

# Medicare Capitation Model, Functional Status, and Multiple Comorbidities: Model Accuracy

Katia Noyes, PhD, MPH; Hangsheng Liu, PhD; and Helena Temkin-Greener, PhD, MPH

**C**hronic conditions such as heart disease, hypertension, arthritis, cancer, and diabetes are the leading causes of disability and death in the United States for people older than 65 years.<sup>1</sup> Medicare beneficiaries with 5 or more chronic conditions account for 68% of the program's spending.<sup>2</sup> Co-occurrence of diseases increases markedly with age, with two-thirds of noninstitutionalized Medicare beneficiaries over the age of 65 years reporting 2 or more chronic conditions,<sup>3</sup> with the prevalence of multiple comorbidities being even higher among the Medicare population overall. Approximately 25% of those who experience chronic illness have some limitations in functional activity, and the percentage of those with disability increases with the number of coexisting conditions.<sup>4</sup> The presence of chronic disease has been consistently shown to be associated with functional dependence,<sup>5-7</sup> with combinations of diseases showing different influence on physical functioning than would be expected with the sum of the individual conditions.<sup>8-10</sup>

Recognizing the increasing prevalence of chronic comorbid conditions in the Medicare population, as well as the need to adequately compensate Medicare managed care plans for the care they provide to this segment of the population, beginning in 2004 the Centers for Medicare & Medicaid Services (CMS) started to phase in a new risk-adjusted payment model. Known as the CMS-Hierarchical Condition Categories (CMS-HCC), this risk-adjustment model relies on demographic and diagnostic information available from administrative data to predict resource use. The model uses a selected subset of *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)* diagnostic codes from hospital and physician encounters to place beneficiaries into 70 disease groups: the HCCs.<sup>11,12</sup> (The original model was developed using 1999-2000 claims. Starting in 2007, the HCC model was recalibrated using 2002-2003 data.) Each disease group includes conditions that are related clinically and have similar cost implications. In addition, the model accounts for the fact that having certain combinations of diseases may result in higher medical expenditures that simply are the sum of the 2 conditions.

For instance, such disease interaction coefficients are allowed for diabetes and congestive heart failure (CHF); diabetes and cerebrovascular disease; diabetes, CHF, and renal failure; and a limited number of others.<sup>12</sup>

**In this issue**

Take-away Points / p689

[www.ajmc.com](http://www.ajmc.com)

Full text and PDF

**Web exclusive**

eAppendix Tables A and B

**Objective:** To examine financial implications of the Centers for Medicare & Medicaid Services Hierarchical Condition Categories (CMS-HCC) risk-adjustment model on Medicare payments for individuals with comorbid chronic conditions.

**Study Design:** The study used 1992-2000 data from the Medicare Current Beneficiary Survey and corresponding Medicare claims. Pairs of comorbidities were formed based on prior evidence about possible synergy between these conditions and activities of daily living (ADLs) deficiencies, and included heart disease and cancer, lung disease and cancer, stroke and hypertension, stroke and arthritis, congestive heart failure (CHF) and osteoporosis, diabetes and coronary artery disease, and CHF and dementia.

**Methods:** For each beneficiary, we calculated the actual Medicare cost ratio as the ratio of the individual's annualized costs to the mean annual Medicare cost for all people in the study. The actual Medicare cost ratios, by ADLs, were compared with HCC ratios under the CMS-HCC payment model. Using multivariate regression models, we tested whether having the identified pairs of comorbidities affected the accuracy of CMS-HCC model predictions.

**Results:** The CMS-HCC model underpredicted Medicare capitation payments for patients with hypertension, lung disease, CHF, and dementia. The difference between the actual costs and predicted payments was partially explained by beneficiary functional status and less-than-optimal adjustment for these chronic conditions.

**Conclusion:** Information about beneficiary functional status should be incorporated in reimbursement models. Underpaying providers who care for populations with multiple comorbidities may provide severe disincentives for managed care plans to enroll such individuals and to appropriately manage their complex and costly conditions.

(*Am J Manag Care.* 2008;14(10):679-690)

**For author information and disclosures, see end of text.**

There have always been concerns regarding the accuracy of the HCC model in predicting Medicare payment.<sup>13-16</sup> Understanding the relationship between functional limitations and cost of medical care in patients with multiple chronic conditions is currently gaining importance and recognition. In 2003, CMS created Special Needs Plans (SNPs), allowing healthcare providers to accept full risk from CMS for all medical and pharmacy health expenses for enrollees with specific chronic diseases.<sup>17</sup> By the beginning of 2008, 775 plans enrolled nearly 1 million beneficiaries.<sup>18</sup>

The HCC model does not (except for the Program of All Inclusive Care for the Elderly [PACE]) include adjustment for functional impairment. Studies have shown that this lack of adjustment results in underestimation of payments for enrollees with disabilities. We also know that people with comorbid conditions tend to be more functionally disabled; hence, our interest in examining the extent to which the HCC model may not pay appropriately for this segment of the population, very significantly represented in the SNPs. Furthermore, the HCC model does not account at all for a number of prevalent chronic conditions (eg, dementia, osteoporosis); hence, our interest in including those conditions in the analyses.

The effect of multiple comorbidities on disability and cost of care is poorly understood. Ettinger and colleagues explored synergy between arthritis and 4 comorbidities (heart disease, pulmonary disease, obesity, and hypertension) and proposed a mechanism explaining increased disability resulting from multiple comorbidities.<sup>19</sup> They suggested that an impairment from one disease (eg, inactivity resulting from arthritis) may exacerbate the impairment from another comorbid condition (eg, low work capacity caused by heart disease), thus modifying the disease-disability relationship. Prior studies also identified additional specific diseases such as cerebrovascular disorders, diabetes, cancer, osteoporosis, atherosclerosis, and neurologic problems that may exacerbate disability resulting from other conditions.<sup>8,7,10,19,23</sup> Based on this evidence, we identified the following 11 target comorbidities to be examined in this study, taking into account the level of functional impairment: arthritis, hypertension, heart disease, cancer, lung disease, stroke, osteoporosis, diabetes, coronary artery disease (CAD), CHF, and dementia.<sup>7</sup>

Furthermore, we hypothesized that certain combinations of the 11 target conditions may have synergistic effects with respect to physical and cognitive functioning when evaluated longitudinally. This in turn would affect patient performance in activities of daily living (ADLs) and the subsequent cost of medical care. These predictions were based on the previous cross-sectional (arthritis and hypertension, heart disease and cancer, lung disease and cancer, and stroke and hypertension)<sup>10,24-26</sup> and longitudinal<sup>7,8,16,21,27</sup> studies. In addition, de-

mentia may accelerate functional decline and mortality, and may exacerbate other chronic conditions as well. Osteoporosis could lead to more fractures and trauma in older patients, which would increase temporary and permanent disability and might limit people's ADL performance as they tried to minimize their risks.

The purpose of this study is to assess the accuracy of the CMS-HCC Medicare capitation model in predicting Medicare expenditures for community-based beneficiaries with at least 2 target comorbidities identified above and various degrees of functional impairment. The population of Medicare beneficiaries with coexisting chronic conditions represents a good case for testing the accuracy of the CMS-HCC Medicare risk-adjustment model, which (1) does not account for patient functional limitations that may exacerbate the inaccuracy of predictions for patients with multiple chronic conditions and (2) does not account for all chronic conditions, which also may result in underestimation of payments.

## METHODS

### Data

The study used 9 years of data (1992-2000 Cost & Use files) from the Medicare Current Beneficiary Survey (MCBS) and corresponding Medicare claims data for the participating beneficiaries. The MCBS includes information about Medicare beneficiaries' health and use of healthcare services, administrative data from CMS, and Medicare claims for the survey participants for the corresponding calendar year. Several reports had been published describing the structure of the MCBS<sup>28</sup> and the link between the survey and expenditure data.<sup>29</sup> Our total sample consisted of 46,790 community-dwelling Medicare beneficiaries who participated in the fee-for-service plans. We defined community population as those beneficiaries who did not stay in institutions for more than 90 days at a time according to the *Medicare Managed Care Manual*.<sup>30</sup> We limited the sample to beneficiaries with continuous Part A and B enrollment for at least 2 calendar years. Beneficiaries with end-stage renal disease were excluded.

