

Medical Costs of CKD in the Medicare Population

Amanda A. Honeycutt,* Joel E. Segel,[†] Xiaohui Zhuo,[‡] Thomas J. Hoerger,* Kumiko Imai,[§] and Desmond Williams[‡]

*Research Triangle International, Research Triangle Park, North Carolina; [†]University of Michigan, School of Public Health, Ann Arbor, Michigan; [‡]Division of Diabetes Translation, National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention, Atlanta, Georgia; and [§]Atlanta, Georgia

ABSTRACT

Estimates of the medical costs associated with different stages of CKD are needed to assess the economic benefits of interventions that slow the progression of kidney disease. We combined laboratory data from the National Health and Nutrition Examination Survey with expenditure data from Medicare claims to estimate the Medicare program's annual costs that were attributable to CKD stage 1–4. The Medicare costs for persons who have stage 1 kidney disease were not significantly different from zero. Per person annual Medicare expenses attributable to CKD were \$1700 for stage 2, \$3500 for stage 3, and \$12,700 for stage 4, adjusted to 2010 dollars. Our findings suggest that the medical costs attributable to CKD are substantial among Medicare beneficiaries, even during the early stages; moreover, costs increase as disease severity worsens. These cost estimates may facilitate the assessment of the net economic benefits of interventions that prevent or slow the progression of CKD.

J Am Soc Nephrol 24: 1478–1483, 2013. doi: 10.1681/ASN.2012040392

Approximately 26 million adults in the United States have CKD.¹ This population is expected to grow as the United States population ages and the prevalence of diabetes and other risk factors for CKD increases among all age groups. Individuals with ESRD, the most severe stage of CKD, or stage 5, generally receive Medicare health care coverage under the ESRD program. By tracking annual Medicare spending on ESRD since the program's inception in 1983, the U.S. Renal Data System (USRDS) has provided a comprehensive picture of the annual costs for people with ESRD. The 2010 USRDS report shows that Medicare spent \$29 billion in 2009, or almost 6% of the annual Medicare budget, for people with ESRD.² However, limited information is available about the costs of earlier stages of CKD. Across all stages of CKD, the 2011 USRDS report shows that annual Medicare spending among adults aged 65 years or older was \$20,432 per person.³

Estimating the medical costs of earlier stages of CKD is challenging because these stages often go unreported on health care claims or in survey data. In a study among persons with diabetes, Kern and colleagues⁴ found that only 20%–40% of persons with CKD, defined as a GFR <60 ml/min per 1.73 m²,

received a renal-related diagnosis code in Department of Veterans Affairs or Medicare claims data. To estimate the health care costs attributable to CKD, people with CKD must be identified by using laboratory data and their costs compared with those of similar people who do not have CKD.

Smith and colleagues⁵ identified people with CKD on the basis of laboratory tests, but their analyses are limited because the study population was from a northwestern United States health maintenance organization (HMO) and was mostly non-Hispanic white (78%). Because HMO enrollees may have a different health use pattern than enrollees in other types of health care plans, and the medical costs may vary by race or ethnicity, the cost estimates by Smith and colleagues^{5,6} may not

Received April 19, 2012. Accepted April 15, 2013.

Published online ahead of print. Publication date available at www.jasn.org.

Correspondence: Amanda A. Honeycutt, Research Triangle International, 3040 Cornwallis Road, P.O. Box 12194, Research Triangle Park, NC 27709. Email: honeycutt@rti.org

Copyright © 2013 by the American Society of Nephrology

be representative of the entire population of the United States.

Our study estimates the medical costs attributable to different stages of CKD among Medicare beneficiaries by using a nationally representative population of fee-for-service (FFS) Medicare enrollees, a population predominantly age 65 years or older, for whom we also have laboratory-based estimates of CKD prevalence from the National Health and Nutrition Examination Survey (NHANES). This linked data set provides a unique data source for examining the effect of CKD on health care costs.

RESULTS

The study sample consisted of 4148 individuals who had both laboratory values from the NHANES data and cost data from Medicare claims. Table 1 shows total annual medical spending and summary statistics for the full study sample and for CKD subsamples. The mean age was 72 years. A large fraction of the sample had comorbid conditions, such as diabetes and hypertension. Coronary heart disease was more prevalent among patients with CKD, and the prevalence increased with the severity of CKD. Twenty-one percent of the sample population had cancer, 45% had arthritis, and 24% had back pain. The characteristics of the study population differed at each CKD stage. Annual medical spending was \$9200 for stage 1 CKD, \$7900 for stage 2, \$9300 for stage 3, and \$18,600 for stage 4.

