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Gregory C. Pope
RTI International

Et al.

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Gregory C. Pope, M.S., John Kautter, Ph.D., Randall P. Ellis, Ph.D., Arlene S. Ash, Ph.D., John Z. Ayanian, M.D., M.P.P., Lisa I. Iezzoni, M.D., M.Sc., Melvin J. Ingber, Ph.D., Jesse M. Levy, Ph.D., and John Robst, Ph.D.

This article describes the CMS hierarchical condition categories (HCC) model implemented in 2004 to adjust Medicare capitation payments to private health care plans for the health expenditure risk of their enrollees. We explain the model's principles, elements, organization, calibration, and performance. Modifications to reduce plan data reporting burden and adaptations for disabled, institutionalized, newly enrolled, and secondary-payer subpopulations are discussed.

INTRODUCTION

Medicare is one of the world's largest health insurance programs, with annual expenditures exceeding $200 billion. It provides health insurance to nearly 40 million beneficiaries entitled by elderly age, disability, or ESRD. Approximately 11 percent of Medicare beneficiaries are enrolled in private managed care health care plans, with the rest in the traditional FFS program. The 1997 BBA modified the Medicare managed care (MMC) and other capitated programs, collectively called M+C.[1] Medicare pays private plans participating in M+C a monthly capitation rate to provide health care services to enrolled beneficiaries.

Historically, capitation payments to MMC plans were linked to FFS expenditures by geographic area, with payments set at 95 percent of an enrollee's county's adjusted average per capita cost (AAPCC). The AAPCC actuarial rate cells were defined by: age, sex, Medicaid enrollment (indicating poverty), institutional status (for nursing home residents), and working aged status (for beneficiaries with employer-based insurance where Medicare is a secondary payer). Separate county factors were calculated for the aged and non-aged disabled (under 65 years), and at the State-level only (due to small numbers), for ESRD-entitled beneficiaries.

The AAPCC payment methodology explains only about 1-percent of the variation in expenditures for Medicare beneficiaries, and does not pay more for sicker people. Thus, research showed that the managed care program was increasing total Medicare Program expenditures, because its enrollees were healthier than FFS enrollees, and the AAPCC did not account for this favorable selection (Brown et al., 1993; Riley et al., 1996; Mello et al.,

Gregory C. Pope and John Kautter are with RTI International. Randall P. Ellis and Arlene S. Ash are with Boston University. John Z. Ayanian is with Harvard Medical School and Brigham and Women's Hospital. Lisa I. Iezzoni is with Harvard Medical School and Beth Israel Deaconess Medical Center. Melvin J. Ingber, Jesse M. Levy, and John Robst are with the Centers for Medicare & Medicaid Services (CMS). The research in this article was funded by CMS to RTI International under Contract Numbers 500-95-048 and 500-00-0030. The views expressed in this article are those of the authors and do not necessarily reflect the views of RTI International, Boston University, Harvard Medical School, Brigham and Women's Hospital, Beth Israel Deaconess Medical Center, or CMS.

[1] The Medicare Prescription Drug, Improvement and Modernization Act of 2003 (MMA) renames the M+C program Medicare Advantage. However, since this renaming does not officially take place until 2006, we continue to use M+C.

2003). Also, more money was not directed to plans enrolling sicker beneficiaries, or to plans specializing in treating high-cost populations, such as beneficiaries with particular chronic diseases or high levels of functional impairment.

The M+C program fundamentally changed the MMC payment method, including a mandate for health-based Medicare capitation payments by 2000. To support this mandate, the BBA required managed care organizations (MCOs) to report inpatient encounter data (i.e., records for each inpatient admission of a plan's enrollees noting, among other things, the beneficiaries' diagnoses) beginning in 1998. In 2000 CMS, which administers the Medicare Program, implemented the PIP-DCG model as a health-based payment adjuster (Pope et al., 2000a). This model estimates beneficiary health status (expected cost next year) from AAPCC-like demographics and the worst principal inpatient diagnosis (principal reason for inpatient stay) associated with any hospital admission. PIP-DCG-based payments were introduced gradually, with only 10 percent of total Medicare capitation payments adjusted by PIP-DCG factors in 2000. The other 90 percent of payments were still adjusted using a purely demographic (AAPCC-like) model.

The PIP-DCG model was intended as a transition, a feasible way to implement risk adjustment based on the readily available, already audited inpatient diagnostic data. Relying on inpatient diagnoses is the PIP-DCG model's major shortcoming, since only illnesses that result in hospital admissions are counted; MCOs that reduce admis-sions (e.g., through good ambulatory care) can end up with apparently healthier patients and lower payments. Congress's BIPA (2000) addressed the PIP-DCG limitations by requiring the use of ambulatory diagnoses in Medicare risk-adjustment, to be phased in from 2004 to 2007 at 30, 50, 75, and 100 percent of total payments. CMS began collecting encounter data from MCOs for the physician office and hospital outpatient settings (i.e., records of each enrollee visit to these providers with dates, procedures performed, diagnoses, etc.) in October 2000 and April 2001, respectively. However, following complaints from MCOs about the burden of reporting encounter data, CMS suspended data collection in May 2001, ultimately adopting a drastically streamlined data reporting strategy (discussed later).

CMS evaluated several risk-adjustment models that use both ambulatory and inpatient diagnoses, including ACGs (Weiner et al., 1996), the chronic disease and disability payment system (CDPS) (Kronick et al., 2000), clinical risk groups (CRGs) (Hughes et al., 2004), the clinically detailed risk information system for cost (CD-RISC) (Kapur et al., 2003), and DCG/HCCs (Pope et al, 2000b). CMS chose the DCG/HCC model for Medicare risk-adjustment, largely on the basis of transparency, ease of modification, and good clinical coherence. The DCG/HCC model, part of the same DCG family of models as the PIP-DCG, was developed with CMS funding by researchers at RTI International[2] and Boston University, with clinical input from physicians at Harvard Medical School.[3]

Prior to implementing Medicare risk-adjustment in 2004, the DCG/HCC model developers and CMS staff adapted the original model for consistency with CMS' simplified data collection, and for customized fit for Medicare subpopulations. The resulting CMS-HCC model reflects these

2 The early development of the DCG/HCC model was done by Health Economics Research, Inc. while under contract to CMS. However, RTI International acquired Health Economics Research, Inc. in 2002.