Using the MCBS data, functional status was measured by the number of impairments in ADLs (0-6), adding 1 point for the presence of each deficiency (eg, whether the beneficiary got help with bathing, dressing, eating, walking, toileting, and transferring, or used assisted devices to perform these functions).

Comorbidities were identified either according to self-reported disease status or through the Medicare claims of the survey participants. We chose 11 target chronic conditions to evaluate for the effect of comorbidity because of their prevalence among the Medicare population as well as their reported association with

disability.<sup>7,8,10,19-23</sup> Arthritis, hypertension, heart disease, cancer, lung disease, stroke, osteoporosis, diabetes, and CAD were self-reported by the MCBS participants (with the question “Has your doctor ever told you that you have?...”), while CHF and dementia were not addressed by the MCBS and, therefore, were identified based on the ICD codes from the Medicare claims data. See [eAppendix Table A](#) for the complete list of codes (available at [www.ajmc.com](http://www.ajmc.com)). Beneficiaries were identified as having CHF if they had any claims with ICD-9 codes 428-428.9.<sup>31</sup> Dementia was identified based on having any Medicare claims containing ICD codes 290.0 to 290.3, 294.1, 294.8, 294.9, 298.9, 331.0, 331.2, 331.3, 331.4, 348.3, 797, and 780.9.<sup>32</sup> Similar ICD-9-CM codes are used by the Medicare risk-adjustment model for Part D prescription drug coverage: RxHCC.<sup>33</sup>

The MCBS reports life-long prevalence of chronic conditions, while a claims-based approach identifies whether a patient had a condition-related utilization in a given year. Nevertheless, because CHF and dementia are chronic conditions that require ongoing treatment, we thought it was reasonable to use claims to identify patients with these conditions. In addition, the CMS-HCC model does not contain separate categories for hypertension or dementia, whereas the effect of CAD is reflected in several categories (HCC81-HCC83). It is assumed, however, that the effect of hypertension and dementia on the costs of care would be accounted for by other related categories (eg, acute or old myocardial infarction and angina for hypertension, Parkinson’s disease for dementia).

### Population Descriptive Statistics

Beneficiaries with the pairs of target conditions were compared with the general Medicare population on characteristics such as sex, race, frequency of each ADL, and place of residence using chi-square tests. Student *t* tests were used to identify significant differences between these groups of patients by age and number of ADLs. Survey weights were incorporated into the comparisons to represent the entire Medicare population. All statistical tests were 2 tailed and were performed using a significance level of 5%.

### Comparing Actual Medicare Costs With the CMS-HCC Model Predictions

We computed the Medicare annualized costs for each beneficiary by adjusting the reported annual Medicare costs for each person’s spell of eligibility. For each beneficiary, we calculated the actual Medicare cost ratio as the ratio of the individual’s annualized costs to the mean annual Medicare cost of all people in the study.

To calculate the HCC scores, we used the available CMS-HCC software.<sup>11</sup> The original CMS-HCC capitation payment approach was developed using year 1999 Medi-

care claims data to predict year 2000 medical expenditures, with 3 individual models developed to predict expenditures for new enrollees, community-based beneficiaries, and facility residents. Under the CMS-HCC model, individuals are assigned to multiple HCC groups based on the prior (base) year diagnoses. In addition, the model uses age, sex, original reason for Medicare entitlement (disability or age), Medicaid eligibility status, and whether the beneficiary resides in the community, facility, or is a new enrollee (enrolled in Medicare for less than 12 months in the prior year) to predict the next (prediction) year expenses.<sup>12</sup> The total individual HCC score is calculated as a sum of multiple HCC scores assigned to a person. For each person, the HCC score indicates how the predicted medical expenses compare with the average for the Medicare population. In this study, we focused only on the community model.

The relative error in the CMS-HCC model was computed as the percent difference between the CMS-HCC predicted cost ratio and the actual Medicare cost ratio, with the positive difference suggesting model underprediction. *P* values less than .05 indicate relative errors significantly different from zero. The 95% confidence intervals (CIs) were reported to illustrate robustness of the estimates.

### Effect of Multiple Comorbidities and Functional Status on the Accuracy of CMS-HCC Model Predictions

Using multiple regressions, we tested whether having the identified pairs of comorbidities affected the accuracy of CMS-HCC model predictions. The dependent variable was the residual Medicare expenditures ratio, defined as the difference between the actual cost ratio and the predicted cost ratio (the HCC score) for each individual (similar to the approach used by Kautter and Pope<sup>13</sup>) and based on the work of Temkin-Greener and colleagues<sup>16</sup> and Riley.<sup>15</sup> The residual ratio reflects the accuracy of CMS-HCC model prediction. The independent variables included the dummy variables for the different levels of physical disability (ADLs), target comorbidities, and the interactions between these comorbidities. Survey sampling weights were incorporated in the multiple regression analysis.

The analyses were conducted using STATA Statistical Software for Windows, Release 8.0 (College Station, TX: StataCorp) and SAS for Unix, Version 9 (Cary, NC: SAS Institute).

## RESULTS

### Population Characteristics

Nearly three-quarters (72.55%) of all Medicare beneficiaries in our study had 2 or more target comorbidities, with

