 (16,595-18,280)	6944 (6611-7270)	48,734 (46,575-51,046)	23,968 (22,966-25,011)	84,213 (81,585-87,050)	24,757 (23,747-25,775)
At-Risk	28,813 (27,822-29,807)	15,233 (14,685-15,815)	85,374 (82,718-88,328)	51,274 (49,517-53,131)	122,044 (119,130-125,541)	53,179 (51,392-55,067)
High-Risk	58,456 (55,613-61,152)	32,474 (30,591-34,207)	158,235 (149,893-166,312)	100,245 (94,514-106,478)	202,751 (193,942-211,333)	104,838 (99,060-111,105)

Number at risk (@ baseline, 30 days, 1 year, 2 years, 3 years); CAP patients: 43,975, 39,678, 23,750, 13,087, 3263; comparison patients: 43,975, 42,170, 28,312, 16,460, 4291

CAP community-acquired pneumonia

*From index CAP hospitalization through end of 3-year follow-up period

More importantly, our findings also suggest that differences in all-cause healthcare expenditures between CAP patients and comparison patients continue to diverge in the long-term (albeit at varying levels over time within subgroups defined on age and risk profile)—in this study, over a period of up to 3 years following the 30-day CAP post-discharge period. More than one-half of attributable CAP expenditures (53% of \$68,319) occurred during the acute phase, while 21%, 14%, and 12% occurred during the first, second, and third years, respectively, after the acute phase. Given that half of the attributable expenditures occurred after the CAP hospitalization, and that attributable expenditures continue to rise, close monitoring of CAP survivors will be critical to mitigate adverse outcomes and associated costs. Additionally, these data suggest that while CAP is often considered an acute infectious disease, the consequences are far reaching, as markers of healthcare utilization, i.e. costs, extend well beyond the typical symptom solution of CAP.

In the aforementioned study by Thomas and colleagues, when using a statistical approach that censors patients on loss to follow-up (irrespective of reason), 19% of excess CAP-related expenditures occurred in months 4–12 of follow-up and 19% occurred in months 13–24 of follow-up [14]. In the study by Wasser and colleagues, the authors

utilized US healthcare claims data (2008–2010) to evaluate the long-term consequences of CAP in US adults based on the ‘time to revert to prediagnosis expenditures’ [13]. Across all strata of the study population defined on age and risk profile, the time to revert to prediagnosis expenditures ranged from 247 days for low-risk CAP patients aged 18–49 years, to 678 days for moderate-risk CAP patients aged ≥ 50 years, leading the authors to conclude that the long-term consequences of CAP extend approximately 9 months following the end of the acute CAP episode. While the estimated persistence of cost consequences is shorter in this study than ours, we note that Wasser et al. included all CAP patients, irrespective of care setting, in their study population, while we included only hospitalized CAP patients (who have more severe disease, on average, and for whom persistence may be markedly greater than those requiring ambulatory care only). We also note that Wasser and colleagues projected expenditures beyond the period of observed data, which could contribute to variation in findings between studies.

While healthcare claims databases provide information on large numbers of patients with specific diagnoses who receive care for specific conditions, several limitations from the use of such databases should be noted. First, while the algorithm for identifying CAP has been used in a prior study [12], to the best of our knowledge, the algorithm has not