3 The original version of the DCG/HCC model is described in Ellis et al. (1996). The DCG/HCC model has been refined as described in Pope et al., 1998 and 2000b.

Medicare-specific adaptations of the DCG/HCC model and provides a comprehensive framework for Medicare risk-adjustment.

This article describes the DCG/HCC and CMS-HCC models. The next section describes the DCG/HCC model, including the principles and elements of its diagnostic classification system and how its performance compares to earlier models. We then describe the modifications to accommodate the simplified data that lead to the CMS-HCC model. The final section describes the CMS-HCC model adaptations for subpopulations.

DCG/HCC MODEL PRINCIPLES

Diagnostic Classification System

The following ten principles guided the creation of the diagnostic classification system.

Principle 1—Diagnostic categories should be clinically meaningful. Each diagnostic category is a set of ICD-9-CM codes (Centers for Disease Control and Prevention, 2004). These codes should all relate to a reasonably well-specified disease or medical condition that defines the category. Conditions must be sufficiently clinically specific to minimize opportunities for gaming or discretionary coding. Clinical meaningfulness improves the face validity of the classification system to clinicians, its interpretability, and its utility for disease management and quality monitoring.

Principle 2—Diagnostic categories should predict medical expenditures. Diagnoses in the same HCC should be reasonably homogeneous with respect to their effect on both current (this year's) and future (next year's) costs. (In this article we present prospective models predicting future costs.)

Principle 3—Diagnostic categories that will affect payments should have adequate sample sizes to permit accurate and stable estimates of expenditures. Diagnostic categories used in establishing payments should have adequate sample sizes in available data sets. Given the extreme skewness of medical expenditure data, the data cannot reliably determine the expected cost of extremely rare diagnostic categories.

Principle 4—In creating an individual's clinical profile, hierarchies should be used to characterize the person's illness level within each disease process, while the effects of unrelated disease processes accumulate. Because each new medical problem adds to an individual's total disease burden, unrelated disease processes should increase predicted costs of care. However, the most severe manifestation of a given disease process principally defines its impact on costs. Therefore, related conditions should be treated hierarchically, with more severe manifestations of a condition dominating (and zeroing out the effect of) less serious ones.

Principle 5—The diagnostic classification should encourage specific coding. Vague diagnostic codes should be grouped with less severe and lower-paying diagnostic categories to provide incentives for more specific diagnostic coding.

Principle 6—The diagnostic classification should not reward coding proliferation. The classification should not measure greater disease burden simply because more ICD-9-CM codes are present. Hence, neither the number of times that a particular code appears, nor the presence of additional, closely related codes that indicate the same condition should increase predicted costs.

Principle 7—Providers should not be penalized for recording additional diagnoses (monotonicity). This principle has

two consequences for modeling: (1) no condition category should carry a negative payment weight, and (2) a condition that is higher-ranked in a disease hierarchy (causing lower-rank diagnoses to be ignored) should have at least as large a payment weight as lower-ranked conditions in the same hierarchy.

Principle 8—The classification system should be internally consistent (transitive). If diagnostic category A is higher-ranked than category B in a disease hierarchy, and category B is higher-ranked than category C, then category A should be higher-ranked than category C. Transitivity improves the internal consistency of the classification system, and ensures that the assignment of diagnostic categories is independent of the order in which hierarchical exclusion rules are applied.

Principle 9—The diagnostic classification should assign all ICD-9-CM codes (exhaustive classification). Since each diagnostic code potentially contains relevant clinical information, the classification should categorize all ICD-9-CM codes.

Principle 10—Discretionary diagnostic categories should be excluded from payment models. Diagnoses that are particularly subject to intentional or unintentional discretionary coding variation or inappropriate coding by health plans/providers, or that are not clinically or empirically credible as cost predictors, should not increase cost predictions. Excluding these diagnoses reduces the sensitivity of the model to coding variation, coding proliferation, gaming, and upcoding.

In designing the diagnostic classification, principles 7 (monotonicity), 8 (transitivity), and 9 (exhaustive classification) were followed absolutely. For example, if the expenditure weights for our models did not originally satisfy monotonicity, we imposed constraints to create models that did. Judgment was used to make tradeoffs among other principles. For example, clinical meaningfulness (principle 1) is often best served by creating a very large number of detailed clinical groupings. But a large number of groupings conflicts with adequate sample sizes for each category (principle 3). Another tradeoff is encouraging specific coding (principle 5) versus predictive power (principle 2). In current coding practice, non-specific codes are common. If these codes are excluded from the classification system, substantial predictive power is sacrificed. Similarly, excluding discretionary codes (principle 10) can also lower predictive power (principle 2). We approached the inherent tradeoffs involved in designing a classification system using empirical evidence on frequencies and predictive power, clinical judgment on relatedness, specificity, and severity of diagnoses, and the judgment of the authors on incentives and likely provider responses to the classification system. The DCG/HCC models balance these competing goals to achieve a feasible health-based payment system.

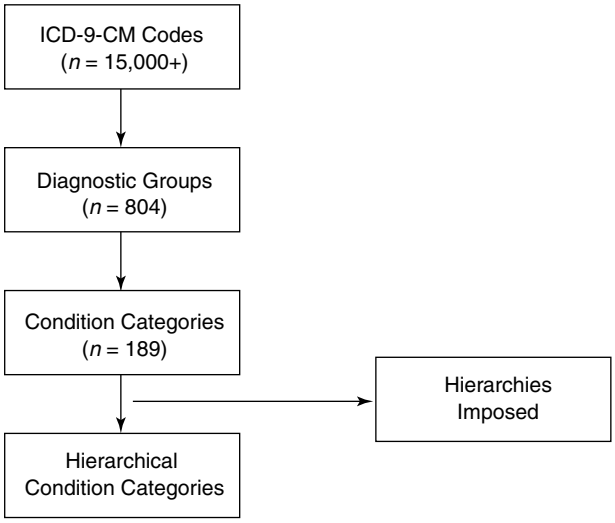
Elements and Organization

As shown in Figure 1, the HCC diagnostic classification system first classifies each of over 15,000 ICD-9-CM codes into 804 diagnostic groups, or DxGroups. Each ICD-9-CM code maps to exactly one DxGroup, which represents a well-specified medical condition, such as DxGroup 28.01 Acute Liver Disease. DxGroups are further aggregated into 189 Condition Categories, or CCs.[4] CCs describe a broader set of similar diseases, generally organized into body systems, somewhat like ICD-9-CM major diagnostic categories.