Table 2 provides results from two-part cost models by stage of CKD. Our estimates show that annual medical costs are higher for the more advanced stages of CKD. We estimate

the average annual per person costs attributable to stage 1 CKD to be \$1600; however, this estimate is not significantly different from zero. The estimated cost is \$1700 for stage 2 and \$3500 for stage 3, both significantly different from zero. Estimated annual costs per person attributable to stage 4 CKD are \$12,700—more than three times the point estimate for stage 3.

In addition to the baseline analysis, we estimated an alternative model specification that included all the covariates from the baseline model in addition to indicators for stroke, myocardial infarction, and congestive heart failure. The estimates from this specification are somewhat lower than baseline estimates from stage 2 to stage 4, as expected. The average cost is \$2100 at stage 1, although this was not statistically significant. The costs are \$1500 at stage 2, \$3000 at stage 3, and \$12,300 at stage 4. Results for stages 2–4 suggest that including indicators for other heart diseases in the model drives the estimates slightly downward. These estimates can serve as a lower bound for the medical costs directly attributable to CKD because some of the cardiovascular complications costs excluded from these estimates were caused by CKD.

Total spending for the Medicare FFS population is estimated to be \$4.6 billion attributable to stage 2 CKD, \$37.2 billion to stage 3 CKD, and \$7.2 billion to stage 4 CKD. In total, stage 2–stage 4 CKD costs Medicare FFS about \$49 billion each year.

DISCUSSION

Our findings highlight the need to identify CKD in its earliest stages to prevent disease progression and avoid the high

Table 1. Summary statistics for overall sample population by stage of CKD

Parameter Description	Overall	No CKD	CKD Stage 1	CKD Stage 2	CKD Stage 3	CKD Stage 4
Patients (n)	4148 ^a	2539	161	438	938	56
Patients (%)	100	45.3 ± 1.6	2.6 ± 0.3	9.1 ± 0.6	21.0 ± 1.1	1.1 ± 0.2
Age (yr)	72.0 ± 0.3	70.4 ± 0.3	69.0 ± 1.5	73.8 ± 0.8	76.4 ± 0.5	77.2 ± 1.4
Women (%)	55.9 ± 1.0	52.9 ± 1.3	44.7 ± 5.4	56.5 ± 3.3	66.6 ± 2.2	58.8 ± 9.8
Race/ethnicity (%)						
White	85.2 ± 1.1	86.1 ± 1.2	64.9 ± 6.1	79.3 ± 2.4	88.0 ± 1.4	80.1 ± 7.3
Hispanic/Latino	2.2 ± 0.2	2.2 ± 0.2	5.2 ± 1.0	3.0 ± 0.4	1.3 ± 0.2	1.5 ± 0.8
Black	8.6 ± 1.1	7.9 ± 1.2	25.5 ± 6.3	10.9 ± 2.4	7.0 ± 1.4	10.2 ± 7.8
Diabetes	13.0 ± 0.6	8.8 ± 0.7	26.4 ± 5.9	25.6 ± 2.9	18.5 ± 1.8	23.0 ± 7.2
Hypertension	64.6 ± 1.0	56.5 ± 1.1	75.1 ± 5.5	78.6 ± 2.4	81.0 ± 1.8	94.6 ± 3.4
Myocardial infarction	11.9 ± 1.0	9.7 ± 1.1	15.1 ± 3.9	12.9 ± 2.4	17.2 ± 1.8	24.3 ± 8.0
Stroke	6.3 ± 0.5	4.7 ± 0.6	6.5 ± 2.2	7.7 ± 1.5	10.3 ± 1.4	14.7 ± 6.6
Congestive heart failure	7.6 ± 0.6	5.1 ± 0.7	5.9 ± 2.4	9.1 ± 1.6	14.2 ± 1.4	23.1 ± 9.0
Cancer	20.6 ± 1.1	19.1 ± 1.2	15.7 ± 3.7	25.1 ± 3.1	24.1 ± 2.1	18.8 ± 6.8
Asthma	8.4 ± 0.5	9.2 ± 0.8	14.3 ± 5.0	7.6 ± 2.0	5.6 ± 1.1	6.5 ± 3.4
Arthritis	45.1 ± 1.2	43.4 ± 1.4	34.7 ± 6.9	44.5 ± 3.4	51.3 ± 2.4	58.8 ± 8.3
Pneumonia	2.9 ± 0.4	2.8 ± 0.4	4.0 ± 3.5	2.4 ± 0.9	3.5 ± 0.7	0.5 ± 0.5
Back pain	24.0 ± 0.9	23.3 ± 1.0	24.8 ± 4.8	25.1 ± 2.8	25.0 ± 2.2	33.6 ± 6.9
Chronic bronchitis	9.4 ± 0.6	8.9 ± 0.9	9.5 ± 4.8	8.9 ± 1.7	10.9 ± 1.5	9.6 ± 5.3
Total medical costs (2010\$) ^b	7200 ± 270	6100 ± 370	9200 ± 1790	7900 ± 900	9300 ± 650	18,600 ± 4520