■ **Table 1.** Population Characteristics<sup>a</sup>

Variable	Total Population	Arthritis & Hypertension	Heart Disease & Cancer	Lung Disease & Cancer	Stroke & Hypertension	Stroke & Arthritis	CHF & Osteoporosis	Diabetes & CAD	CHF & Dementia
<b>No. of person-years<sup>b</sup></b>	46,790	16,844	6936	2455	3760	3508	795	2499	598
Prevalence	100	35.85	14.65	5.24	7.80	7.03	1.52	5.32	1.11
<b>Mean age, y</b>	72.75	74.27 <sup>c</sup>	75.64 <sup>c</sup>	73.25 <sup>d</sup>	74.24 <sup>c</sup>	74.64 <sup>c</sup>	79.05 <sup>c</sup>	73.45 <sup>c</sup>	80.07 <sup>c</sup>
<b>Male</b>	42.44	33.56 <sup>c</sup>	45.98 <sup>c</sup>	46.58 <sup>c</sup>	42.75	39.46 <sup>d</sup>	12.12 <sup>c</sup>	48.01 <sup>c</sup>	38.67
<b>White</b>	87.64	84.09 <sup>c</sup>	93.88 <sup>c</sup>	93.94 <sup>c</sup>	83.39 <sup>c</sup>	85.49 <sup>d</sup>	89.85	84.90 <sup>c</sup>	83.57 <sup>c</sup>
<b>Married</b>	52.99	48.73 <sup>c</sup>	55.15 <sup>c</sup>	53.58	48.79 <sup>c</sup>	46.32 <sup>c</sup>	30.45 <sup>c</sup>	51.08	37.73 <sup>c</sup>
<b>Medicaid</b>	14.69	18.02 <sup>c</sup>	11.52 <sup>c</sup>	15.77	22.22 <sup>c</sup>	22.51 <sup>c</sup>	23.99 <sup>c</sup>	22.27 <sup>c</sup>	27.97 <sup>c</sup>
<b>Metropolitan area residence</b>	69.39	68.73	68.14	65.57	68.86	69.25	67.78	69.91	73.13
<b>Mean income (2002 \$)</b>	34,015	29,677 <sup>c</sup>	36,022 <sup>d</sup>	32,936	28,673 <sup>c</sup>	27,689 <sup>c</sup>	23,223 <sup>c</sup>	28,601 <sup>c</sup>	24,626 <sup>c</sup>
<\$15,000	29.71	33.93 <sup>c</sup>	25.22 <sup>c</sup>	28.18	36.99 <sup>c</sup>	38.72 <sup>c</sup>	44.38 <sup>c</sup>	34.54 <sup>c</sup>	44.01 <sup>c</sup>
\$15,000-\$30,000	31.82	33.20 <sup>c</sup>	32.21	34.21	32.86	32.98	33.60	34.10	32.47
\$30,001-\$50,000	21.79	20.20 <sup>c</sup>	23.53 <sup>c</sup>	22.27	19.02 <sup>c</sup>	17.30 <sup>c</sup>	15.72 <sup>c</sup>	20.61	15.15 <sup>c</sup>
>\$50,000	16.69	12.68 <sup>c</sup>	19.03 <sup>c</sup>	15.34	11.13 <sup>c</sup>	11.00 <sup>c</sup>	6.30 <sup>c</sup>	10.75 <sup>c</sup>	8.37 <sup>c</sup>
<b>Mean number of ADLs</b>	0.29	0.38 <sup>c</sup>	0.39 <sup>c</sup>	0.38 <sup>c</sup>	0.87 <sup>c</sup>	0.89 <sup>c</sup>	1.22 <sup>c</sup>	0.58 <sup>c</sup>	1.85 <sup>c</sup>
Difficulty in bathing	7.96	10.41 <sup>c</sup>	10.88 <sup>c</sup>	11.46 <sup>c</sup>	22.57 <sup>c</sup>	23.22	34.34 <sup>c</sup>	16.25 <sup>c</sup>	47.11 <sup>c</sup>
Difficulty in dressing	5.52	7.09 <sup>c</sup>	6.83 <sup>c</sup>	6.56	16.95 <sup>c</sup>	17.01 <sup>c</sup>	21.52 <sup>c</sup>	10.72 <sup>c</sup>	37.28 <sup>c</sup>
Difficulty in eating	1.43	1.60	1.64	1.28	5.44 <sup>c</sup>	5.61 <sup>c</sup>	5.31 <sup>c</sup>	2.24 <sup>d</sup>	12.91 <sup>c</sup>
Difficulty in transferring	5.06	6.97 <sup>c</sup>	6.90 <sup>c</sup>	6.14	14.85 <sup>c</sup>	15.68 <sup>c</sup>	20.50 <sup>c</sup>	10.14 <sup>c</sup>	30.06 <sup>c</sup>
Difficulty in walking	6.57	8.89 <sup>c</sup>	9.78 <sup>c</sup>	10.32 <sup>c</sup>	17.66 <sup>c</sup>	18.66 <sup>c</sup>	27.53 <sup>c</sup>	13.67 <sup>c</sup>	35.36 <sup>c</sup>
Difficulty in toileting	2.63	3.18 <sup>c</sup>	3.12 <sup>d</sup>	2.64	9.10 <sup>c</sup>	9.30 <sup>c</sup>	12.59 <sup>c</sup>	5.14 <sup>c</sup>	22.21 <sup>c</sup>
<b>Geographic area</b>									
New England	3.24	3.01 <sup>d</sup>	3.42	2.82	2.72 <sup>d</sup>	3.01	4.85	2.67	4.57 <sup>d</sup>
Middle Atlantic	17.82	16.95 <sup>d</sup>	16.47	13.44 <sup>c</sup>	16.07 <sup>d</sup>	14.33 <sup>c</sup>	16.04	18.66	18.96
East North Central	18.41	17.57	16.18 <sup>c</sup>	17.68	17.99	18.06	17.26	18.03	16.34
West North Central	6.92	5.65 <sup>c</sup>	6.59	6.13	5.55 <sup>c</sup>	5.54 <sup>c</sup>	4.95 <sup>d</sup>	4.74 <sup>c</sup>	5.48
South Atlantic	21.21	23.28 <sup>c</sup>	22.46	21.39	23.59 <sup>c</sup>	23.91 <sup>c</sup>	21.87	23.91 <sup>d</sup>	22.55
East South Central	6.18	7.17 <sup>c</sup>	6.92 <sup>d</sup>	8.02 <sup>c</sup>	7.04	7.75 <sup>c</sup>	5.29	6.50	7.34
West South Central	11.04	11.19	12.28	12.67	11.81	11.41	12.11	11.99	11.53
<b>Mountain</b>	4.90	4.66	5.28	6.42 <sup>c</sup>	4.56	5.08	4.73	2.84 <sup>c</sup>	2.79 <sup>c</sup>
<b>Pacific</b>	9.02	8.98	10.05	10.84	10.03	10.26	10.57	7.95	8.42
<b>Puerto Rico</b>	1.27	1.55 <sup>c</sup>	0.36 <sup>d</sup>	0.58	0.65 <sup>c</sup>	0.64 <sup>c</sup>	2.32	2.73 <sup>c</sup>	2.01 <sup>c</sup>

ADLs indicates activities of daily living; CAD, coronary artery disease; CHF, congestive heart failure.

<sup>a</sup>Values are percentages unless otherwise indicated.

<sup>b</sup>The total number of person-years was 46,790, including those who participated in the Medicare Current Beneficiary Survey for at least 2 years.

<sup>c</sup>Compared with the total population, significant at the 1% level.

<sup>d</sup>Compared with the total population, significant at the 5% level.

the prevalence of different target comorbidities varying substantially. In **Table 1**, we compared the characteristics of the general Medicare population with those of beneficiaries who had pairs of target chronic conditions. Although more than a third of all beneficiaries had arthritis and hypertension, only about 1% of people had either CHF and osteoporosis or

CHF and dementia. Patients with chronic illnesses were significantly older than the study population overall (age 72.75 years). Proportion of women was greater among patients with osteoporosis and CHF (87.88% women,  $P < .01$ ), and arthritis and stroke (60.54%, women  $P < .05$ ) or hypertension (66.44% women,  $P < .01$ ) compared to the general Medicare popula-

tion (57.56% women). Among patients with cancer and heart (45.98% men,  $P < .01$ ) or lung disease (46.58% men,  $P < .01$ ), diabetes and CAD (48.01% men,  $P < .01$ ) proportion of men was greater compared to the general Medicare population (42.44% male). Except for the beneficiaries with cancer and heart disease, patients with the pairs of target comorbidities had lower income and were more likely to be on Medicaid than the general Medicare population.

**Functional Status of Medicare Beneficiaries With Chronic Conditions**

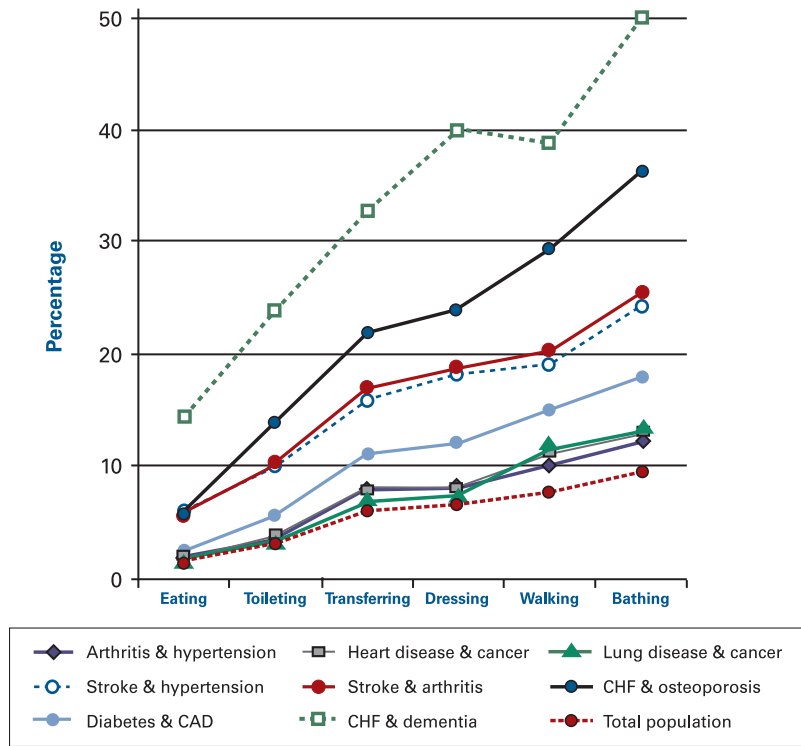
Patients with multiple comorbid conditions had a much greater level of ADL deficiencies than Medicare beneficiaries overall (Figure). The profiles of disability also varied substantially between patients with different chronic illnesses. Patients with CHF and dementia reported the highest level of deficiency across all ADL categories: 14.38% relied on others' help with eating (feeding), and more than 50% used help or assisted devices for bathing. Other groups with a high ADL deficiency level included patients with stroke combined with hypertension or arthritis, CHF and osteoporosis, and CAD and diabetes. However, the ranking of the prevalence of individual ADLs was consistent among all patient groups, with eating being the least common and bathing being the most common function for which beneficiaries received help.

