

Comorbidity Status and Annual Total Medical Expenditures in U.S. Hypertensive Adults



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Introduction: The purpose of this study is to investigate comorbidity status and its impact on total medical expenditures in non-institutionalized hypertensive adults in the U.S.

Methods: Data from the 2011–2014 Medical Expenditure Panel Survey were used. Patients were included if they had a diagnosis code for hypertension, were aged ≥ 18 years, and were not pregnant during the study period (N=26,049). The Elixhauser Comorbidity Index was modified to add hypertension-related comorbidities. The outcome variable was annual total medical expenditures, and a generalized linear model regression (gamma distribution with a log link function) was used. All costs were adjusted to 2014 U.S. dollars.

Results: Based on the modified Elixhauser Comorbidity Index, 14.0% of patients did not have any comorbidities, 23.0% had one, 24.4% had two, and 38.7% had three or more. The five most frequent comorbidities were hyperlipidemia, diabetes, rheumatoid arthritis, depression, and chronic pulmonary disease. Estimated mean annual total medical expenditures were \$3,914 (95% CI=\$3,456, \$4,372) for those without any comorbidity; \$5,798 (95% CI=\$5,384, \$6,213) for those with one comorbidity; \$8,333 (95% CI=\$7,821, \$8,844) for those with two comorbidities; and \$13,920 (95% CI=\$13,166, \$14,674) for those with three or more comorbidities. Of the 15 most frequent comorbidities, the condition with the largest impact on expenditures for an individual person was congestive heart failure (\$7,380). Hypertensive adults with stroke, coronary heart disease, diabetes, renal diseases, and hyperlipidemia had expenditures that were \$6,069, \$6,046, \$5,039, \$4,974, and \$4,851 higher, respectively, than those without these conditions.

Conclusions: Comorbidities are highly prevalent among hypertensive adults, and this study shows that each comorbidity significantly increases annual total medical expenditures.

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INTRODUCTION

Hypertension is a highly prevalent health condition; approximately one third of U.S. adults have this problem.¹ Previous studies have provided estimates of the economic burden of hypertension^{2–13}; the American Heart Association estimated that the national annual direct and indirect costs of hypertension were \$47.3 billion and \$3.9 billion (average annual 2012–2013).³ Annual costs for the treatment of hypertension were estimated to be \$812 per adult in 2014.¹⁴ However, most adults have been diagnosed with more than one chronic condition, and relatively few suffer from hypertension exclusively.¹⁵ Additionally, hypertension is a major risk factor for

many costly chronic conditions, such as heart disease and stroke.

Multimorbidity is considered the presence of multiple diseases in an individual.¹⁶ A study found that approximately one fourth of the population had multimorbidity.¹⁷ Multimorbidity is an issue for the management of hypertension. Among elderly patients with hypertension, 43% had

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two or fewer coexisting chronic conditions, 34% had three to four, and 23% had five or more such conditions.¹⁵

Although earlier studies have estimated the economic burden of hypertension, little is known about the effect of having multiple comorbidities on medical expenditures in adults with hypertension. The objectives of the present study are to describe comorbidity status among non-institutionalized adults with hypertension and to estimate annual medical expenditures according to the presence of comorbidities in this population.

METHODS

Data from the 2011–2014 Medical Expenditure Panel Survey (MEPS) were used for this analysis. MEPS is a nationally representative survey of the U.S. civilian non-institutionalized population that provides comprehensive information on healthcare utilization and costs under the U.S. healthcare system. MEPS data have been used extensively for studying medical expenditures for various health conditions, including hypertension and cardiovascular disease (CVD).^{18–22} The MEPS data on medical conditions were used to define hypertension and comorbidities based on ICD-9 codes. The MEPS full-year consolidated data were employed to define medical expenditures and patient characteristics.

Study Population

Adults with hypertension were included if they met all of the following criteria: any diagnosis codes for hypertension (ICD-9 codes: 401–405); age ≥ 18 years; and were not pregnant during the study period. Among pregnant women, hypertension and gestation hypertension might affect the use and cost of medical services differently from the general population. A total of 26,049 persons were included.