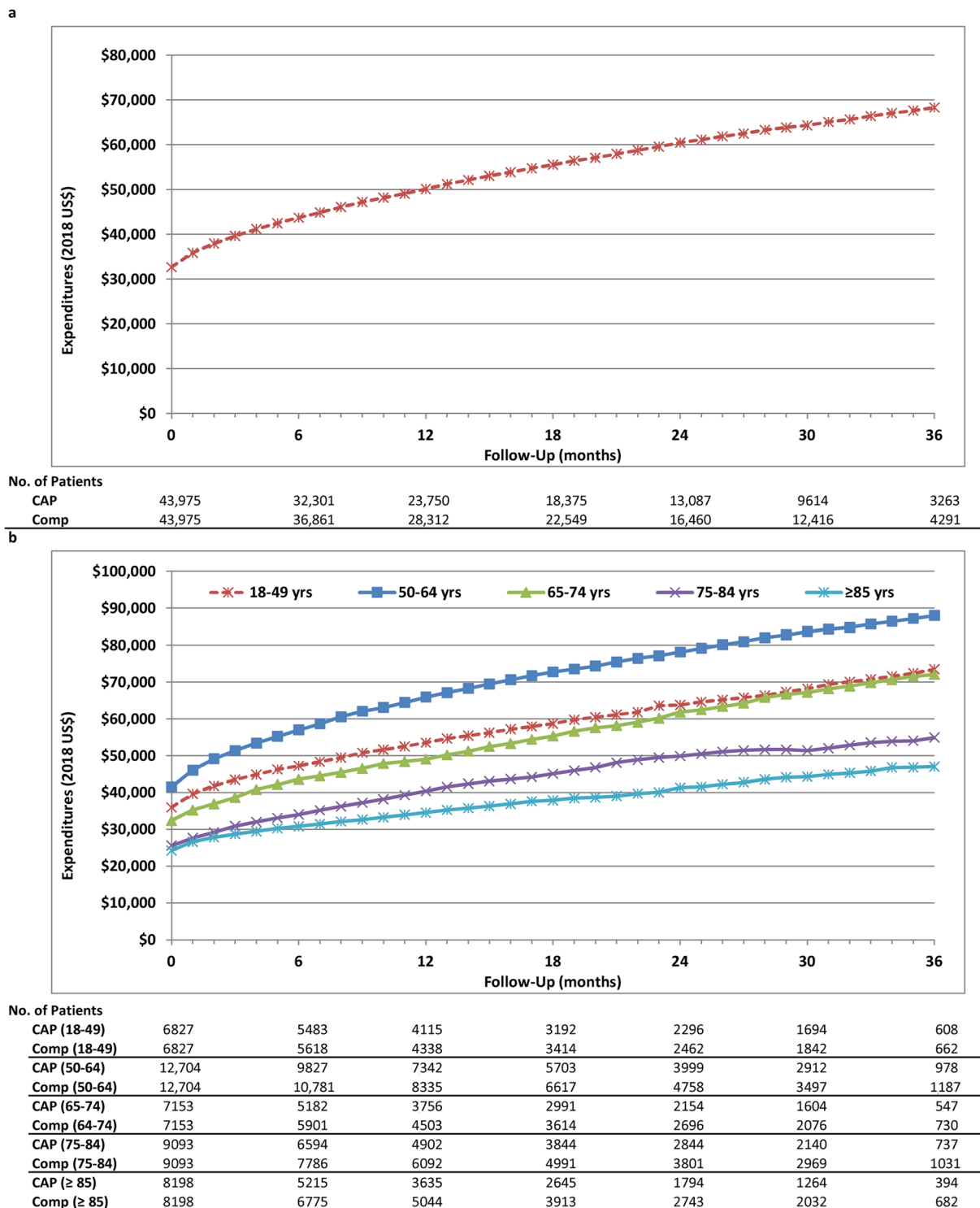


Fig. 1 Attributable healthcare expenditures during the 3-year period from the beginning of CAP hospitalization. **a** All matched pairs; **b** patients by age; **c** patients by risk profile. CAP community-acquired pneumonia