**Comparing Actual Medicare Costs With CMS-HCC Predicted Payments**

Overall, the CMS-HCC model significantly underpredicted medical expenses of patients with target single comorbidities, except for arthritis ( $P = .13$ ), cancer ( $P = .21$ ), and osteoporosis ( $P = .32$ ) (Table 2 and Table 3). We found that for beneficiaries without functional limitations (0 ADLs), the CMS-HCC predicted expenses were no different from the actual cost ratios except for patients with CHF (underpredicted by 18.47%;  $P = .01$ ). As the disability level increased, the model increasingly underpredicted the expenses—up to 43.65% ( $P < .001$ ) for patients with 6 ADLs.

The discrepancy between the actual and predicted cost ratios was larger for beneficiaries with multiple co-

**Figure.** Prevalence of ADL Deficiencies Among Medicare Beneficiaries With Different Comorbid Conditions



ADL indicates activity of daily living; CAD, coronary artery disease; CHF, congestive heart failure.

morbidities than for those with a single target condition. For example, the CMS-HCC model underpredicted the expenses of the beneficiaries with CHF and osteoporosis by 30.02% (Table 4 and Table 5), while the predictions were 20.60% lower ( $P < .001$ ) for patients with CHF only and no different from actual costs ( $P = .32$ ) for osteoporosis only (Tables 2-3). The model also underpredicted medical expenses for the beneficiaries with arthritis and hypertension by 7.08% ( $P = .01$ ), while underpredicting expenses by 5.70% for the patients with hypertension ( $P = .01$ ) only; expenditures were underpredicted by 18.70% for patients with diabetes and CAD ( $P < .001$ ), but only by 9.77% ( $P < .001$ ) for patients with diabetes and 10.40% ( $P < .001$ ) for patients with CAD. Moreover, the magnitude of the prediction error was greater for the pairs that included conditions without corresponding HCCs than for the conditions with corresponding HCCs (eg, CHF, cancer) or those accounted for by other HCCs (eg, hypertension, heart disease) (Tables 4-5).

The 95% CIs around the error estimates demonstrated that the study sample size was generally sufficient to make robust predictions. In some cases where the predicted error was not statistically significantly different from zero, the analy-



■ **Table 2.** Cost Ratios for Target Chronic Conditions Included in HCCs, by ADLs<sup>a,b</sup>

Chronic Condition	No. of ADLs							Total
	0	1	2	3	4	5	6	
<b>Arthritis</b>	23,507	1739	866	547	506	501	264	27,930
Actual cost	0.93	1.71	2.19	2.57	2.54	2.69	3.54	1.11
Predicted cost	0.96	1.47	1.63	1.80	1.93	2.26	2.61	1.07
Predicted error, %	-3.77	19.06	41.09	42.94	44.39	31.76	56.71	1.27
95% CI	-7.89, 0.35	5.90, 32.22	16.38, 65.80	19.22, 66.66	19.00, 69.78	9.97, 53.56	22.42, 91.00	-2.47, 5.02
P value	.07	.00	.00	.00	.00	.00	.00	.50
<b>Cancer</b>	12,009	801	406	236	222	197	128	13,999
Actual cost	1.00	2.18	2.15	2.52	2.94	3.42	3.64	1.19
Predicted cost	1.05	1.69	1.78	1.92	2.09	2.43	2.62	1.16
Predicted error, %	-4.24	26.76	14.49	43.45	85.22	52.07	54.99	0.84
95% CI	-9.52, 1.04	7.09, 46.44	-5.13, 34.10	15.56, 71.33	24.64, 145.80	28.10, 76.04	17.45, 92.54	-4.02, 5.69
P value	.12	.01	.15	.00	.01	.00	.00	.74
<b>Lung disease</b>	5759	492	275	144	133	108	75	6986
Actual cost	1.23	2.48	2.56	3.17	3.40	2.79	3.81	1.49
Predicted cost	1.19	1.70	1.89	2.01	2.22	2.63	2.88	1.32
Predicted error, %	2.40	32.00	70.31	50.80	69.25	53.22	44.05	10.00
95% CI	-5.53, 10.33	9.56, 54.44	4.63, 135.99	-5.22, 106.83	5.43, 133.07	-31.69, 138.14	6.50, 81.60	2.51, 17.49
P value	.55	.01	.04	.08	.03	.22	.02	.01
<b>Stroke</b>	3663	459	294	202	232	251	206	5307
Actual cost	1.24	1.83	2.15	2.47	2.45	2.61	3.91	1.59
Predicted cost	1.20	1.70	1.85	1.99	1.96	2.38	2.67	1.44
Predicted error, %	8.50	-1.00	47.43	31.77	38.30	23.13	50.15	13.94
95% CI	-2.22, 19.22	-16.17, 14.16	-10.56, 105.43	5.71, 57.83	-10.27, 86.88	1.87, 44.38	24.03, 76.27	5.30, 22.58
P value	.12	.90	.11	.02	.12	.03	.00	.00
<b>CHF</b>	3601	520	285	192	207	221	149	5175
Actual cost	2.56	3.23	3.50	4.21	3.39	3.37	5.44	2.87
Predicted cost	2.16	2.55	2.73	2.94	3.17	3.38	3.62	2.38
Predicted error, %	10.89	19.34	23.56	42.31	18.47	5.30	54.44	14.64
95% CI	-1.89, 23.67	2.20, 36.48	5.20, 41.91	-0.27, 84.89	-1.02, 37.96	-9.40, 20.00	20.01, 88.87	5.18, 24.10
P value	.09	.03	.01	.05	.06	.48	.00	.00
<b>Diabetes</b>	5991	571	287	210	176	174	88	7497
Actual cost	1.29	2.50	2.92	3.65	2.79	3.80	5.04	1.61
Predicted cost	1.28	1.96	2.21	2.21	2.52	2.99	3.20	1.47
Predicted error, %	1.29	21.57	34.29	60.24	22.53	47.93	64.67	7.37
95% CI	-6.28, 8.86	2.18, 40.95	5.05, 63.53	13.59, 106.89	-9.99, 55.04	20.96, 74.90	22.86, 106.48	0.80, 13.95
P value	.74	.03	.02	.01	.17	.00	.00	.03
<b>CAD</b>	8486	759	404	251	202	246	155	10,503
Actual cost	1.24	2.02	2.56	2.75	2.45	2.88	3.51	1.45
Predicted cost	1.18	1.70	1.87	2.00	2.25	2.47	2.69	1.32
Predicted error, %	4.79	21.55	34.49	45.73	10.39	32.33	44.09	8.96
95% CI	-1.56, 11.14	0.03, 43.07	15.78, 53.19	7.67, 83.79	-18.93, 39.71	7.48, 57.17	16.07, 72.11	3.38, 14.55
P value	.14	.05	.00	.02	.49	.01	.00	.00

ADLs indicates activities of daily living; CAD, coronary artery disease; CHF, congestive heart failure; CI, confidence interval; HCCs, Hierarchical Condition Categories.