Measures

Various comorbidity indices have been developed to measure important coexisting medical conditions. The Elixhauser Comorbidity Index (EI) is one of the most frequently used and validated comorbidity indices, and the original EI includes a set of 30 conditions that are coded as present or absent to produce 30 binary variables.²³ In addition, the score version of the EI has also been validated.^{24,25} The score version of the EI was used to measure comorbidity because it is better than the original version for exploring individual comorbidity status and the impact of individual comorbidity on medical expenditures. In addition, using the score version of the EI has been validated by its ability to outperform the Charlson Comorbidity Index, the most commonly used comorbidity index.^{26–34}

The authors expanded the EI to better analyze the impact of hypertension-related comorbidities on medical expenditures by including a broader range of CVD-related conditions than the original EI. First, 27 conditions from the original version of the EI indicators were obtained. These modifications included excluding hypertension; combining two types of diabetes (diabetes with complication and diabetes without complication) into one condition (diabetes); and combining two types of anemia (blood loss anemia and deficiency anemia) into one condition (anemia). Second, three conditions were added: coronary heart disease (CHD); stroke; and hyperlipidemia. Finally, two conditions were redefined: renal failure to renal disease, and arrhythmia to

heart rhythm disorders. In sum, a total of 30 possible comorbidities were included, as follows:

- CVD and hypertension-related conditions: congestive heart failure (CHF), heart rhythm disorders, valvular disease, CHD, stroke, hyperlipidemia, pulmonary circulation disorders, peripheral vascular disorders, diabetes, renal disease, obesity, and depression; and
- other conditions: paralysis, neurologic disorders, hypothyroidism, liver disease, peptic ulcer, HIV/AIDS, lymphoma, metastatic cancer, solid tumor, rheumatoid arthritis, coagulopathy, weight loss, fluid and electrolyte disorders, anemia, alcohol abuse, drug abuse, psychoses, and chronic pulmonary disease.

The modified EI score was defined as the sum of each of the 30 comorbidities, with a possible range of 0–30. Depression was included in the CVD and hypertension-related conditions based on the results of previous meta-analyses on the association of hypertension with depression.^{35,36} Appendix Table 1 (available online) shows the list of the comorbidities and the ICD-9 code for each condition.

The outcome variable was annual total medical expenditures that were not specifically related to hypertension diagnosis or management. The expenditures included those for inpatient hospitalizations, outpatient visits, emergency department visits, office-based physician visits, home healthcare visits, and prescription medications. The annual medical expenditures included the total of all expenditures paid by all payers, including Medicare, Medicaid, other public insurance, private insurance, and payments made by the adult with hypertension or that person's family during the calendar year. In terms of cost of illness studies, the perspective for this study was that of the healthcare sector as a whole, with expenditures used as a proxy for costs. All costs were adjusted to 2014 U.S. dollars using the personal consumption expenditure index–health by function. Ten covariates were included: age group, gender, race/ethnicity, U.S. region, insurance type, marital status, education level, poverty level, smoking status, and health status.

Statistical Analysis

Bivariate analyses were conducted to assess the associations between personal characteristics and the EI. Chi-square tests were used for the categorical variables for the population's characteristics, and ANOVA was used for the continuous variables. Descriptive statistics were employed to describe the frequencies of comorbidities.

A generalized linear model regression (gamma distribution with a log link function) was used to estimate the associations between the modified EI and total medical expenditures while controlling for covariates. A log link and gamma distribution was selected because the distribution of medical expenditures was positively skewed, and 99% of the sample had positive medical expenditures. Mean annual medical expenditures by the EI score were predicted using the average marginal effects method from the model. All analyses were performed using SAS, version 9.3, and Stata/SE, version 14.

RESULTS

A total of 26,049 patients were included in this study. Table 1 shows the characteristics of U.S. hypertensive

Table 1. Sample Characteristics of U.S. Hypertensive Adults by Modified Elixhauser Comorbidity Index (EI), 2011–2014 Medical Expenditure Panel Survey (n=26,049)