Unless otherwise noted, values are expressed as mean ± SEM.

^aIncludes 16 people who had ESRD.

^bUpdated to 2010 dollars by using the medical care component of the Consumer Price Index, rounded to the nearest \$100.

Table 2. Per person and total costs attributable to CKD

CKD Stage	Per Person Costs (95% CI) ^a	Estimated Medicare FFS Enrollees, 2008 (n) ^b	Total CKD Costs for Medicare FFS Enrollees (\$) ^c
1	1600 (–900 to 3870)	474,012	0.76 billion
2	1700 (530 to 2840)	2,700,432	4.56 billion
3	3500 (1780 to 4620)	10,726,317	37.18 billion
4	12,700 (6000 to 19,650)	563,787	7.17 billion

Updated to 2010 dollars by using the medical care component of the Consumer Price Index. Each part of the two-part cost models estimated also included controls for age, age-squared, sex, race/ethnicity, education, region of residence, and each of the following comorbid conditions: diabetes, hypertension, cancer, arthritis, pneumonia, back pain, chronic bronchitis, and asthma. CI, confidence interval.

^aBootstrapped 95% CIs by using 1000 iterations.

^bCalculated by using estimates of CKD prevalence for the population age 65 years or older to most closely approximate the Medicare population; prevalence estimated by using 1999–2004 NHANES data applied to 2010 Medicare enrollment data.

^cEstimates are the product of the per person cost point estimates and the number of enrollees.

medical costs attributable to the latter stages of the disease. We found that Medicare beneficiaries with early stages of CKD have considerable medical costs that can be attributed to CKD. The annual per person medical cost attributable to CKD was \$1700 for stage 2, \$3500 for stage 3, and \$12,700 for stage 4. The medical costs attributable to CKD for persons with stage 1 CKD were not significantly different from zero. The total annual medical costs attributable to stage 2 through stage 4 CKD among the Medicare FFS beneficiary population are almost \$49 billion.

Our mean spending estimates are lower than the USRDS annual estimate of \$20,432 per person for Medicare patients with CKD aged 65 years or older.² The difference could result from the different study populations. The USRDS analysis includes only enrollees with diagnosed CKD as identified in Medicare FFS claims. Those patients are likely to have more advanced stages, and thus higher costs, than our study population. Our study sample included persons with both diagnosed and undiagnosed CKD.

Our estimates are similar to those obtained by Smith and colleagues⁵ for stage 3 but much higher for stage 4. Smith *et al.* estimated CKD-attributable costs of \$2600 in 2001 dollars, or \$3700 adjusted to 2010 dollars, compared with our estimate of \$3500 (2010 dollars). However, our costs for stage 4 are almost twice as high as the estimates from Smith and colleagues.⁵ We found stage 4 costs of \$12,700 per person, compared with their estimate of \$6800 (adjusted to 2010 dollars). Because the samples and methods differ considerably between the study by Smith *et al.* and ours, we are unable to determine what drives the differences in cost estimates. However, some important differences are that our study sample was nationally representative of the Medicare FFS population, whereas their sample was representative of privately insured HMO enrollees in the Pacific Northwest. Another difference is that Smith and colleagues⁶ were able to identify stage 2–4 CKD only for individuals who had undergone laboratory tests. If those who had laboratory tests were systematically different from the controls or from the rest of the population, then Smith and colleagues' estimates could be biased. Our study used a sample of individuals from NHANES—all of whom were tested for urine albumin and creatinine. The higher stage 4 costs in our

analysis may also result from lags between the year of laboratory testing and the year or years of Medicare cost data if people we identified as having stage 4 CKD had progressed to ESRD in the years for which we have cost data.