<sup>a</sup>Actual costs are presented as the ratio of the individual's annualized costs to the mean annual Medicare cost of all people in the study. Predicted costs were estimated by HCC scores.

<sup>b</sup>The total number of person-years was 46,790, including those who participated in the Medicare Current Beneficiary Survey for at least 2 years.

sis of CIs illustrated clinically or practically substantial error (eg, for osteoporosis with 3 ADLs:  $P = .08$ ; 95% CI = -5.69, 92.68; for lung disease and cancer with 1 ADL:  $P = .15$ ; 95% CI = -7.37, 47.21).

### Effect of Functional Status and Comorbidity on Medical Expenses

Because the majority of beneficiaries in our sample had more than 1 of the target comorbidities and various levels of

## HCC Performance for Multiple Comorbidities

**Table 3.** Actual/Predicted Cost Ratios for Target Chronic Conditions *Not* Included in HCCs, by ADLs<sup>a</sup>

Chronic Condition	No. of ADLs							Total
	0	1	2	3	4	5	6	
<b>Hypertension</b>	21,238	1493	726	484	467	393	247	25,048
Actual cost ratio	0.97	1.85	2.13	2.67	2.94	2.92	4.07	1.16
Predicted cost ratio	0.98	1.52	1.72	1.85	1.99	2.36	2.69	1.10
Predicted error, %	-0.72	21.85	34.45	45.02	67.56	45.22	71.10	4.52
95% CI	-5.19, 3.76	5.47, 38.24	8.10, 60.79	17.82, 72.21	32.48, 102.64	17.54, 72.90	33.24, 108.95	0.40, 8.64
P value	.75	.01	.01	.00	.00	.00	.00	.03
<b>Heart disease</b>	16,170	1306	677	412	393	430	251	19,639
Actual cost ratio	1.16	2.15	2.44	2.66	2.65	2.69	3.96	1.37
Predicted cost ratio	1.13	1.69	1.85	1.99	2.13	2.37	2.82	1.26
Predicted error, %	2.80	31.72	33.90	46.42	38.32	26.86	60.10	8.04
95% CI	-2.00, 7.60	12.79, 50.66	14.57, 53.23	18.00, 74.83	2.29, 74.34	9.66, 44.06	24.80, 95.39	3.69, 12.39
P value	.25	.00	.00	.00	.04	.00	.00	.00
<b>Osteoporosis</b>	4136	427	222	158	160	184	109	5396
Actual cost ratio	0.95	2.04	2.23	2.81	2.24	2.18	3.00	1.23
Predicted cost ratio	1.01	1.64	1.57	1.81	1.94	2.05	2.27	1.17
Predicted error, %	-6.71	31.56	25.72	43.49	33.93	36.74	97.40	2.74
95% CI	-14.22, 0.80	5.14, 57.98	0.73, 50.71	-5.69, 92.68	-14.82, 82.67	-14.83, 88.31	22.33, 172.48	-4.16, 9.63
P value	.08	.02	.04	.08	.17	.16	.01	.44
<b>Dementia</b>	1421	218	165	118	143	177	158	2400
Actual cost ratio	1.79	2.43	3.18	3.33	3.03	3.03	4.13	2.31
Predicted cost ratio	1.61	2.09	2.19	2.40	2.48	2.60	3.08	1.93
Predicted error, %	6.86	7.79	46.81	45.82	22.27	31.87	32.43	15.72
95% CI	-5.33, 19.06	-15.94, 31.53	6.89, 86.72	5.64, 86.00	-3.59, 48.13	1.37, 62.36	8.29, 56.58	6.84, 24.59
P value	.27	.52	.02	.03	.09	.04	.01	.00

ADLs indicates activities of daily living; CI, confidence interval; HCCs, Hierarchical Condition Categories.

<sup>a</sup>The total number of person-years was 46,790, including those who participated in the Medicare Current Beneficiary Survey for at least 2 years.

functional impairment, we examined the joint impact of the multiple comorbidities and disability on the accuracy of the CMS-HCC capitation model (Table 3).

Among the pairs of comorbid conditions, having arthritis and hypertension (0.079,  $P = .05$ ), diabetes and CAD (0.260,  $P = .01$ ), or CHF and dementia (0.783,  $P = .01$ ) led to substantial underpayments as calculated by the CMS-HCC model. However, these differences were mainly due to the underpayment for the single conditions (CHF and dementia) rather than additional error due to having multiple comorbidities, because adding single conditions improved the explanatory power of the model ( $R^2 = 0.34$  compared with 0.21; Table 6) and reduced the significance of  $P$  values ( $>.05$ ) for the variables identifying pairs of conditions. Functional status helped explain even more of the difference between the actual costs and the predicted amount based on the capitation model ( $R^2 = 0.46$ ). The number of ADLs was highly significant ( $P < .01$ ) in explaining the variation between actual costs and predicted

payment, and so was the presence of hypertension, lung disease, and CHF ( $P < .05$ ).

## DISCUSSION

Although several studies have examined the effect of multiple comorbidities on physical functioning and disability, less is known about the financial implications of the Medicare capitation payment model for health plans serving enrollees with comorbid chronic conditions and functional impairment. Our results demonstrate that the CMS-HCC model is likely to underpredict expenses for such Medicare beneficiaries and that the disability level accounts for a substantial portion of the difference between actual and predicted expenses. The CMS-HCC model significantly underpredicts expenses for patients with hypertension, lung disease, CHF, and dementia after adjusting for patients' disability level. This observation is supported by other studies

■ **Table 4.** Actual/Predicted Cost Ratios for Pairs of Target Chronic Conditions Included in HCCs, by ADLs<sup>a</sup>

Chronic Conditions	No. of ADLs							Total
	0	1	2	3	4	5	6	
<b>Lung disease and cancer</b>	1983	205	102	60	48	39	18	2455
Actual cost ratio	1.35	2.15	2.69	2.84	3.64	3.61	4.44	1.59
Predicted cost ratio	1.29	1.86	1.95	2.26	2.69	2.87	3.28	1.44
Predicted error, %	8.63	19.92	25.23	28.30	72.16	34.68	39.83	12.30
95% CI	-3.84, 21.10	-7.37, 47.21	-8.88, 59.34	-15.04, 71.63	-29.43, 173.74	-9.23, 78.58	-15.63, 95.29	1.57, 23.03
P value	.17	.15	.15	.20	.16	.12	.15	.02
<b>Stroke and arthritis</b>	2357	330	219	153	163	159	127	3508
Actual cost ratio	1.25	1.93	2.52	2.67	2.43	2.46	4.31	1.64
Predicted cost ratio	1.26	1.78	1.89	2.04	2.11	2.39	2.80	1.51
Predicted error, %	7.30	1.76	75.92	44.00	13.10	6.22	53.97	13.98
95% CI	-3.80, 18.41	-16.92, 20.43	-2.09, 153.94	11.07, 76.92	-8.31, 34.50	-12.32, 24.77	21.35, 86.59	4.66, 23.30
P value	.20	.85	.06	.01	.23	.51	.00	.00
<b>Diabetes and CAD</b>	1,869	234	132	83	70	74	37	2,499
Actual cost ratio	1.67	2.46	3.85	4.21	3.57	4.59	5.78	2.10
Predicted cost ratio	1.54	2.14	2.37	2.29	3.06	3.23	3.86	1.77
Predicted error, %	12.12	14.14	61.33	46.36	41.18	68.79	44.26	18.33
95% CI	-0.71, 24.95	-12.92, 41.20	30.61, 92.06	-39.33, 132.04	-31.55, 113.92	27.82, 109.77	0.35, 88.18	7.59, 29.07
P value	.06	.30	.00	.28	.26	.00	.05	.00

ADLs indicates activities of daily living; CAD, coronary artery disease; CI, confidence interval; HCCs, Hierarchical Condition Categories.