Variable/category	Number (weighted %)					p-value
	Total	EI=0	EI=1	EI=2	EI≥3	
Overall	26,049 (100.0)	4,073 (100.0)	6,135 (100.0)	6,310 (100.0)	9,531 (100.0)	
Age (years)						
18–44	3,470 (11.8)	1,074 (25.2)	978 (14.3)	754 (11.2)	664 (5.9)	< 0.001
45–64	12,029 (43.9)	2,100 (51.2)	3,097 (49.9)	2,926 (44.0)	3,906 (37.7)	
≥65	10,550 (44.3)	899 (23.6)	2,060 (35.9)	2,630 (44.9)	4,961 (56.3)	
Gender						
Male	11,772 (49.0)	2,022 (56.3)	2,871 (50.4)	2,908 (50.1)	3,971 (44.7)	< 0.001
Female	14,277 (51.0)	2,051 (43.7)	3,264 (49.6)	3,402 (49.9)	5,560 (55.3)	
Race/ethnicity						
Hispanic	4,855 (9.8)	874 (12.4)	1,171 (10.3)	1,244 (10.1)	1,566 (8.3)	< 0.001
White, non-Hispanic	11,969 (69.9)	1,377 (59.4)	2,634 (67.1)	2,885 (70.3)	5,073 (75.2)	
Black, non-Hispanic	7,081 (14.2)	1,462 (21.7)	1,740 (15.2)	1,612 (13.3)	2,267 (11.5)	
Asian/Other, non-Hispanic	2,144 (6.1)	360 (6.6)	590 (7.4)	569 (6.3)	625 (4.9)	
Region						
Northeast	4,267 (17.6)	635 (16.5)	1,017 (18.3)	1,055 (18.6)	1,560 (17.0)	0.038
Midwest	5,023 (22.2)	683 (20.2)	1,106 (20.9)	1,196 (22.1)	2,038 (23.7)	
South	11,046 (40.8)	1,866 (43.6)	2,588 (40.5)	2,583 (39.5)	4,009 (40.9)	
East	5,713 (19.4)	889 (19.7)	1,424 (20.3)	1,476 (19.7)	1,924 (18.4)	
Insurance						
Any private	13,899 (62.8)	2,518 (71.9)	3,599 (68.3)	3,375 (63.5)	4,407 (55.7)	< 0.001
Public only	9,686 (30.7)	919 (17.1)	1,828 (23.5)	2,320 (29.7)	4,619 (40.5)	
Uninsured	2,464 (6.5)	636 (11.0)	708 (8.2)	615 (6.9)	505 (3.7)	
Marital status						
Married	13,482 (57.0)	2,267 (61.5)	3,357 (59.4)	3,379 (59.0)	4,479 (52.6)	< 0.001
Unmarried	12,567 (43.0)	1,806 (38.5)	2,778 (40.6)	2,931 (41.0)	5,052 (47.4)	
Education						
Less than high school	5,932 (15.4)	695 (11.0)	1,268 (13.1)	1,528 (16.2)	2,441 (17.9)	< 0.001
High school	8,382 (32.0)	1,367 (30.8)	1,887 (29.7)	1,984 (31.6)	3,144 (34.2)	
College or higher	11,454 (52.5)	1,961 (58.2)	2,915 (57.2)	2,730 (52.2)	3,848 (47.9)	
Income						
Low or below	11,248 (32.6)	1,505 (24.4)	2,296 (27.2)	2,660 (31.0)	4,787 (39.8)	< 0.001
Middle	7,456 (28.7)	1,283 (29.7)	1,847 (29.0)	1,787 (28.5)	2,539 (28.2)	
High	7,345 (38.7)	1,285 (45.9)	1,992 (43.7)	1,863 (40.4)	2,205 (32.1)	
Current smoker						
Yes	3,774 (15.1)	534 (13.4)	869 (15.6)	873 (14.0)	1,498 (16.1)	0.021
No	19,775 (84.9)	3,032 (86.6)	4,639 (84.4)	4,853 (86.0)	7,251 (83.9)	
Health status						
Excellent	2,401 (10.7)	675 (18.6)	723 (14.0)	575 (11.6)	428 (5.4)	< 0.001
Very good	6,389 (28.2)	1,422 (40.6)	1,856 (34.9)	1,566 (28.5)	1,545 (19.5)	
Good	9,362 (35.7)	1,463 (31.8)	2,285 (35.4)	2,417 (38.0)	3,197 (35.8)	
Fair/poor	7,795 (25.4)	489 (8.9)	1,245 (15.7)	1,721 (21.9)	4,340 (39.3)	
Expenditure for medical care						
Yes	25,588 (98.9)	3,855 (96.4)	6,012 (98.5)	6,227 (99.1)	9,494 (99.7)	< 0.001
No	461 (1.1)	218 (3.6)	123 (1.5)	83 (0.9)	37 (0.3)	

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Table 1. Sample Characteristics of U.S. Hypertensive Adults by Modified Elixhauser Comorbidity Index (EI), 2011–2014 Medical Expenditure Panel Survey (n=26,049) (continued)