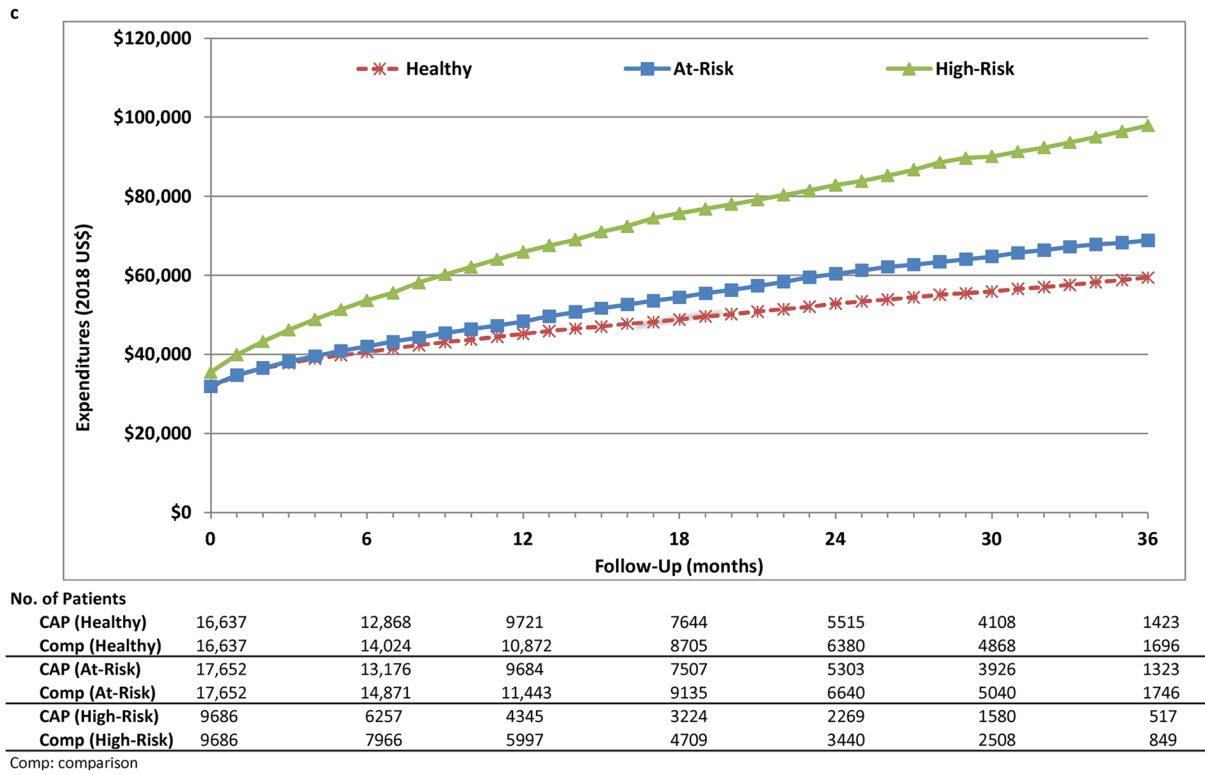
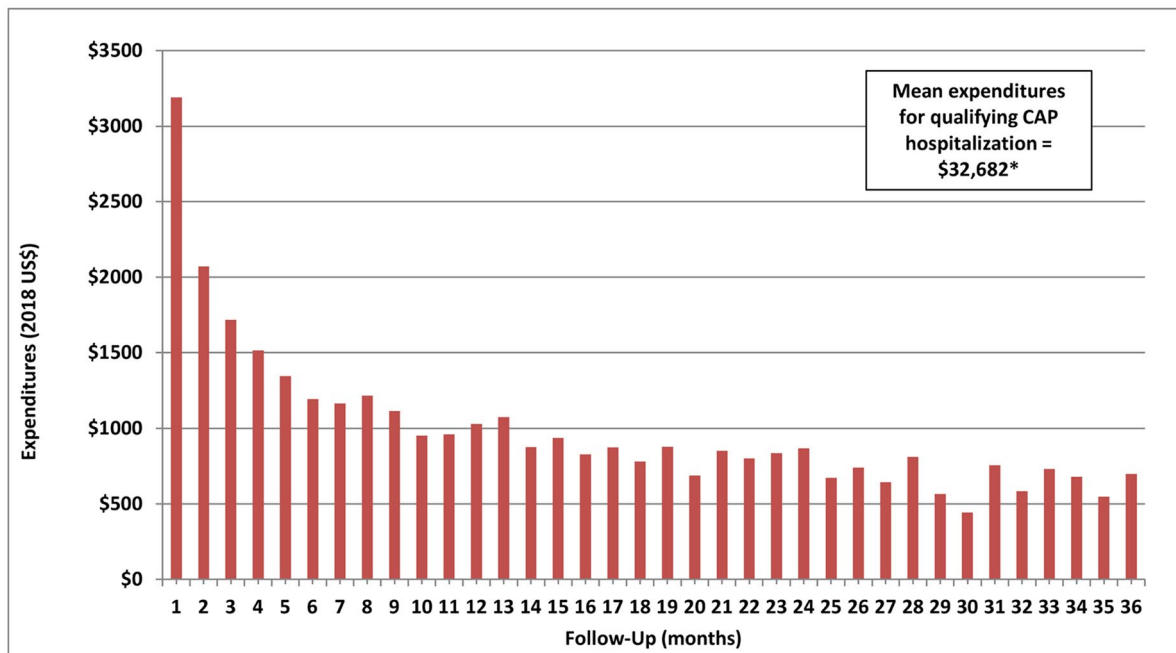