<sup>a</sup>The total number of person-years was 46,790, including those who participated in the Medicare Current Beneficiary Survey for at least 2 years.

reporting that the accuracy of expenditure models varies by medical condition.<sup>34</sup>

Currently, the CMS-HCC model does not account for additional costs of functional impairments that often accompany chronic health conditions. However, CMS has always accounted for beneficiary ADL levels when calculating reimbursement for the PACE plans.<sup>27</sup>

Our results demonstrate that unless a special disability adjustment is introduced for patients with comorbidities, entering into risk arrangements with Medicare for services provided to people with multiple comorbid conditions may be more risky for health plans serving this population than anticipated. Capitation payments for SNPs are calculated based on the HCCs just as for the Medicare Advantage plans. It is anticipated that if the existing SNPs perform well over time, new disease management SNPs will be established for patients with a wider range of chronic conditions. Currently, SNPs do not receive frailty adjustments, while some demonstration programs do. If the SNPs are not qualified for the frailty adjustment, then to the extent that comorbid conditions result in greater disability and thus higher medical expenses, these plans are financially at a disadvantage in providing care to the very frail and disabled. The Medicare Advocacy commission report demonstrated that beneficiaries in private fee-for-service plans have had difficulties receiving

care.<sup>35</sup> This could be partially explained by financial disincentives resulting from low reimbursement that providers receive for these patients and serves as evidence that financial incentives play a role in determining providers' behavior. Similar effects are expected in managed care plans.

In addition to the SNPs, hospitals and physicians are developing clinical specialty-services lines, competing for patients and looking for ways to maximize profits.<sup>24</sup> By focusing on specific patient populations (currently those with heart disease, cancer, or orthopedic problems), providers are trying to avoid really sick patients for whom they do not receive a sufficient reimbursement, a practice that can be minimized by proper risk adjustment of payments.

There could be several possible explanations why adjusting for disability decreases the prediction error of the CMS-HCC risk-adjustment model. Some combinations of chronic conditions are more likely to lead to disability and worsening of health. For instance, patients with cardiovascular conditions who have a disease of bone, muscles, and joints are likely to have a worse prognosis because of the limited possibility for physical activity essential for preventing worsening of their conditions and maintaining their cardiovascular health. Having dementia would exacerbate any existing health problems because of the limited ability of the patient to participate in his/her own care.



## HCC Performance for Multiple Comorbidities

**Table 5.** Actual/Predicted Cost Ratios for Pairs of Target Chronic Conditions, with One of the Conditions *Not* Included in HCCs, by ADLs<sup>a</sup>

Chronic Conditions	No. of ADLs							Total
	0	1	2	3	4	5	6	
<b>Arthritis and hypertension</b>	13,885	1178	556	388	353	299	185	16,844
Actual cost ratio	1.02	1.73	2.31	2.74	2.85	2.91	4.11	1.23
Predicted cost ratio	1.02	1.53	1.69	1.82	2.01	2.37	2.76	1.14
Predicted error, %	0.82	19.63	47.61	40.46	54.71	43.78	79.86	6.57
95% CI	-4.55, 6.20	3.49, 35.77	14.23, 80.99	11.67, 69.26	22.11, 87.32	10.89, 76.67	33.17, 126.55	1.70, 114.43
P value	.76	.02	.01	.01	.00	.01	.00	.01
<b>Heart disease and cancer</b>	5657	528	252	150	137	128	84	6936
Actual cost ratio	1.27	2.42	2.66	2.81	3.03	3.46	4.28	1.52
Predicted cost ratio	1.24	1.82	1.87	2.08	2.30	2.64	2.94	1.38
Predicted error, %	6.91	34.67	33.29	48.81	75.05	47.28	56.97	12.83
95% CI	-1.06, 14.87	7.56, 61.78	8.07, 58.52	14.90, 82.71	-11.01, 161.12	18.27, 76.29	13.08, 100.86	5.66, 20.00
P value	.09	.01	.01	.01	.09	.00	.01	.00
<b>Stroke and hypertension</b>	2590	342	210	146	164	171	137	3760
Actual cost ratio	1.31	1.78	2.29	2.40	2.97	2.82	4.53	1.68
Predicted cost ratio	1.24	1.74	1.92	1.97	2.17	2.51	2.87	1.49
Predicted error, %	13.06	-3.33	62.94	27.61	60.26	34.07	62.74	19.27
95% CI	0.95, 25.16	-20.88, 14.23	-15.34, 141.22	-1.97, 57.19	-6.55, 127.07	7.64, 60.51	30.00, 95.47	9.10, 29.43
P value	.03	.71	.11	.07	.08	.01	.00	.00
<b>CHF and osteoporosis</b>	441	114	53	46	46	63	32	795
Actual cost ratio	2.96	3.12	4.35	5.86	3.07	2.48	3.27	3.23
Predicted cost ratio	2.24	2.64	2.58	2.84	3.00	2.86	3.25	2.48
Predicted error, %	12.60	13.00	54.56	75.83	10.38	-10.84	18.57	17.49
95% CI	-14.32, 39.51	-18.67, 44.66	3.00, 106.12	-70.67, 222.32	-29.42, 50.17	-35.51, 13.82	-19.36, 56.51	-0.88, 35.87
P value	.36	.42	.04	.30	.60	.38	.33	.06
<b>CHF and dementia</b>	259	65	60	33	57	59	65	598
Actual cost ratio	4.06	3.96	4.66	4.40	3.53	3.66	6.14	4.23
Predicted cost ratio	3.04	3.03	3.20	3.46	3.61	3.66	4.24	3.30
Predicted error, %	17.64	24.02	19.60	31.78	7.74	17.50	54.09	21.80
95% CI	-7.70, 42.97	-14.29, 62.32	-14.63, 53.83	-23.74, 87.31	-27.95, 43.43	-12.63, 47.64	10.78, 97.39	7.63, 35.97
P value	.17	.21	.26	.25	.67	.25	.02	.00

ADLs indicates activities of daily living; CHF, congestive heart failure; CI, confidence interval; HCCs, Hierarchical Condition Categories.

<sup>a</sup>The total number of person-years was 46,790, including those who participated in the Medicare Current Beneficiary Survey for at least 2 years.

The study has several limitations. First, we used the 1992-2000 MCBS data to verify the performance of the CMS-HCC model that was developed using 1999-2000 data only. It is conceivable that the main discrepancy between the actual and the HCC-based cost ratios is explained by the different relationship between the risk factors and the healthcare costs in the early and late 1990s. We included a time dummy variable in the model (Table 6) but did not find any significant time trends. Also, to use the CMS-HCC software, we had to have at least 2 years of data for each beneficiary included in our study. Hence, it is conceivable that by excluding subjects who did not have 2 years of the claims data, we limited our sample to healthier individuals, which could result in the underestimation of underpayments.