Variable/category	Number (weighted %)					p-value
	Total	EI=0	EI=1	EI=2	EI≥3	
Medical expenditures (2014 USD), M (SE)						
Overall adults	9,673 (189)	3,167 (203)	5,242 (191)	7,986 (244)	15,722 (384)	<0.001
Adults with spending	9,785 (191)	3,284 (211)	5,320 (194)	8,058 (245)	15,762 (385)	<0.001
EI score	2.26 (0.02)					

Note: Hypertensive was defined based on ICD-9 codes 401–405. The following comorbid conditions were included: (1) congestive heart failure; (2) heart rhythm disorders; (3) valvular disease; (4) coronary heart disease; (5) stroke; (6) hyperlipidemia; (7) pulmonary circulation disorders; (8) peripheral vascular disorders; (9) chronic pulmonary disease; (10) diabetes; (11) renal disease; (12) obesity; (13) depression; (14) paralysis; (15) neurologic disorders; (16) hypothyroidism; (17) liver disease; (18) peptic ulcer; (19) HIV/AIDS; (20) lymphoma; (21) metastatic cancer; (22) solid tumor; (23) rheumatoid arthritis; (24) coagulopathy; (25) weight loss; (26) fluid and electrolyte disorders; (27) anemia; (28) alcohol abuse; (29) drug abuse; and (30) psychoses. The *p*-values were generated from χ^2 tests for the categorical variables and ANOVA for the continuous variables. Percentages may not total 100% due to rounding. USD, U.S. dollar.

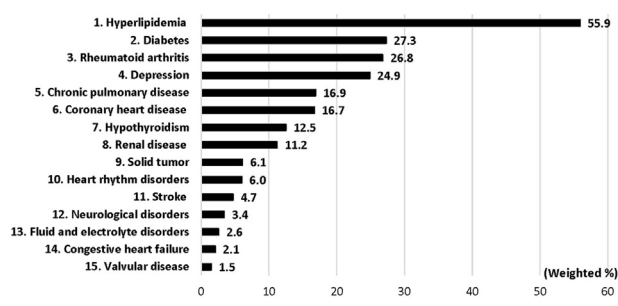
adults by the modified EI. The weighted average estimate of the number of U.S. hypertensive adults was 64,147,867 per year, and the weighted percentage of hypertension in the population of interest was 27.8%.

In all, 14.0% of U.S. hypertensive adults did not have any comorbidity ($n=4,073$), whereas 23.0% had one ($n=6,135$); 24.4% had two ($n=6,310$); and 38.7% had three or more ($n=9,531$). Figure 1 shows the percentages of the 15 most frequent comorbidities in U.S. hypertensive adults, which were hyperlipidemia, diabetes, rheumatoid arthritis, depression, chronic pulmonary disease, CHD, hypothyroidism, renal disease, solid tumor, heart rhythm disorders, stroke, neurologic disorders, fluid and electrolyte disorders, CHF, and valvular heart disease.

Table 2 shows the estimated total medical expenditures by personal descriptors and the number of comorbidities in U.S. hypertensive adults. Overall, the mean annual medical expenditure was \$9,841 (95% CI=\$9,464, \$10,218). The comorbidity score was positively associated with the estimated mean annual total medical expenditures. Estimates were \$3,914 (95% CI=\$3,456, \$4,372) for those without any comorbidity; \$5,798 (95%

CI=\$5,384, \$6,213) for those with one; \$8,333 (95% CI=\$7,821, \$8,844) for those with two; and \$13,920 (95% CI=\$13,166, \$14,674) for those with three or more comorbidities. Appendix Table 2 (available online) describes generalized linear model estimates and associated *p*-values for total medical expenditures.

Figure 2 shows the estimated medical expenditures by the presence of nine hypertension-related comorbidities among the 15 most frequent comorbidities. The impact of comorbidities on medical expenditures varied by type, with CHF associated with the largest impact on expenditures. Annual total medical expenditures were \$17,063 (95% CI=\$16,224, \$17,902) in persons with CHF versus \$9,683 (95% CI=\$9,313, \$10,053) in persons without CHF, a difference of \$7,380. The increased medical expenditures from specific comorbidities were \$6,069 for stroke, \$6,046 for CHD, \$5,093 for heart rhythm disorders, \$4,851 for hyperlipidemia, and \$4,453 for valvular disease. Diabetes, renal disease, and depression each increased expenditures by \cong \$5,000. Appendix Table 3 (available online) describes the differences in estimated annual medical expenditures by the presence of comorbidities.