[4] Most CCs are assigned entirely with ICD-9-CM codes. But CCs 185-189 are assigned by beneficiary utilization of selected types of DME, such as wheelchairs. CC 173, Major Organ Transplant, is defined by procedure codes only. CC 129, ESRD is defined by Medicare entitlement status. None of these CCs are included in the CMS-HCC model.

Figure 1

Hierarchical Condition Categories Aggregations of ICD-9-CM Codes



NOTE: ICD-9-CM is *International Classification of Diseases, Ninth Revision, Clinical Modification.*
SOURCE: (Pope et al., 2000b.)

Although they are not as homogeneous as DxGroups, CCs are both clinically- and cost-similar. An example is CC 28 Acute Liver Failure/Disease that includes DxGroups 28.01 and 28.02 Viral Hepatitis, Acute or Unspecified, with Hepatic Coma.

Hierarchies are imposed among related CCs, so that a person is only coded for the most severe manifestation among related diseases. For example (Figure 2), ICD-9-CM Ischemic Heart Disease codes are organized in the Coronary Artery Disease hierarchy, consisting of 4 CCs arranged in descending order of clinical severity and cost, from CC 81 Acute Myocardial Infarction to CC 84 Coronary Athlerosclerosis/Other Chronic Ischemic Heart Disease. A person with an ICD-9-CM code in CC 81 is excluded from being coded in CCs 82, 83, or 84 even if codes that group into those categories were also present. Similarly, a person with ICD-9-CM codes that group into both CC 82 Unstable Angina and Other Acute Ischemic Heart Disease, and CC 83 Angina Pectoris/Old Myocardial Infarction is coded for CC 82, but not CC 83. After imposing hierarchies, CCs become Hierarchical Condition Categories, or HCCs.[5]

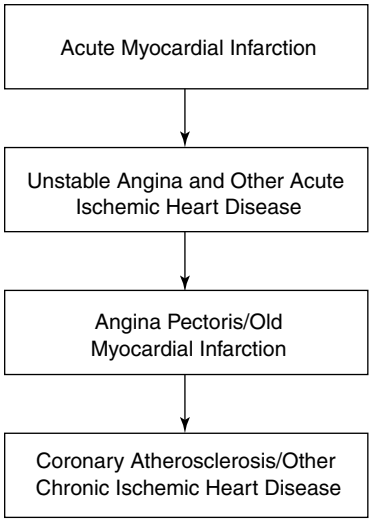
Although HCCs reflect hierarchies among related disease categories, for unrelated diseases, HCCs accumulate. For example, a male with heart disease, stroke, and cancer has (at least) three separate HCCs coded, and his predicted cost will reflect increments for all three problems. The HCC model is more than simply additive because some disease combinations interact. For example, the presence of both Diabetes and Congestive Heart Failure (CHF) could increase predicted cost by more (or less) than the sum of the separate increments for people who have diabetes or CHF alone.

We tested 35 two- and three-way interactions among six common and high-cost chronic diseases defined by HCCs or

[5] The full list of hierarchies used in the CMS-HCC model is available on request from the authors.

Figure 2

Hierarchical Condition Categories Coronary Artery Disease Hierarchy



SOURCE: (Pope et al., 2000b.)

groups of HCCs: diabetes, cerebrovascular disease, vascular disease, or chronic obstructive pulmonary disease (COPD), CHF, and coronary artery disease (Pope et al., 2000b), as well as three interactions of several of these conditions with renal failure.[6] Simple additivity yields most of the explanatory power, in the sense that adding all 38 interactions barely increased the base DCG/HCC model's R^2 (from 11.10 to 11.13 percent). However, six interactions were substantial in magnitude, statistically significant, and clinically plausible. Hence, to improve clinical face validity and predictive accuracy for important subgroups of beneficiaries, we include them in the DCG/HCC model. For example, the simultaneous presence of CHF and COPD leads to higher expected costs than would be calculated by adding the separate increments for CHF and COPD alone.

Because a single beneficiary may be coded for none, one, or more than one DxGroup or HCC, the DCG/HCC model can individually price tens of thousands of distinct clinical profiles using fewer than 200 parameters. The model's structure thus provides, and predicts from, a detailed comprehensive clinical profile for each individual.

HCCs are assigned using hospital and physician diagnoses from any of five sources: (1) principal hospital inpatient; (2) secondary hospital inpatient; (3) hospital outpatient; (4) physician; and (5) clinically-trained non-physician (e.g., psychologist, podiatrist). The DCG/HCC model does not distinguish among sources; in particular, it places no premium on diagnoses from inpatient care. Using Medicare 5-percent sample FFS data, we investigated adding diagnoses from other sources (Pope et al., 2000b). Adding diagnoses from home health providers raised the explanatory power of the base model from

[6] In later work unpublished work, we also examined all two-way interactions of cancer with the other six diagnoses, but did not find any significant effects.

11.15 to 11.65 percent. Further adding diagnoses from DME suppliers raised the explanatory power from 11.65 to 11.85 percent. All other sources of diagnoses either add no predictive power (SNF, ASC, or hospice) or detract from predictive power (clinical laboratory and radiology/imaging clinics). Diagnoses assigned by home health and DME providers are likely to be less reliable than those assigned by physicians or other providers with greater clinical training. Diagnoses from laboratory and imaging tests are also problematic given the significant proportion of rule-out diagnoses. In implementing the CMS-HCC model, potential gains in predictive power from using additional sources were balanced against the costs of collecting and auditing these data; the decision was to only ask MCOs to collect diagnoses from the five baseline sources previously listed.