Second, we did not control for other potential comorbidities in our sample population that could bias our estimates. We chose to concentrate on these heterogeneous groups rather than limiting the sample to beneficiaries with only the target comorbidities because that could introduce a different type of selection bias. Although disability status and comorbidities were significant predictors of the discrepancy between the actual expenses and HCC-based reimbursement, together they explained less than 1% of variation in the cost difference. Similarly, Kautter and Pope showed that frailty explains about 1% of the variation.<sup>13</sup> One reason we may not have seen more statistically significant results is because we used cost ratios (on the scale of 0 and 6) rather than

■ **Table 6.** Impact of Chronic Conditions and Physical Disabilities on Cost Predictions<sup>a</sup>

Chronic Conditions or ADLs	Corresponding HCC	Model With Disease Interactions Only	Model Without ADL	Model With ADL
Having 1 or 2 ADLs	+	—	—	0.257 <sup>b</sup>
Having 3 or more ADLs	+	—	—	0.542 <sup>b</sup>
Arthritis	+	—	0.069	0.065
Cancer	+	—	0.011	0.015
Lung disease	+	—	0.175 <sup>c</sup>	0.169 <sup>c</sup>
Stroke	+	—	0.151	0.070
CHF	+	—	0.384 <sup>c</sup>	0.339 <sup>c</sup>
Diabetes	+	—	0.042	0.026
CAD	+	—	-0.004	-0.006
Hypertension	Other HCC	—	0.087	0.094 <sup>c</sup>
Heart disease	Other HCC	—	0.024	0.021
Osteoporosis	-	—	-0.022	-0.051
Dementia	-	—	0.257 <sup>b</sup>	0.154
Lung disease and cancer	+/+	0.073	-0.097	-0.104
Stroke and arthritis	+/+	-0.077	-0.171	-0.159
Diabetes and CAD	+/+	0.260 <sup>b</sup>	0.157	0.154
Arthritis and hypertension	+/-	0.079 <sup>c</sup>	-0.032	-0.045
Heart disease and cancer	+/-	0.092	0.057	0.058
Stroke and hypertension	+/-	0.164	0.033	0.040
CHF and osteoporosis	+/-	0.576	0.286	0.246
CHF and dementia	+/-	0.783 <sup>b</sup>	0.235	0.211
Year 1999		-0.103	-0.106	-0.100
Intercept		-0.074 <sup>b</sup>	-0.185 <sup>b</sup>	-0.201 <sup>b</sup>
R <sup>2</sup> , %		0.21	0.34	0.46

ADLs indicates activities of daily living; CAD, coronary artery disease; CHF, congestive heart failure; HCC, Hierarchical Condition Category.  
<sup>a</sup>The dependent variable was the difference between the actual cost ratio and predicted cost ratio; the number of observations was 46,790; sampling weights were used in the model estimation.  
<sup>b</sup>Significant at the 1% level.  
<sup>c</sup>Significant at the 5% level.

expenditures (\$0-\$100,000), thus resulting in fairly small effect size.

Finally, the accuracy and the specificity of the ICD codes vary by condition. Our results demonstrated that having CHF in addition to other chronic conditions resulted in substantial underpredictions of the CMS-HCC model. Because there is a great variation in the severity of the CHF that is not reflected in the ICD codes (ICD 428 is predominantly used to code for heart failure, see eAppendix Table A, available at [www.ajmc.com](http://www.ajmc.com)), it is conceivable that our sample by chance had a higher prevalence of severe CHF than the population for whom HCC was developed. In contrast, there are a variety of codes for diabetes (see eAppendix Table B, available at [www.ajmc.com](http://www.ajmc.com)) that reflect the severity of the condition and associated

expenditures. Hence, HCC predictions for diabetic patients (9.77% underprediction error) were more accurate than they were for patients with CHF (20.60% underprediction).

For this study we used both self-reported disease status from the MCBS (for arthritis, hypertension, heart disease, cancer, lung disease, stroke, osteoporosis, diabetes, and CAD) and claims-based identification of patients with specific conditions (for CHF and dementia). Prior reports suggested that information elicited from subjects face to face is generally of high accuracy.<sup>36,37</sup> Numerous studies that examined sensitivities of claims-based identification algorithms compared with a variety of gold standards reported satisfactory results that varied, however, by disease (Parkinson's disease using MCBS<sup>38</sup> or Veterans Administration medical records<sup>39</sup>; diabetes using

MCBS<sup>40</sup>; chronic kidney disease using charts and Medicare claims<sup>41</sup>; breast cancer using Surveillance, Epidemiology, and End Results [SEER]-Medicare data<sup>25,42-44</sup>; dementia using medical records<sup>32</sup>; and cardiovascular disease and stroke using Medicare medical records<sup>45</sup>).

On the basis of our findings, we conclude that the CMS-HCC model quite fairly calculates the Medicare capitation payments for beneficiaries with most chronic conditions except for patients with functional impairments and those with hypertension, lung disease, CHF, and dementia. The discrepancy between the predicted and actual expenditures was larger for patients with CHF and dementia than for beneficiaries with other pairs of target comorbidities. However, more research is needed to understand the pathophysiology of physical disability in these chronic conditions and what makes medical expenses of patients with chronic illnesses so much higher than expenses of beneficiaries without such conditions.

## CONCLUSION

Our findings indicate that information about beneficiary functional status should be incorporated in Medicare reimbursement models because without functional-status adjustment such models are likely to underestimate costs of caring for patients with disability and multiple comorbidities. Underpaying providers who care for populations with multiple comorbidities may provide severe disincentives for managed care plans to enroll such individuals and to appropriately manage their complex and costly conditions.

**Author Affiliations:** From the Department of Community and Preventive Medicine, University of Rochester (KN, HL, HT-G), Rochester, NY; and RAND Corporation (HL), Pittsburgh, PA.

**Funding Source:** This publication was supported in part by a K01 AG 20980 grant from the National Institute on Aging (KN, HL). The use of the Medicare Current Beneficiary Survey was covered by the Data Use Agreement #12874. The contents are solely the responsibility of the authors and do not necessarily represent the official views of the National Institute on Aging or the National Institutes of Health.

**Author Disclosure:** The authors (KN, HL, HT-G) report no relationship or financial interest with any entity that would pose a conflict of interest with the subject matter of this article.

**Authorship Information:** Concept and design (KN, HL, HT-G); acquisition of data (KN, HT-G); analysis and interpretation of data (KN, HL, HT-G); drafting of the manuscript (KN, HT-G); critical revision of the manuscript for important intellectual content (KN, HL, HT-G); statistical analysis (KN, HL, HT-G); obtaining funding (KN); administrative, technical, or logistic support (KN); and supervision (KN).

**Address correspondence to:** Katia Noyes, PhD, MPH, Department of Community and Preventive Medicine, University of Rochester, 601 Elmwood Ave, Box 644, Rochester, NY 14620. E-mail: [katia\\_noyes@urmc.rochester.edu](mailto:katia_noyes@urmc.rochester.edu).

### Take-away Points

Our findings indicate that information about beneficiary functional status should be incorporated in Medicare reimbursement models.

- Without adjustment for functional status, such models are likely to underestimate costs of caring for patients with disability and multiple comorbidities.
- Underpaying providers who care for populations with multiple comorbidities may provide severe disincentives for managed care plans to enroll such individuals and to appropriately manage their complex and costly conditions.