**Figure 1.** Fifteen most frequent comorbid conditions in U.S. hypertensive adults, 2011–2014 Medical Expenditure Panel Survey (n=26,049).

DISCUSSION

The present study used a nationally representative sample of the U.S. population to estimate medical expenditures in hypertensive adults according to comorbidity status. To the authors' knowledge, this is the first study that provides insight into the economic burden of hypertension by comorbidity status. Overall, as expected, the study found that a higher comorbidity score was associated with higher total medical expenditures in adults with hypertension. In addition, the differences in expenditures varied by type of comorbidity.

Table 2. Estimated Annual Medical Expenditures (2014 USD) by Comorbidity Status for U.S. Hypertensive Adults, 2011–2014 Medical Expenditure Panel Survey (n=26,049)

Variable/category	Medical expenditure, \$ (95% CI)				
	Total	EI=0	EI=1	EI=2	EI≥3
Overall	9,841 (9,464, 10,218)	3,914 (3,456, 4,372)	5,798 (5,384, 6,213)	8,333 (7,821, 8,844)	13,920 (13,166, 14,674)
Age (years)					
18–44	8,059 (7,107, 9,011)	3,221 (2,716, 3,727)	4,771 (4,119, 5,423)	6,857 (6,036, 7,677)	11,454 (10,013, 12,896)
45–64	9,893 (9,294, 10,492)	3,954 (3,464, 4,445)	5,857 (5,381, 6,333)	8,417 (7,729, 9,105)	14,061 (13,050, 15,072)
≥65	10,125 (9,663, 10,586)	4,047 (3,550, 4,543)	5,994 (5,524, 6,465)	8,615 (8,064, 9,165)	14,391 (13,546, 15,236)
Gender					
Male	9,477 (8,991, 9,962)	3,773 (3,311, 4,234)	5,588 (5,145, 6,031)	8,031 (7,444, 8,618)	13,416 (12,578, 14,254)
Female	10,159 (9,651, 10,667)	4,044 (3,555, 4,533)	5,991 (5,522, 6,459)	8,609 (8,035, 9,183)	14,382 (13,455, 15,309)
Race/ethnicity					
Hispanic	8,368 (7,559, 9,177)	3,337 (2,864, 3,810)	4,943 (4,343, 5,544)	7,104 (6,396, 7,812)	11,867 (10,620, 13,114)
White	10,264 (9,779, 10,749)	4,093 (3,586, 4,601)	6,063 (5,600, 6,526)	8,713 (8,109, 9,317)	14,556 (13,678, 15,433)
Black	9,149 (8,570, 9,729)	3,649 (3,234, 4,063)	5,405 (4,955, 5,855)	7,767 (7,162, 8,373)	12,975 (11,970, 13,980)
Asian/other	8,381 (7,419, 9,343)	3,342 (2,827, 3,858)	4,951 (4,304, 5,598)	7,115 (6,216, 8,013)	11,885 (10,459, 13,311)
Region					
Northeast	10,865 (9,937, 11,793)	4,321 (3,730, 4,912)	6,401 (5,790, 7,012)	9,199 (8,283, 10,115)	15,367 (13,900, 16,835)
Midwest	10,261 (9,459, 11,064)	4,081 (3,466, 4,696)	6,045 (5,373, 6,717)	8,688 (7,888, 9,488)	14,513 (13,343, 15,683)
South	9,116 (8,623, 9,608)	3,626 (3,213, 4,038)	5,370 (4,980, 5,761)	7,718 (7,174, 8,262)	12,893 (11,977, 13,808)
East	9,922 (8,995, 10,849)	3,946 (3,380, 4,513)	5,845 (5,167, 6,523)	8,400 (7,516, 9,285)	14,033 (12,637, 15,428)
Insurance					
Any private	10,390 (9,877, 10,903)	4,143 (3,641, 4,645)	6,137 (5,677, 6,596)	8,819 (8,221, 9,417)	14,733 (13,812, 15,654)
Public only	9,674 (9,122, 10,226)	3,858 (3,380, 4,335)	5,714 (5,195, 6,233)	8,212 (7,622, 8,801)	13,718 (12,771, 14,665)
Uninsured	4,973 (4,013, 5,932)	1,983 (1,538, 2,427)	2,937 (2,376, 3,498)	4,221 (3,319, 5,122)	7,051 (5,692, 8,410)
Marital status					
Married	9,554 (9,044, 10,065)	3,804 (3,335, 4,273)	5,634 (5,218, 6,050)	8,097 (7,564, 8,630)	13,526 (12,603, 14,449)
Unmarried	10,185 (9,601, 10,769)	4,055 (3,553, 4,557)	6,006 (5,463, 6,548)	8,631 (7,930, 9,332)	14,419 (13,466, 15,371)
Education					
Less than high school	8,991 (8,129, 9,853)	3,567 (3,064, 4,071)	5,284 (4,735, 5,833)	7,594 (6,676, 8,512)	12,686 (11,367, 14,005)
High school	9,278 (8,731, 9,824)	3,681 (3,191, 4,171)	5,453 (4,967, 5,938)	7,836 (7,261, 8,411)	13,090 (12,207, 13,974)
College or higher	10,521 (10,001, 11,042)	4,175 (3,681, 4,668)	6,184 (5,695, 6,672)	8,887 (8,322, 9,451)	14,845 (13,903, 15,788)
Income					
Low or below	10,076 (9,474, 10,679)	4,009 (3,460, 4,558)	5,938 (5,391, 6,485)	8,533 (7,902, 9,165)	14,255 (13,261, 15,249)
Middle	9,293 (8,700, 9,885)	3,697 (3,248, 4,146)	5,476 (5,057, 5,895)	7,870 (7,222, 8,518)	13,147 (12,137, 14,156)