Consistent with principle 10, we excluded discretionary diagnostic categories (HCCs) from the preliminary prospective payment model. We excluded diagnoses that were vague/non-specific (e.g., symptoms), discretionary in medical treatment or coding (e.g., osteoarthritis), not medically significant (e.g., muscle strain), or transitory or definitively treated (e.g., appendicitis). We also excluded HCCs that did not (empirically) add to costs, and finally, the five HCCs that were defined by the presence of procedures or use of DME, because, as much as possible, we wanted payments to follow what medical problems were present as opposed to what services were offered.[7] Altogether, we excluded 88 of the 189 HCCs, leaving 101 HCCs in the preliminary prospective payment model. As discussed further, additional HCCs were excluded from the final, 70-category CMS-HCC model.

The DCG/HCC model also relies on demographics. Demographic adjusters included in the model are 24 mutually exclusive age/sex cells (e.g., female, age 65-69), an indicator for at least 1-month of Medicaid enrollment in the base year (a poverty indicator), and an indicator of originally disabled status. The age cells distinguish beneficiaries currently entitled to Medicare by age (65 or over) versus disability (under 65); a separate, explicit aged versus disabled entitlement status indicator would be redundant. The originally disabled indicator distinguishes beneficiaries who are currently age 65 or over, but were first entitled to Medicare before age 65 by disability. The age/sex, Medicaid, and originally disabled categories add to each other and to the HCC diagnostic categories.[8] The demographic variables are the same as have been used in the PIP-DCG model, and are discussed at greater length elsewhere (Pope et al., 2000a).

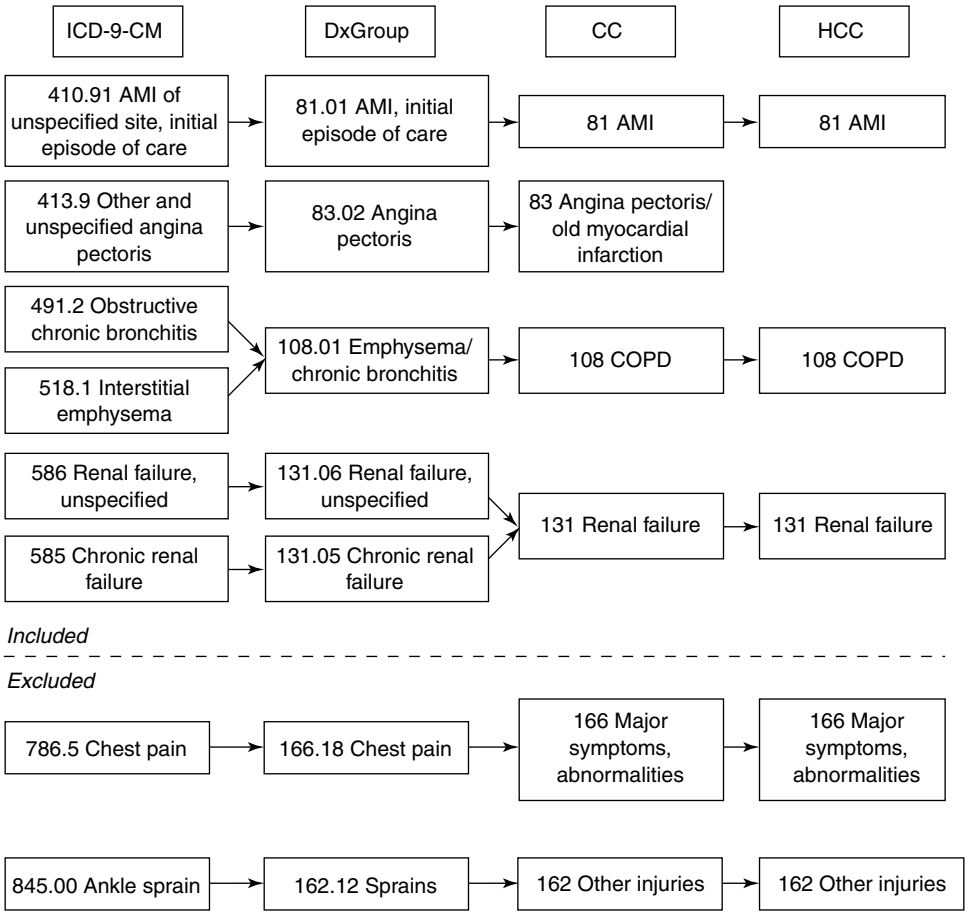
Figure 3 displays a hypothetical clinical vignette of a female age 79, eligible for Medicaid and diagnosed with acute myocardial infarction (AMI), angina pectoris, COPD, renal failure, chest pain, and an ankle sprain. Note that although this female receives CCs for both AMI and angina, she receives no HCC for angina because AMI is a more severe manifestation of coronary artery disease. Also note that while payment includes additive increments for females age 75-79 (demographic categories not shown in Figure 3), Medicaid, AMI, COPD, and renal failure, the HCCs for major symptoms and other injuries are excluded from the payment calculation. Chest pain is a symptom associated with a variety of medical conditions ranging from minor to serious, and sprains are transitory, with minimal implications for next year's cost.

[7] The DME HCCs were developed to predict costs associated with functional impairment not captured by diagnoses. Although they did improve prediction for the functionally impaired, substantial under-prediction remained (Pope et al., 2000b; Kautter and Pope, 2001).

[8] We did not systematically investigate interactions of age and sex with HCCs (diagnoses). This is a subject for future research.

Figure 3

Clinical Vignette for Hierarchical Condition Categories Classification 79 Year Old Female with AMI, Angina Pectoris, COPD, and Renal Failure



NOTES: AMI is acute myocardial infarction. COPD is chronic obstructive pulmonary disease.

SOURCE: (Pope et al., 2000b.)

PERFORMANCE OF DCG/HCC AND PIP-DCG MODELS

The predictive accuracy of risk-adjustment models is typically judged by the R^2 statistic (percentage of variation explained) to measure predictive accuracy for individuals and predictive ratios (ratios of mean predicted to mean actual expenditures for subgroups of beneficiaries) to measure predictive accuracy for groups. The R^2 of age/sex, PIP-DCG, and DCG/HCC models as measured on 1996-1997 Medicare's 5-percent sample FFS data are: age/sex, 1.0 percent; PIP-DCG, 6.2 percent; and DCG/HCC, 11.2 percent.