This study has several limitations. First, because we use Medicare claims to estimate CKD expenditures, we are limited to the types of care reimbursed by the Medicare program from 1991 to 1994; our costs do not include prescription drug costs, nursing home costs, or payments from sources other than the Medicare program. In additional analyses of Medical Expenditure Panel Survey data, we have estimated prescription drug costs attributable to CKD of approximately \$2200 per person for those age 65 years or older. Assuming this estimate represents prescription drug costs attributable to stage 4 CKD, our estimates of the Medicare costs attributable to stage 4 CKD may undercount the true costs by 15%–20% owing to the exclusion of prescription drug costs. We also use the medical care Consumer Price Index, which represents an average of costs for prescription and nonprescription drugs, medical products, and medical services (*e.g.*, doctors' visits and hospital services), to account for price inflation between 1991–1994 and 2010. If we use the medical care services component only, which excludes drug prices, our cost estimates in 2010 dollars would be somewhat higher, although not statistically significantly higher.

Second, we were unable to identify persistent microalbuminuria using NHANES. Although NHANES is the only nationally representative data set with laboratory values that can be used to identify CKD, we could only identify indicators of stages 1 and 2 CKD. We expect that this approach may lead to conservative cost estimates for stages 1 and 2 because we probably categorized some people as having stages 1 and 2 CKD who did not have persistent microalbuminuria (and therefore had less severe CKD). Third, our estimates are limited in that we define CKD on the basis of NHANES III laboratory tests that were conducted some time during 1988–1994. Those CKD diagnoses were then linked to annual Medicare costs from 1991 to 1994. This approach assumes that individuals did not shift between CKD stages from the time of laboratory testing until the time for which we have their Medicare costs. If so, our cost estimates for the earlier stages of CKD may be

biased upward. We conducted a sensitivity analysis to explore the potential impact on our stage 4 cost estimates of progression from stage 4 CKD to ESRD for a subset of our sample. We used estimates of the percentage of patients with GFR < 45 ml/min per 1.73 m² who died (61%) and the percentage who progressed to ESRD (5%) over 9 years of follow-up⁷ to estimate the percentage of survivors who progressed to ESRD. Applying these percentages to our CKD stage 4 cost estimates, for which the maximum possible time period between laboratory measurements and claims data assessment was only 6 years, and assuming an annual cost attributable to ESRD of \$50,000, we nonetheless estimate that substantial costs would be attributable to stage 4 CKD—\$7200 per year.

Our analysis demonstrates that the economic burden of CKD is high among the older adult population. The earlier stages of CKD contribute to high aggregate costs because of the large number of older adults with stage 1, 2, or 3 CKD. These estimates may be useful in analyses of the cost-effectiveness of CKD preventive interventions for older adults. Our findings further suggest that efforts to prevent the development of CKD, such as diabetes and hypertension control, may be associated with significant medical cost savings. In addition, early identification of CKD may help to prevent the high costs associated with advanced renal disease and failure. Our analysis suggests a need for more recent and comprehensive data (*e.g.*, all age groups) to better document how prevalent CKD is among the United States population and to assess the full economic burden of CKD.

CONCISE METHODS

We used a data set created by the National Center for Health Statistics (NCHS) Research Data Center (RDC) that linked data from NHANES III with data from Medicare claims for respondents who were Medicare beneficiaries. The reimbursements reported in the Medicare claims data reflect the actual payments made by the Medicare program, including costs for inpatient, outpatient, emergency department, skilled-nursing facility, home health, durable medical equipment, and hospice care. Because we conducted analyses from the Medicare perspective, Medicare beneficiaries' out-of-pocket spending and secondary insurance payments were not included.

NHANES is a nationally representative data set designed to collect data on the health and nutrition status of civilians in the United States, noninstitutionalized population. Respondents answer demographic and health questions during an interview and are given a physical examination to collect laboratory samples and other health measurements. NHANES III data were collected from 1988 to 1994. Additional survey details are available from NCHS.^{7,8}

The RDC link combined publicly available NHANES III data with restricted-access Medicare claims from 1991 to 1994, the most recently available linked NHANES and cost data at the time of our analysis. Individual records from Medicare claims and NHANES were matched by individual identifier and year. For some individuals in the sample, NHANES III laboratory and survey data are from years before their

Medicare claims data (*e.g.*, NHANES III data from 1988 are linked to claims data from 1992). Because most Medicare recipients are 65 years of age or older, the match rate between the NHANES data and the Medicare claims data were >95% for the population older than 65 years but <5% for the population younger than 65 years.