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Table 2. Estimated Annual Medical Expenditures (2014 USD) by Comorbidity Status for U.S. Hypertensive Adults, 2011–2014 Medical Expenditure Panel Survey (n=26,049) (continued)

Variable/category	Medical expenditure, \$ (95% CI)				
	Total	EI=0	EI=1	EI=2	EI≥3
High	10,046 (9,418, 10,674)	3,997 (3,514, 4,479)	5,920 (5,400, 6,440)	8,507 (7,836, 9,179)	14,212 (13,182, 15,242)
Current smoker					
Yes	8,747 (7,859, 9,634)	3,477 (3,014, 3,940)	5,150 (4,548, 5,753)	7,401 (6,674, 8,129)	12,364 (10,952, 13,776)
No	10,056 (9,665, 10,448)	3,998 (3,515, 4,480)	5,921 (5,493, 6,349)	8,510 (7,951, 9,068)	14,215 (13,468, 14,963)
Health status					
Excellent	5,899 (5,240, 6,558)	2,447 (2,173, 2,721)	3,625 (3,203, 4,046)	5,209 (4,569, 5,849)	8,702 (7,614, 9,789)
Very good	6,871 (6,392, 7,350)	2,850 (2,498, 3,202)	4,222 (3,878, 4,566)	6,067 (5,569, 6,565)	10,135 (9,278, 10,992)
Good	9,159 (8,591, 9,727)	3,799 (3,295, 4,303)	5,628 (5,143, 6,112)	8,088 (7,446, 8,730)	13,511 (12,525, 14,496)
Fair/poor	14,765 (14,031, 15,499)	6,125 (5,329, 6,920)	9,072 (8,274, 9,870)	13,038 (12,122, 13,954)	21,780 (20,528, 23,032)

Note: The estimated annual medical expenditures were estimated using the average marginal effects method from the generalized linear model (GLM) with log link and gamma distribution. As a comparator, for U.S. non-hypertensive adults (n=66,888), the mean annual medical expenditure was \$3,633 (95% CI=\$3479, \$3736); \$1,656 (95% CI=\$1556, \$1757) for those without any comorbid condition; \$3,887 (95% CI=\$3645, \$4128) for those with one comorbidity, \$3,547 (95% CI=\$4917, \$5776) for those with two comorbidities, and \$7,952 (95% CI=\$7348, \$8556) for those with three or more comorbid conditions.

EI, Elixhauser Comorbidity Index; USD, U.S. dollar.

Also as expected, having incrementally more total comorbidities was associated with increasing medical expenditures. In non-hypertensive adults without any of the listed comorbidities, annual total medical expenditures were \$1,656 (authors' calculation from the 2011–2014 MEPS), which could reflect the use of preventive services or medical services for other conditions that were not included in the modified EI. Thus, having hypertension alone added \$2,258 per year, because annual medical expenditures were \$3,914 in hypertensive adults without any comorbidities included in the EI, and this figure increased to \$13,920 in those with three or more comorbidities included in the EI. The findings of the present study extend this work to pinpoint even further which American adults with hypertension generally incur the highest expenses for medical care.