Adding PIP-DCG to demographic predictors (age/sex) increases predictive power sixfold. Adding secondary inpatient and ambulatory diagnoses (hospital outpatient and physician), and arraying them in a multi-condition cumulative model (DCG/HCC) nearly doubles the power again. Besides the R^2, another interesting summary statistic is the percentage of payments based on demographic variables: 100

Table 1

Predictive Ratios[1] for Alternative Risk-Adjustment Models

Category	Model		
Quintiles of Expenditures	Age/Sex	PIP-DCG	DCG/HCC
First (Lowest)	2.66	2.09	1.23
Second	1.93	1.54	1.23
Third	1.37	1.10	1.14
Fourth	0.95	0.84	1.02
Fifth (Highest)	0.44	0.75	0.86
Top 5 Percent	0.28	0.61	0.77
Top 1 Percent	0.17	0.47	0.69
Hospitalizations			
None	1.33	1.07	1.03
1	0.63	1.02	1.02
2	0.44	0.91	0.98
3 or More	0.26	0.69	0.82
Diagnoses[2]			
Heart Failure	0.47	0.74	0.97
Heart Attack	0.45	0.78	0.98
COPD	0.59	0.79	0.99
Hip Fracture	0.56	0.83	0.99
Depression	0.54	0.77	0.92
Colorectal Cancer	0.60	0.78	0.98
Cerebral Hemorrhage	0.44	0.73	1.04

[1] Mean predicted cost divided by mean actual cost.

[2] From either inpatient or ambulatory setting.

NOTES: Expenditures, hospitalizations, and diagnoses are measured in the base year. COPD is chronic obstructive pulmonary disease.

SOURCE: (Pope et al., 2000b.)

percent in a demographic model, 81 percent in the PIP-DCG model, but only 43 percent in the DCG/HCC model (Pope et al., 2001). With over one-half of payments determined by diagnoses, the DCG/HCC model moves decisively away from the AAPCC demographic-based payment system.

Table 1 shows predictive ratios for selected groups of Medicare beneficiaries. Ratios close to 1.0 indicate accurate prediction of costs; less than 1.0, under prediction; and, more than 1.0, over prediction. The PIP-DCG model improves substantially on age/sex, and in almost all cases, the DCG/HCC model improves significantly on the PIP-DCG model. This is true even for hospitalizations, where the PIP-DCG model distinguishes between those hospitalized or not, while the DCG/HCC model makes no distinction by source of diagnosis.[9] Despite the DCG/HCC model's impressive gains over the age/sex and PIP-DCG models, it still under-predicts for the most expensive and most often hospitalized beneficiaries.

[9] The DCG/HCC model captures multiple conditions that might be diagnosed in multiple inpatient stays, whereas the PIP-DCG model captures only the single principal inpatient diagnosis most predictive of future costs if multiple inpatient stays occur.

CMS-HCC MODEL

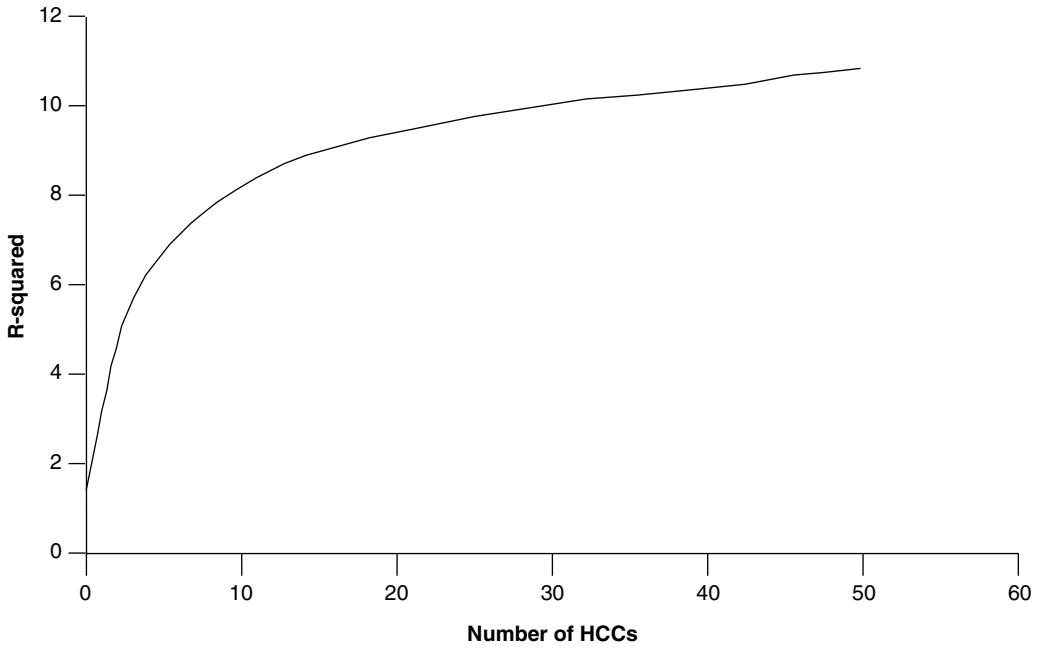
This section describes how the DCG/HCC model was modified before implementation as the M+C risk adjuster for capitation payments in 2004. We will refer to the modified model as CMS-HCC.

DCG/HCC Model Modification to Simplify Data Collection

When several MCOs withdrew from the M+C program around the year 2000, CMS sought to improve plan retention. Since some MCOs had complained of the burden of collecting encounter data for risk-adjustment, CMS sought to develop risk adjustment models that predict well and rely on ambulatory data, but with reduced data col-

Figure 4

Model Explanatory Power as a Function of Number of Hierarchical Condition Categories (HCC)



NOTES: All models, including the one with zero HCCs, include 24 age/sex cells, and Medicaid and originally disabled status. Results based on stepwise regression analysis.

SOURCE: (Pope et al., 2001.)

lection requirements. One measure of the data collection burden imposed by a model is its number of diagnostic categories.[10]

We investigated the relationship between number of diagnostic categories used in the DCG/HCC model and its predictive power (Pope et al., 2001). Figure 4 plots the relationship between number of diagnostic categories and model explanatory power measured by R^2. Diagnostic categories (HCCs) were entered into the model in descending order of their incremental explanatory power using stepwise regression. The base model (with zero HCCs) includes 26 demographic variables, the 24 age/sex cells, and Medicaid and originally disabled status. Its R^2 is 1.69 percent.