Using the NHANES laboratory data, we identified CKD by stage for each person according to the Kidney Disease Outcomes Quality Initiative guidelines.⁹ First, we calculated the estimated GFR using serum creatinine values from NHANES that were standardized using the correction recommended by the NCHS¹⁰ and the four-variable simplified Modification of Diet in Renal Disease equation.¹¹ Per NCHS guidance, we calculated the standard serum creatinine value as equal to $0.960 \times (\text{original serum creatinine}) - 0.184$. The laboratory data were collected at a single point in time for all NHANES III participants. We calculated the albumin-to-creatinine ratio (ACR) for each person using urine albumin and urine creatinine values from NHANES to identify the presence of albuminuria. Albuminuria was defined as microalbuminuria (ACR, 30–299 mg/g) or macroalbuminuria (ACR \geq 300 mg/g) on the basis of the definition used by Coresh and colleagues.¹ Next, we identified the stage of CKD according to KDOQI guidelines by using the estimated GFR and the presence of albuminuria.

Although the guidelines indicate that stages 1 and 2 require the presence of persistent albuminuria, only a limited number of individuals in the NHANES sample have the two sets of urine albumin and creatinine values needed to identify persistence. To ensure a sufficient sample size for our cost analysis, we did not eliminate individuals with only a single measurement indicating the presence of albuminuria. Therefore, stages 1 and 2 in our study sample may be described more accurately as indicators of stages 1 and 2, similar to the distinction used by Saydah and colleagues.¹² In addition, we excluded stage 5 from our analysis because only 16 people in our sample had stage 5 CKD.

More than 70% of the individuals in our analytic sample for whom we were able to match NHANES and Medicare claims data had only a single-year record of claims. For these people, we used annual Medicare costs for the available year. For the rest who had multiple-year records, we used mean annual Medicare costs across the available years. For example, for a person surveyed by NHANES in 1992 who had Medicare claims records for 1991 and 1992, we used the mean of 1991 and 1992 Medicare costs. To calculate the medical costs attributable to each stage of CKD, we estimated multivariate regression models of annual Medicare spending (Supplemental Table 1). We used model selection criteria recommended by Manning and Mullahy¹³ and Buntin and Zaslavsky¹⁴ to determine the most appropriate regression model, given the distribution and other characteristics of our medical cost data. We found that a two-part generalized linear model worked best.

In the first part, we used a logistic model to estimate the probability of having positive Medicare costs. In the second part, we used a generalized linear model with a gamma distribution and a log link to estimate cost levels for those with positive Medicare costs. In both models, the primary variables of interest were indicators for stage 1–4 CKD. We also controlled for eight comorbid conditions that are correlated with the presence of CKD, including diabetes, hypertension,

cancer, asthma, arthritis, pneumonia, back pain, and chronic bronchitis, to ensure that the costs of these conditions were not attributed to CKD. Other independent variables included in both model stages were age, age-squared, sex, race/ethnicity (*i.e.*, white, black, Hispanic, other), education (*i.e.*, less than high school, some college, college graduate), and United States Census region (*i.e.*, Midwest, South, West, Northeast).

For individuals with CKD, we multiplied predictions from each of the two model parts to estimate per person average annual costs. We then modeled costs for these individuals, assuming they did not have CKD, by treating the CKD indicator as equal to zero. These models allow us to generate medical spending estimates for people without CKD who are otherwise similar to those in our sample with CKD. As a result, the mean of the difference between the two sets of predictions provides a measure of the annual, per person Medicare costs attributable to CKD, after adjustment for other differences observed in the data (*e.g.*, other medical conditions). This method, an extension of the case-control approach, has been used extensively to isolate the effect of disease on medical costs.^{15–17} We estimated nonparametric, bootstrapped, 95% confidence intervals around the estimates using 1000 iterations and accounting for the complex survey design. We inflated all Medicare costs to 2010 dollars using the medical care component of the Consumer Price Index, which reflects changes in prices for medical equipment and supplies as well as medical care services.¹⁸

As a sensitivity test on our model specification, we reran the regression models using an alternative specification in which we additionally controlled for three heart diseases (myocardial infarction, stroke, and congestive heart failure) that may result from CKD in addition to the eight comorbid conditions. Because some of these cardiovascular diseases result from CKD, this specification may underestimate CKD costs by attributing heart disease costs that arise because of CKD to other conditions. However, this sensitivity analysis produces a lower bound of the medical spending attributable to CKD.