Hyperlipidemia, CHD, heart rhythm disorders, CHF, valvular disease, and stroke were classified in this study as comorbidities related to CVD. Notably, all six CVD-related comorbidities emerged in the list of the 15 most frequent comorbidities in the population of interest.

Hyperlipidemia was the most frequent comorbidity in adults with hypertension in this study, indicating more than half of adults with hypertension had hyperlipidemia. Similarly, a study using 2009 MEPS data also found that hypertension and hyperlipidemia was the most frequent dyad.³⁷ Based on the 2012 edition of the chartbook, 52.9% of Medicare beneficiaries had both hypertension and hyperlipidemia.³⁸ The present study found that having hyperlipidemia added \$4,851 in medical expenditures per year at the individual level, albeit this marginal increase was lower than it was for the other CVD-related comorbidities except for valvular disease (\$4,453). This is a substantial economic burden to society because of the high prevalence of hypertension and hyperlipidemia. Because hypertension and hyperlipidemia are major CVD risk factors and often coexist, adults with hypertension and hyperlipidemia should adopt healthier lifestyles and adhere to prescribed medications to reduce their risk of CVD.³⁹

In this study, having CHF was associated with the highest incremental medical expenditure in hypertensive adults for the 15 most common comorbidities. Annual total medical expenditures were \$17,063 in persons with CHF and \$9,683 in those without CHF, a difference of \$7,380. Stroke and CHD were ranked as the third and fourth most costly comorbidities among the 15 most frequent, each adding approximately \$6,000. Among Medicare beneficiaries, hypertension, hyperlipidemia, and ischemic heart disease, together, was the most prevalent triad with a prevalence of 33.7%.³⁸ In addition, approximately 55% of Medicare beneficiaries with stroke and heart failure had five or more additional chronic health conditions. As such, a patient with stroke or heart

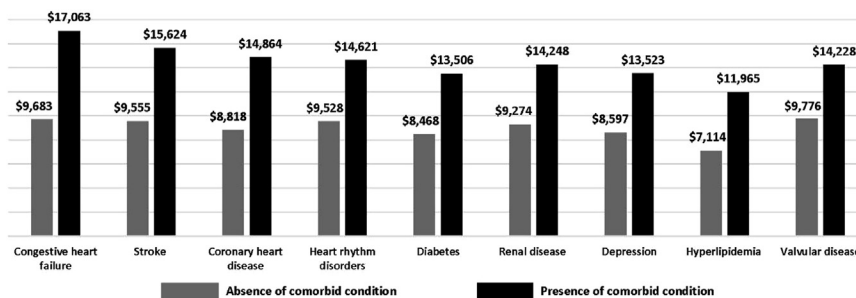


Figure 2. Estimated annual medical expenditures (2014 USD) for nine hypertension-related comorbid conditions among the 15 most frequent comorbid conditions in U.S. hypertensive adults, 2011–2014 Medical Expenditure Panel Survey.

Note: Mean annual total healthcare expenditures were estimated using the average marginal effects method from the generalized linear model (GLM) with log link and gamma distribution.

failure also had many other conditions contributing to the overall difference in expenditures.³⁸ Hypertension is an independent risk factor for both stroke and CHD. Moreover, appropriate hypertension treatment has been found to reduce the incidence of CHF by >50%, of stroke by 30%–40%, and of myocardial infarction by 20%–25%.^{40–42} Thus, the appropriate management of hypertension, by itself, can reduce the economic burdens to society. Furthermore, such management can decrease the prevalence of these CVDs and reduce overall medical expenditures incurred.

Diabetes is closely related to hypertension. Indeed, hypertension and diabetes share several biological and environmental risk factors, and they frequently occur together.⁴³ In this study, diabetes was the second most common comorbidity; 27.3% of hypertensive adults also had diabetes. Similarly, in a study using 2009 MEPS data, diabetes with hypertension and hyperlipidemia was the most frequent triad.³⁷ In addition, a previous study found that the prevalence of diabetes in a hypertensive population was 27%.⁴⁴ In the whole population, a previous study using the MEPS data reported that the prevalence of diabetes was 8%.⁴⁵ Thus, the prevalence of diabetes in hypertensive adults seems to be roughly three times that seen in the general population. Because of the higher prevalence of diabetes in persons with hypertension, managing diabetes and hypertension together could be an effective way to reduce the economic burden on society. A community health workers program may be a good example.⁴⁶