The incremental contribution to predictive power declines rapidly with the number of diagnostic categories added to the model. The first diagnostic category entered by the stepwise regression is CHF, which more than doubles the demographic model R^2 to 4.11 percent. The second condition category entered is COPD, raising the R^2 to 4.94 percent. This is an incremental gain of 0.83 percentage points, substantial, but much less then the increment of 2.42 percentage points due to CHF. With 5 HCCs included, 61 percent of the maximum explanatory power of the full (101 HCC) model is attained; with 10 HCCs, 74 percent of the maximum is achieved; with 20, 85 percent, and with 30, 90 percent. The incremental R^2 from adding a diagnostic category is 0.48 percentage points at 5 HCCs; 0.26 percentage points at 10 HCCs; 0.08 percentage points at 20 HCCs; and 0.05 percentage points at 30 HCCs.

[10] The relationship between number of diagnostic categories and data collection burden is controversial. Some MCOs seemed to feel that it would be less burdensome to report all diagnoses, which CMS allows.

This analysis shows that a parsimonious risk-adjustment model with a substantially reduced number of diagnostic categories is almost as predictive as a full model. But parsimony has a cost. In limiting the number of conditions that affect payment, many serious, high-cost diagnoses—especially rare ones—will be ignored. MCOs enrolling beneficiaries with excluded diagnoses will be disadvantaged, and beneficiaries with such conditions may not be well served by MCOs.

CMS considered these results, and consulted with clinicians, on the tradeoff between number of diagnostic categories and predictive power, and also other criteria for diagnostic categories to include in risk adjustment, such as well-defined diagnostic criteria and clinical coherence and homogeneity. It was important that the HCC hierarchies not be disrupted by deletion of higher-ranked HCCs while lower-ranked HCCs were retained. After this process, CMS selected 70 HCCs to include in the CMS-HCC model. The choices reflect a balance among the competing considerations of reducing data collection burden, maximizing predictive power, including rare, high-cost conditions, and selecting only well-defined and clinically coherent conditions. Generally, the higher-cost, more severe conditions at the top of the HCC disease hierarchies were retained, while some lower-cost, more frequent and more discretionary conditions at the bottom of the hierarchies were pruned. For example, in the coronary artery disease hierarchy, AMI (heart attack), other acute IHD (e.g., unstable angina), and angina pectoris/old myocardial infarction were retained, but chronic IHD (e.g., coronary atherosclerosis) was excluded.

After the CMS-HCC model was finalized, a list of approximately 3,000 of the more than 15,000 ICD-9-CM diagnosis codes was identified that are sufficient to define the model's 70 HCCs. In addition, because the CMS-HCC model does not give extra credit for multiple reports of the same diagnosis, MCOs need only report a single encounter during the relevant year of data collection that establishes the diagnosis. The information required for the single encounter is: (1) beneficiary identification number, (2) date (to establish that the diagnosis was made during the relevant reporting period), (3) setting (to establish that the diagnosis was made in one of the allowed hospital or physician settings), and (4) ICD-9-CM diagnosis code. In short, MCOs are required to report only the minimum.

Concern about the quality of diagnostic reporting is the greatest in physician offices, where diagnoses have not heretofore affected payment, and recording of diagnoses is less rigorously practiced than in hospitals. The auditing standard that CMS has promulgated for reporting of physician office diagnoses is that a physician has established the diagnosis in the medical record, and that medical coders have recorded it in accordance with ICD-9-CM rules. CMS will conduct coding audits, but not clinical audits. That is, CMS will require MCOs to demonstrate that a diagnosis is present in the medical record on the specified date and has been coded according to ICD-9-CM. CMS will not require clinical verification of these diagnoses, such as diagnostic test results.

CMS-HCC Model Calibration

We calibrated the CMS-HCC model to 1999-2000 Medicare 5-percent sample FFS data for beneficiaries entitled by age or disability (beneficiaries entitled by ESRD were excluded). The model is prospective, meaning that diagnoses collected in a base year (1999) are used to predict expenditures in the following year (2000). An

important operational change from the PIP-DCG model is that the data lag will be eliminated, making the application of the model consistent with its calibration. With the PIP-DCG model, the data collection period for a payment year ended 6 months before the start of the year, i.e., on June 30 of the previous year, so that final capitation rates could be published by January 1 of the payment year. With the CMS-HCC model, provisional rates will be established by January 1 based on 6-month lagged data, and final rates will be available by June 30 of the payment year based on the previous calendar year's diagnoses. A reconciliation process will adjust the first 6 months of payments to the final rates, if necessary.

A standard set of sample restrictions was employed to ensure a population of beneficiaries with complete 12-month base year diagnostic profiles and complete payment year Medicare expenditures from the FFS claims for aged and disabled beneficiaries (Pope et al., 2000b). Decedents are included in the payment year for their eligible period. Complete FFS claims are not available for months of M+C enrollment or when Medicare is a secondary payer, and M+C plans are not responsible for hospice care, so these months were excluded from our sample. The final sample size is 1,337,887 beneficiaries.

We summed all Medicare payments for a beneficiary for months in 2000 satisfying our sample restrictions, excluding (1) deductibles and copayments paid by the beneficiary; (2) hospice payments; and (3) indirect medical education payments. Hospice and indirect medical education payments are excluded because they were not included in M+C capitation rates, but were paid directly to hospices and teaching hospitals utilized by M+C enrollees. Payments were annualized by dividing them by the fraction of months in 2000 that satisfy our sample restrictions; all analyses are weighted by this eligibility fraction. In general, annualization and weighting ensures that monthly payments are correctly estimated for all beneficiaries, including those who died (Ellis et al., 1996).[11]

The model was calibrated using weighted least squares multiple regression. The CMS-HCC regression model estimated for the combined aged and disabled Medicare population is shown in Table 2.

The elements of the model are:

- Age/sex cells (24).
- Medicaid interacted with sex and age/disabled entitlement status.
- Originally disabled status interacted with sex.
- HCC diagnostic categories (70).
- Interactions of diagnostic categories with entitlement by disability (5).
- Disease interactions (6).