Fig. 1 (continued)



*Net of expenditures among comparison patients during corresponding period

Fig. 2 Monthly healthcare expenditures attributable to CAP following CAP. CAP community-acquired pneumonia

been formally evaluated against a ‘gold standard’ and thus its accuracy (i.e. in terms of sensitivity and specificity) is unknown. Similarly, the use of operational algorithms to characterize patient risk and comorbidity profiles undoubtedly resulted in misclassification of some patients who had the underlying conditions as well as some patients who did not. These algorithms have been employed in several previously published studies [4, 5, 7, 12]. Unfortunately, it is not possible to undertake a formal evaluation—for example, via chart review or use of additional data sources (e.g. electronic medical records)—of the accuracy of these algorithms within the context of this study.

We note that, to evaluate the robustness of our findings, we replicated the matching process, creating an additional three independent samples of matched comparison patients. In each sample, expenditures attributable to CAP during the acute and long-term phases were comparable ($\pm 3\%$) to base-case estimates. Although CAP patients and comparison patients were matched on their demographic, risk profile, comorbidity profile, and healthcare experience, the possibility exists that CAP patients are systematically different from comparison patients in terms of unobserved characteristics, which could bias study results. Other unmeasured factors (e.g. family sociodemographic status) may also confound study results if they are correlated with both CAP and study outcomes. In addition, although hospitalized CAP patients and comparison patients were matched on observed baseline characteristics believed to be important drivers of subsequent healthcare expenditures, comparison patients were not required to have evidence of hospitalization in the match month, which may upwardly bias our estimates of expenditures attributable to CAP during the long-term phase. On the other hand, implementation of such a criterion would create an imbalance between hospitalized CAP patients and comparison patients (e.g. if comparison patients were disproportionately hospitalized for serious conditions/procedures such as heart disease and bypass), which would downwardly bias our estimates.

As noted in Sect. 2, because it is not possible to differentiate loss to follow-up based on reason, death was not treated as a competing risk and thus patients were censored on the date of loss to follow-up. Accordingly, study findings reflect attributable expenditures, assuming (implicitly) that all patients are tracked throughout the follow-up period. While the MarketScan Database should be sufficiently large to evaluate research questions among all matched pairs, comparisons within subgroups defined therein may be underpowered and should be interpreted with caution. The true cost of healthcare (i.e. the cost to healthcare providers for the rendering of services) is not available in the MarketScan Database, and thus expenditures (i.e. amounts paid by health plans and patients for services rendered) were employed. Finally, adults with public health insurance and

adults without health insurance are not represented in the study database; caution should be used when generalizing study results to other populations and settings.

5 Conclusion

Our findings provide additional evidence that the cost of CAP requiring hospitalization is high and that the impact of CAP extends well beyond the expected time for resolution of acute inflammatory signs, and thus emphasize the importance of pneumonia prevention. Additional research using clinically rich data sources is needed to further evaluate the underlying relationship between pneumonia and associated long-term clinical and economic consequences.

Declarations

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Conflicts of Interest/Competing Interests Aaron Moynahan, Amanda Silvia, and Derek Weycker are employees of PAI. Reiko Sato is an employee of, and owns stock in, Pfizer Inc.

Availability of Data and Material (Data Transparency) The data are proprietary, provided by a third-party vendor, and the authors do not have permission to disseminate the data without approval of the vendor.

Author Contributions Authorship was designated based on the guidelines promulgated by the International Committee of Medical Journal Editors (2004). All persons who meet the criteria for authorship are listed as authors on the title page. The contribution of each of these persons to this study is as follows: (1) conception and design (RS, DW), acquisition of data (AM, RS, DW), analysis or interpretation of data (all authors); and (2) preparation of the manuscript (AS, DW) and critical review of the manuscript (AM, RS). The study sponsor reviewed the study research plan and the study manuscript; data management, processing, and analyses were conducted by PAI, and all final analytic decisions were made by the study investigators. All authors read and approved the final version of the manuscript.

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