## REFERENCES

1. Hoffman C, Rice D, Sung H. Persons with chronic conditions: their prevalence and costs. *JAMA*. 1996;276(18):1473-1479.
2. Anderson GF. Medicare and chronic conditions. *N Engl J Med*. 2005;353(3):305-309.
3. Anderson G, Horvath J. The growing burden of chronic disease in America. *Public Health Rep*. 2004;119(3):263-270.
4. Partnership for Solutions: Better Lives for People with Chronic Conditions. *Chronic Conditions and Disability: Analysis of 2000 Census*. June 2003. [http://www.partnershipforsolutions.org/statistics/issue\\_briefs.html](http://www.partnershipforsolutions.org/statistics/issue_briefs.html). Accessed June 9, 2008.
5. Gijsen R, Hoeymans N, Schellevis F, et al. Causes and consequences of comorbidity: a review. *J Clin Epidemiol*. 2001;54(7):661-674.
6. Stuck A, Walthert J, Nikolaus T, Bula C, Hoffman C, Beck J. Risk factors for functional status decline in community-living elderly people: a systematic literature review. *Soc Sci Med*. 1999;48(4):445-469.
7. Boulton C, Kane RL, Louis TA, Boulton L, McCaffrey D. Chronic conditions that lead to functional limitation in the elderly. *J Gerontol*. 1994;49(1):M28-M36.
8. Kriegsman D, Deeg D, Stalman W. Comorbidity of somatic chronic diseases and decline in physical functioning: the Longitudinal Aging Study Amsterdam. *J Clin Epidemiol*. 2004;57(1):55-65.
9. Fried LP, Ettinger WH, Lind B, Newman AB, Gardin J. Physical disability in older adults: a physiologic approach. Cardiovascular Health Study Research Group. *J Clin Epidemiol*. 1994;47(7):747-760.
10. Fried LP, Bandeen-Roche K, Kasper J, Guralnik JM. Association of comorbidity with disability in older women: the Women's Health and Aging Study. *J Clin Epidemiol*. 1999;52(1):27-37.
11. Centers for Medicare & Medicaid Services (CMS). CMS-HCC payment model software and data. [http://www.cms.hhs.gov/MedicareAdvSpecRateStats/06\\_Risk\\_adjustment.asp](http://www.cms.hhs.gov/MedicareAdvSpecRateStats/06_Risk_adjustment.asp). Accessed September 26, 2008.
12. Pope GC, Kautter J, Ellis RP, et al. Risk adjustment of Medicare capitation payments using the CMS-HCC model. *Health Care Financ Rev*. 2004;25(4):119-141.
13. Kautter J, Pope GC. The CMS frailty adjustment model. *Health Care Financ Rev*. 2004;26(2):1-201.
14. McCall N, Khatutsky G, Smith K, Pope GC. Estimation of non-response bias in the Medicare FFS HOS. *Health Care Financ Rev*. 2004;25(4):27-41.
15. Riley GF. Risk adjustment for health plans disproportionately enrolling frail Medicare beneficiaries. *Health Care Financ Rev*. 2000;21(3):135-148.
16. Temkin-Greener H, Meiners MR, Gruenberg L. PACE and the Medicare+Choice risk-adjusted payment model. *Inquiry*. 2001;38(1):69-72.
17. Centers for Medicare & Medicaid Services. Special needs plans. Updated March 20, 2008. <http://www.cms.hhs.gov/SpecialNeedsPlans>. Accessed June 9, 2008.
18. Center for Medicare Advocacy. Medicare Advantage Special Needs Plans: A Beneficiary Perspective; October 18, 2007; Washington, DC. <http://www.medicareadvocacy.org/SNP%20Conference/Home.htm>. Accessed June 9, 2008.
19. Ettinger WH, Davis M, Neuhaus J, Mallon K. Long-term physical functioning in persons with knee osteoarthritis from NHANES-1: effect of comorbid medical conditions. *J Clin Epidemiol*. 1994;47(7):809-815.
20. Fillenbaum G, Pieper C, Cohen H, Comoni-Huntley JC, Guralnik JM. Comorbidity of five chronic health conditions in elderly community residents: determinants and impact on mortality. *J Gerontol A Biol Sci Med Sci*. 2000;55(2):M84-M89.

21. Guralnik JM, LaCroix AZ, Abbott RD, et al. Maintaining mobility in late life, I: demographic characteristics and chronic conditions. *Am J Epidemiol*. 1993;137(8):845-857.
22. Newschaffer CJ, Bush TL, Penberthy LT. Comorbidity measurement in elderly female breast cancer patients with administrative and medical records data. *J Clin Epidemiol*. 1997;50(6):725-733.
23. van den Bos GAM. The burden of chronic illness in terms of disability, use of health care and health life expectancies. *Eur J Public Health*. 1995;5:29-34.
24. Berenson RA, Bodenheimer T, Pham HH. Specialty-service lines: salvos in the new medical arms race. *Health Aff (Millwood)*. 2006;25(5):w337-w343.
25. Freeman JL, Zhang D, Freeman DH, Goodwin JS. An approach to identifying incident breast cancer cases using Medicare claims data. *J Clin Epidemiol*. 2000;53(6):605-614.
26. Verbrugge LM, Lepkowski JM, Imanka Y. Comorbidity and its impact on disability. *Milbank Q*. 1989;67(3-4):450-484.
27. Centers for Medicare & Medicaid Services. *Advance Notice of Methodological Changes for Calendar Year 2008 for Medicare Advantage (MA) Capitation Rates*. February 16, 2007. <http://www.cms.hhs.gov/MedicareAdvgtgSpecRateStats/Downloads/Advance2008.pdf>. Accessed June 10, 2008.
28. Adler GS. A profile of the Medicare Current Beneficiary Survey. *Health Care Financ Rev*. 1994;15(4):153-163.
29. Eppig F, Chulis GS. Matching MCBS and Medicare data: the best of the both worlds. *Health Care Financ Rev*. 1997;18(3):211-229.
30. Centers for Medicare & Medicaid Services. *Medicare Managed Care Manual*. 2004. Publication 100-16. <http://www.cms.hhs.gov/Manuals/IOM/itemdetail.asp?> Accessed June 10, 2008.
31. Barker WH, Mullooly JP, Getchell W. Changing incidence and survival for heart failure in a well-defined older population, 1970-1974 and 1990-1994. *Circulation*. 2006;113(6):799-805.
32. Pippenger M, Holloway RG, Vickrey BG. Neurologists' use of ICD-9CM codes for dementia. *Neurology*. 2001;56(9):1206-1209.
33. Centers for Medicare & Medicaid Services. Drug coverage claims data. Part D payment and risk adjustment. 2008. [http://www.cms.hhs.gov/DrugCoverageClaimsData/02\\_RxClaims\\_PaymentRiskAdjustment.asp](http://www.cms.hhs.gov/DrugCoverageClaimsData/02_RxClaims_PaymentRiskAdjustment.asp). Accessed June 10, 2008.
34. Mark TL, Ozminkowski RJ, Kirk A, Ettner SL, Drabek J. Risk adjustment for people with chronic conditions in private sector health plans. *Med Decis Making*. 2003;23(5):397-405.
35. Center for Medicare Advocacy. *Medicare Advantage Private Fee-for-Service (PFFS) Plans: A Primer for Advocates*. 2008. [http://www.medicareadvocacy.org/MA\\_PFFSPrimerForAdvocates.pdf](http://www.medicareadvocacy.org/MA_PFFSPrimerForAdvocates.pdf). Accessed June 10, 2008.
36. Marder K, Levy G, Louis ED, et al. Accuracy of family history data on Parkinson's disease. *Neurology*. 2003;61(1):18-23.
37. Strickland D, Bertoni JM. Parkinson's prevalence estimated by a state registry. *Mov Disord*. 2004;19(3):318-323.
38. Noyes K, Liu H, Holloway RG, Dick AW. Accuracy of Medicare claims data in identifying Parkinsonism cases. *Mov Disord*. 2006;9(6):339-348.
39. Swartztrauber K, Anau J, Peters D. Identifying and distinguishing cases of Parkinsonism and Parkinson's disease using ICD-9-CM codes and pharmacy data. *Mov Disord*. 2005;20(8):964-970.
40. Hebert PI, Geiss LS, Tierney EF, Engelgau MM, Yawn BP. Identifying persons with diabetes using Medicare claims data. *Am J Med Qual*. 1999;14(6):270-277.
41. Winkelmayer WC, Schneeweiss S, Mogun H, Patrick AR, Avorn J, Soloman DH. Identification of individuals with CKD from Medicare claims data: a validation study. *Am J Kidney Dis*. 2005;46(2):225-232.
42. Gold HT, Do HT. Evaluation of algorithms to identify incident breast cancer in Medicare claims data. *Health Serv Res*. 2007;42(5):2056-2069.
43. Nattinger AB, Laud PW, Bajorunaite R, Sparapani RA, Freeman JL. An algorithm for the use of Medicare claims data to identify women with incident breast cancer. *Health Serv Res*. 2004;39(6, pt 1):1733-1749.
44. Warren JL, Feuer E, Potosky AL, Riley GF, Lynch CF. Use of Medicare hospital and physician data to assess breast cancer incidence. *Med Care*. 1999;37(5):445-456.
45. Birman-Deych E, Waterman AD, Yan Y, Nilasena DS, Radford MJ, Gage BF. Accuracy of ICD-9-CM codes for identifying cardiovascular and stroke risk factors. *Med Care*. 2005;43(5):480-485. ■