The R^2 for this model is 9.8 percent. Several coefficients are constrained because the unconstrained coefficients violate the principle that higher-ranked conditions in a hierarchy should have higher predicted costs, or for other reasons.[12]

As an example of expenditure prediction, consider our hypothetical scenario in Figure 3 of a female age 79 eligible for Medicaid diagnosed with AMI, angina pectoris, COPD, renal failure, chest pain, and an ankle sprain. The female receives the following incremental cost predictions: female, 75 to 79, $2,562; aged, female, Medicaid, $616; AMI (HCC 81), $1,885; angina pectoris, $0; COPD (HCC 108), $1,936; renal failure (HCC 131), $2,908;

[11] In our calibration, we did not make any geographic adjustments to Medicare payments. In past work, we have found that deflating payments by a geographic input price index had little effect on estimated risk-adjustment model parameters.

[12] Clinical consultants to CMS suggested that metastatic cancer is not consistently correctly coded, so HCCs 7 and 8 were constrained to have equal coefficients. HCCs 81 and 82 were constrained to have equal coefficients because the ICD-9-CM diagnostic detail CMS collects from health plans is not sufficient to distinguish them.

Table 2

Centers for Medicare & Medicaid Services-Hierarchical Condition Categories (CMS-HCC) Combined, Community, and Institutional Models

		Models					
		Combined		Community		Institutional	
Number of Observations		1,337,887		1,291,308		65,593	
R^2		0.0977		0.0976		0.0596	
Adjusted R^2		0.0977		0.0976		0.0589	
Dependent Variable Mean		5,352		5,213		8,937	
Root Mean Square Error		13,407		13,337		15,954	
Model Parameters		105		105		50	
Variable		Parameter Estimate	*t*-ratio	Parameter Estimate	*t*-ratio	Parameter Estimate	*t*-ratio	
Female								
0-34 Years		678	3.81	598	3.36	5,457	11.72	
35-44 Years		1,110	8.82	1,012	8.03	5,457	11.72	
45-54 Years		1,177	11.20	1,096	10.40	5,457	11.72	
55-59 Years		1,463	11.87	1,360	11.00	5,457	11.72	
60-64 Years		1,996	17.26	1,924	16.56	5,457	11.72	
65-69 Years		1,648	42.11	1,572	40.15	5,970	11.73	
70-74 Years		2,061	60.25	1,970	57.42	6,049	17.09	
75-79 Years		2,562	71.59	2,475	68.56	5,089	19.63	
80-84 Years		2,998	71.39	2,936	68.34	4,813	22.51	
85-89 Years		3,360	63.45	3,408	61.01	4,515	23.28	
90-94 Years		3,683	46.81	4,077	46.25	4,048	19.08	
95 Years or Over		3,128	23.27	4,130	25.32	2,980	10.34	
Male								
0-34 Years		405	2.72	346	2.32	5,664	13.77	
35-44 Years		701	6.63	617	5.81	5,664	13.77	
45-54 Years		1,059	12.15	973	11.14	5,664	13.77	
55-59 Years		1,460	13.42	1,386	12.68	5,664	13.77	
60-64 Years		1,824	17.90	1,755	17.13	5,664	13.77	
65-69 Years		1,827	41.47	1,774	40.28	7,435	13.24	
70-74 Years		2,380	59.66	2,323	58.17	6,350	14.34	
75-79 Years		3,031	69.04	2,960	67.13	6,210	16.45	
80-84 Years		3,454	62.03	3,372	59.83	6,201	17.67	
85-89 Years		4,129	52.24	4,050	49.80	6,366	17.40	
90-94 Years		4,505	32.20	4,620	31.08	5,378	11.29	
95 Years or Over		4,753	15.83	5,307	15.89	4,287	5.34	
Medicaid and Originally Disabled Interactions with Age and Sex								
Medicaid-Female-Disabled		1,141	11.31	1,133	11.18	—	—	
Medicaid-Female-Aged		616	12.91	940	18.18	—	—	
Medicaid-Male-Disabled		632	6.80	592	6.31	—	—	
Medicaid-Male-Aged		788	10.33	944	11.62	—	—	
Originally Disabled-Female		1,231	17.34	1,213	16.44	—	—	
Originally Disabled-Male		809	11.66	757	10.73	—	—	
Disease Coefficients	**Label**							
HCC1	HIV/AIDS	3,587	13.16	3,514	12.88	6,893	5.42	C1
HCC2	Septicemia/Shock	4,365	34.74	4,563	32.92	4,854	13.89	
HCC5	Opportunistic Infections	3,643	10.43	3,346	9.29	6,893	5.42	C1
HCC7	Metastatic Cancer and Acute Leukemia	7,438	81.16	7,510	81.00	2,771	4.54	
HCC8	Lung, Upper Digestive Tract, and Other Severe Cancers	7,438	81.16	7,510	81.00	2,771	4.54	
HCC9	Lymphatic, Head and Neck, Brain, and Other Major Cancers	3,540	35.91	3,539	35.51	2,319	3.50	
HCC10	Breast, Prostate, Colorectal and Other Cancers and Tumors	1,209	26.35	1,194	25.79	1,330	4.01	

Refer to NOTES at end of table.

Table 2—Continued

Centers for Medicare & Medicaid Services-Hierarchical Condition Categories (CMS-HCC) Combined, Community, and Institutional Models