In addition to estimating the annual costs at the individual level, we estimated annual CKD costs for the total Medicare FFS population. To estimate the total number of Medicare enrollees with stage 1–4 CKD, we first estimated the prevalence rate by stage for persons aged 65 or older from 1999 to 2004 NHANES data by using the methods described by Coresh and colleagues.¹ Because prevalence is a population-level estimate, we used the persistent albuminuria multipliers used by Coresh and colleagues to estimate the prevalence of CKD stages 1 and 2 among those age 65 years or older. Macroalbuminuria was assumed to be 100% persistent, whereas 50.9% of microalbuminuria for a GFR ≥ 90 ml/min per 1.73 m² and 75% for a GFR of 60–89 ml/min per 1.73 m² were assumed to be persistent. Then we multiplied by the total number of Medicare FFS enrollees in 2010. Total annual national costs were calculated as the estimated per person annual costs attributable to CKD multiplied by the estimated number of Medicare FFS enrollees with each stage of CKD.

ACKNOWLEDGMENTS

We would like to thank the NCHS for their assistance with setting up the NHANES-Medicare linked data (<http://www.cdc.gov/nchs/about/>

major/nhanes/nhanes_citation.htm). The findings and conclusions in this paper are those of the authors and do not necessarily represent the views of the NCHS or the Centers for Disease Control and Prevention. We thank Susan Murchie for editorial assistance.

We would also like to acknowledge support from the Centers of Excellence in Health Promotion Economics, grant #1 P30 CD000138.

DISCLOSURES

None.

REFERENCES

1. Coresh J, Selvin E, Stevens LA, Manzi J, Kusek JW, Eggers P, Van Lente F, Levey AS: Prevalence of chronic kidney disease in the United States. *JAMA* 298: 2038–2047, 2007
2. U.S. Renal Data System (USRDS): *USRDS 2010 Annual Data Report: Atlas of Chronic Kidney Disease and End-Stage Renal Disease in the United States*, Bethesda, MD, National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases, 2010
3. U.S. Renal Data System (USRDS): *USRDS 2011 Annual Data Report: Atlas of Chronic Kidney Disease and End-Stage Renal Disease in the United States*, Bethesda, MD, National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases, 2011
4. Kern EF, Maney M, Miller DR, Tseng C-L, Tiwari A, Rajan M, Aron D, Pogach L: Failure of ICD-9-CM codes to identify patients with comorbid chronic kidney disease in diabetes. *Health Serv Res* 41: 564–580, 2006
5. Smith DH, Nichols GA, Gullion CM, Johnson ES, Keith D: Predicting costs of care in chronic kidney disease: The role of comorbid conditions. *Internet J Nephrology* 4(1), doi: 10.5580/1d9e
6. Smith DH, Gullion CM, Nichols G, Keith DS, Brown JB: Cost of medical care for chronic kidney disease and comorbidity among enrollees in a large HMO population. *J Am Soc Nephrol* 15: 1300–1306, 2004
7. Dalrymple LS, Katz R, Kestenbaum B, Shlipak MG, Sarnak MJ, Stehman-Breen C, Seliger S, Siscovick D, Newman AB, Fried L: Chronic kidney disease and the risk of end-stage renal disease versus death. *J Gen Intern Med* 26: 379–385, 2011
8. National Center for Health Statistics (NCHS): National Health and Nutrition Survey III. Available at: <http://www.cdc.gov/nchs/about/major/nhanes/nh3data.htm>. Accessed June 27, 2008
9. National Kidney Foundation: K/DOQI clinical practice guidelines for chronic kidney disease: evaluation, classification, and stratification. *Am J Kidney Dis* 39[Suppl 1]: S1–S266, 2002
10. National Center for Health Statistics: Note for correction of serum creatinine for NHANES III, NHANES 1999–2000, 2001–2002 and 2003–2004. Available at: http://www.cdc.gov/nchs/data/nhanes/nhanes_03_04/general_%20note_for_serum_creatinine.pdf. Accessed February 28, 2013
11. Levey AS, Coresh J, Greene T, Stevens LA, Zhang YL, Hendriksen S, Kusek JW, Van Lente F; Chronic Kidney Disease Epidemiology Collaboration: Using standardized serum creatinine values in the modification of diet in renal disease study equation for estimating glomerular filtration rate. *Ann Intern Med* 145: 247–254, 2006
12. Saydah S, Eberhardt M, Rios-Burrows N, Williams D, Geiss L, Dorsey R; Centers for Disease Control and Prevention (CDC): Prevalence of chronic kidney disease and associated risk factors—United States, 1999–2004. *MMWR Morb Mortal Wkly Rep* 56: 161–165, 2007
13. Manning WG, Mullahy J: Estimating log models: to transform or not to transform? *J Health Econ* 20: 461–494, 2001
14. Buntin MB, Zaslavsky AM: Too much ado about two-part models and transformation? Comparing methods of modeling Medicare expenditures. *J Health Econ* 23: 525–542, 2004