Hypertension and renal disease are interrelated, and hypertension may cause or result from renal disease.^{47,48} In previous studies, although the prevalence of hypertension varied in patients with renal disease, hypertension was present in up to 90% of such patients.^{49–51} Management of hypertension is more difficult when there is poorer renal function. This study found that renal disease is not only a frequent comorbidity but also a costly problem in hypertensive adults. Implementing effective awareness and prevention programs for renal disease could help to reduce costs

in hypertensive adults with renal disease and respond to public health demand.⁵²

In this study, depression was the fourth most common comorbidity in adults with hypertension, affecting one fourth of this population. This result is quite similar to that obtained by a meta-analysis published in 2015 that found the prevalence of depression to be 26.8% in patients with hypertension.⁵³ Depression is known to have a negative impact on health outcomes in patients with hypertension.^{21,54,55} The present study found that the presence of depression increased expenditures by just under \$5,000. Thus, effective screening for depression and appropriate monitoring of this disorder is important in caring for hypertensive patients. In addition, education in self-management can be a solution to empowering patients to reduce blood pressure and reduce stress and depressive feelings.

Efforts to prevent and control hypertension are critical because hypertension is a major risk factor for heart disease, stroke, and renal disease. In this study, CHF, stroke, CHD, and renal disease were all in the top expenditures category. Hypertension can be better controlled by several approaches, including diet, nutritional supplements, lifestyle modification, and conventional antihypertensive medications.⁵⁶ The Community Guide has found several strategies to be effective for hypertension prevention and control, including self-measured blood pressure, community health workers, clinical decision support systems, reducing out-of-pocket costs for clinical services, and team-based care.^{57–59} In addition, managing obesity could be one of the effective ways for controlling of hypertension and other chronic conditions.⁶⁰ Furthermore, appropriate hypertension management strategies should be developed for hypertensive adults with rheumatoid arthritis, depression, and chronic pulmonary diseases. Although these conditions are not directly associated with hypertension, these are frequent comorbidities in hypertensive adults. Nevertheless, little is known about the evidence on hypertension management strategies with these comorbidities.

This study had several strengths. First, the sample used was large, with a nationally representative database. The large sample enabled exploration into detailed comorbidity status and its impact on medical expenditures. Second, this study used a modified EI, expanding the list of CVD-related diseases to include such disorders as CHD, stroke, and hyperlipidemia. To the authors' knowledge, this is the only study focusing on issues of comorbidity among hypertensive adults. Finally, a rigorous empirical approach that specified various regression models for the estimation was employed, which were able to control for various covariates.

Limitations

This study had several limitations. First, the data used were cross-sectional, and thus the authors can only claim that the medical expenditures were disease-associated although acknowledging that they may not have been the treatment costs for each specific disease. Furthermore, the impact of each comorbidity on the total medical expenditures cannot be interpreted as hypertension-associated. The purpose of this study was to determine how much the comorbidity increased the annual total medical expenditures in hypertensive adults. Second, MEPS does not include institutionalized persons in its database. Such people may have many serious comorbidities, and thus this study no doubt underestimated the percentage of hypertensive adults in the U.S. with comorbidities and therefore the associated direct medical costs. Third, because MEPS is a national survey, there is a possibility of recall bias. Respondents might not be able to correctly provide certain types of information, such as medical history. Fourth, this study did not investigate indirect costs, such as caregiver burden and absenteeism. Further research may be needed to examine the impact of comorbidity on productivity loss and the associated indirect costs in adults with hypertension. Fifth, the outcome variable was annual total medical expenditures including any types of medical services. For future studies, analyzing the breakdown of total medical expenditures by the type of services, such as inpatient hospitalizations, outpatient visits, emergency department visits, office-based physician visits, home health-care visits, and prescription medications could provide additional insights about cost burdens and guide intervention efforts. Finally, it was found that being a current nonsmoker was associated with higher annual medical expenditures among hypertensive adults, compared with being a current smoker. However, it is previously known that smoking in hypertensive adults, including former smokers, was associated with increased medical expenditures.⁶¹ In MEPS, there is no information about smoking history. The most likely explanation is that hypertensive adults who are sick, with higher expenditures, are more likely to quit smoking.

CONCLUSIONS

Comorbidities were highly prevalent among U.S. hypertensive adults, and each successive comorbidity significantly increased the medical expenditures. The expenditure increases varied by the type and number of comorbidities. These findings illustrate the importance of looking at the impact of comorbidities and can be used to help develop and evaluate interventions for hypertension prevention and control.

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SUPPLEMENTAL MATERIAL

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