15. Honeycutt AA, Segel JE, Hoerger TJ, Finkelstein EA: Comparing cost-of-illness estimates from alternative approaches: an application to diabetes. *Health Serv Res* 44: 303–320, 2009
16. Brandle M, Zhou H, Smith BR, Marriott D, Burke R, Tabaei BP, Brown MB, Herman WH: The direct medical cost of type 2 diabetes. *Diabetes Care* 26: 2300–2304, 2003
17. Trogon JG, Hylands T: Nationally representative medical costs of diabetes by time since diagnosis. *Diabetes Care* 31: 2307–2311, 2008
18. U.S. Department of Labor: Bureau of Labor Statistics: Consumer Price Index. Available at: <http://data.bls.gov/cgi-bin/surveymost?cu>. Accessed February 20, 2012

This article contains supplemental material online at <http://jasn.asnjournals.org/lookup/suppl/doi:10.1681/ASN.2012040392/-/DCSupplemental>.

Supplemental Table 1 for “Medical Costs of Chronic Kidney Disease in the Medicare Population”

Regression Coefficients from Cost Models that use the linked NHANES III-Medicare claims dataset

Part 1 (logistic) models estimated the probability of positive medical spending, and Part 2 (GLM) models estimated total medical expenditures for those with positive spending

Variable	Baseline model		All conditions (sensitivity analysis) model	
	Part 1 Coefficients	Part 2 Coefficients	Part 1 Coefficients	Part 2 Coefficients
Age	-0.255 *	-0.116 *	-0.260 *	-0.123 *
Age-squared	0.002 *	0.001 *	0.002 *	0.001 *
Female	-0.289	-0.456 *	-0.266	-0.377 *
White	0.283	-0.206 *	0.330	-0.210 *
Mexican-American	0.431	-0.121	0.485	-0.150
Other race	1.182 *	-0.369	1.255	-0.361
Cancer	0.176	0.112	0.170	0.074
Arthritis	0.537	0.088	0.514	0.063
Pneumonia	-0.514	0.814 *	-0.504	0.795 *
Back pain	0.064	0.170	0.029	0.081
Chronic bronchitis	0.977	0.062	0.948	0.027
Asthma	-0.099	0.083	-0.092	0.025
Diabetes	-0.200	0.249 *	-0.294	0.162
Hypertension	0.732 *	-0.082	0.727 *	-0.128
Congestive heart failure	-	-	0.731	0.418 *
Stroke	-	-	1.888 *	0.352 *
Myocardial infarction	-	-	-0.196	0.340 *
Less than high school	-0.127	-0.172	-0.119	-0.183
Missing degree	16.485	0.064	16.376 *	0.122
Some college	-0.372	-0.139	-0.332	-0.160
College graduate	0.605	-0.101	0.606	-0.122
Midwest	0.169	-0.097	0.148	-0.095
South	-0.039	0.044	-0.056	0.011
West	-0.537	0.065	-0.629	0.082
Stage 1	1.099 *	0.166	1.151	0.211
Stage 2	0.545	0.207	0.553	0.193
Stage 3	-0.176	0.447 *	-0.233	0.375 *
Stage 4	1.188	1.064 *	1.115	0.908 *
Stage 5	16.072 *	2.030 *	16.029 *	2.072 *
Constant	9.340 *	12.662 *	9.411 *	12.830 *

* Significant at the 95% level