Variable		Models						
		Combined		Community		Institutional		
		Parameter Estimate	*t*-ratio	Parameter Estimate	*t*-ratio	Parameter Estimate	*t*-ratio	
Disease Coefficients	**Label**							
HCC15	Diabetes with Renal or Peripheral Circulatory Manifestation	3,827	37.71	3,921	36.90	3,137	10.49	
HCC16	Diabetes with Neurologic or Other Specified Manifestation	2,931	30.09	2,833	28.43	3,137	10.49	
HCC17	Diabetes with Acute Complications	2,056	7.84	2,008	7.41	3,137	10.49	
HCC18	Diabetes with Ophthalmologic or Unspecified Manifestation	1,839	18.35	1,760	17.32	3,137	10.49	
HCC19	Diabetes without Complication	1,055	26.10	1,024	25.02	1,308	5.32	
HCC21	Protein-Calorie Malnutrition	3,818	27.52	4,727	29.77	2,193	6.49	
HCC25	End-Stage Liver Disease	4,496	14.91	4,616	14.92	1,375	5.09	
HCC26	Cirrhosis of Liver	2,727	11.93	2,645	11.37	1,375	5.09	
HCC27	Chronic Hepatitis	1,839	6.73	1,841	6.71	1,375	5.09	
HCC31	Intestinal Obstruction/ Perforation	1,997	21.69	2,094	21.62	1,375	5.09	
HCC32	Pancreatic Disease	2,336	17.30	2,281	16.61	1,375	5.09	
HCC33	Inflammatory Bowel Disease	1,574	10.25	1,575	10.16	1,375	5.09	
HCC37	Bone/Joint/Muscle Infections/ Necrosis	2,629	19.68	2,546	18.41	2,539	4.42	
HCC38	Rheumatoid Arthritis and Inflammatory Connective Tissue Disease	1,683	27.72	1,653	26.93	1,463	3.61	
HCC44	Severe Hematological Disorders	5,055	30.80	5,188	30.69	2,299	4.08	
HCC45	Disorders of Immunity	4,224	26.77	4,260	26.64	2,299	4.08	
HCC51	Drug/Alcohol Psychosis	1,571	6.57	1,810	6.99	1,131	6.06	
HCC52	Drug/Alcohol Dependence	1,477	6.15	1,361	5.44	1,131	6.06	
HCC54	Schizophrenia	2,592	26.75	2,786	27.04	1,131	6.06	
HCC55	Major Depressive, Bipolar, and Paranoid Disorders	2,024	30.00	2,209	30.85	1,131	6.06	
HCC67	Quadriplegia, Other Extensive Paralysis	5,665	27.45	6,059	27.20	504	3.94	
HCC68	Paraplegia	5,665	27.45	6,059	27.20	504	3.94	
HCC69	Spinal Cord Disorders/ Injuries	2,484	17.77	2,526	17.45	504	3.94	
HCC70	Muscular Dystrophy	2,239	3.82	1,981	3.27	504	3.94	
HCC71	Polyneuropathy	1,480	19.74	1,377	18.06	504	3.94	
HCC72	Multiple Sclerosis	2,329	11.44	2,654	12.19	504	3.94	
HCC73	Parkinson's and Huntington's Diseases	1,954	19.69	2,436	22.04	504	3.94	
HCC74	Seizure Disorders and Convulsions	1,334	17.25	1,381	16.68	504	3.94	
HCC75	Coma, Brain Compression/ Anoxic Damage	2,396	7.88	C1 2,912	8.62	C1 504	3.94	C2
HCC77	Respirator Dependence/ Tracheostomy Status	10,417	29.54	10,783	28.46	7,259	8.19	
HCC78	Respiratory Arrest	7,543	20.23	7,327	18.79	7,259	8.19	
HCC79	Cardio-Respiratory Failure and Shock	3,451	42.70	3,550	42.39	1,481	4.31	
HCC80	Congestive Heart Failure	2,055	38.48	2,141	38.54	903	4.16	
HCC81	Acute Myocardial Infarction	1,885	31.23	1,785	29.13	1,476	5.75	
HCC82	Unstable Angina and Other Acute Ischemic Heart Disease	1,885	31.23	1,785	29.13	1,476	5.75	
HCC83	Angina Pectoris/Old Myocardial Infarction	1,246	22.82	1,205	21.76	1,476	5.75	

Refer to NOTES at end of table.

Table 2—Continued

Centers for Medicare & Medicaid Services-Hierarchical Condition Categories (CMS-HCC) Combined, Community, and Institutional Models

Variable		Models						
		Combined		Community		Institutional		
		Parameter Estimate	*t*-ratio	Parameter Estimate	*t*-ratio	Parameter Estimate	*t*-ratio	
Disease Coefficients	**Label**							
HCC92	Specified Heart Arrhythmias	1,362	31.73	1,363	30.95	961	4.62	
HCC95	Cerebral Hemorrhage	1,901	10.05	2,011	9.88	774	4.01	
HCC96	Ischemic or Unspecified Stroke	1,498	20.90	1,569	20.34	774	4.01	
HCC100	Hemiplegia/Hemiparesis	1,678	13.96	2,241	16.61	504	3.94	
HCC101	Cerebral Palsy and Other Paralytic Syndromes	767	3.34	840	3.42	504	3.94	C2
HCC104	Vascular Disease with Complications	3,432	36.22	3,473	35.49	2,612	6.30	
HCC105	Vascular Disease	1,662	39.94	1,832	41.72	583	3.72	
HCC107	Cystic Fibrosis	1,936	45.73	1,929	44.87	1,180	4.69	
HCC108	Chronic Obstructive Pulmonary Disease	1,936	45.73	1,929	44.87	1,180	4.69	
HCC111	Aspiration and Specified Bacterial Pneumonias	3,010	20.47	3,556	21.53	2,377	6.82	
HCC112	Pneumococcal Pneumonia, Empyema, Lung Abscess	1,151	6.55	1,034	5.68	2,377	6.82	
HCC119	Proliferative Diabetic Retinopathy and Vitreous Hemorrhage	1,975	13.36	1,791	11.96	5,102	5.46	
HCC130	Dialysis Status	15,926	26.97	15,778	25.96	15,959	5.82	
HCC131	Renal Failure	2,908	23.20	2,954	22.73	2,152	6.26	
HCC132	Nephritis	1,541	6.95	1,401	6.23	2,152	6.26	
HCC148	Decubitus Ulcer of Skin	3,888	32.32	5,285	37.28	1,628	5.98	
HCC149	Chronic Ulcer of Skin, Except Decubitus	2,381	26.76	2,485	26.65	1,346	3.98	
HCC150	Extensive Third-Degree Burns	4,427	2.36	4,935	2.54	1,274	3.37	
HCC154	Severe Head Injury	2,396	7.88	C1 2,912	8.62	C1 1,274	3.37	
HCC155	Major Head Injury	1,211	8.43	1,239	8.08	1,274	3.37	C3
HCC157	Vertebral Fractures w/o Spinal Cord Injury	2,462	20.64	2,514	20.23	504	3.94	C2
HCC158	Hip Fracture/Dislocation	1,301	13.37	2,010	18.51	0	—	
HCC161	Traumatic Amputation	3,965	17.86	C2 4,322	17.92	C2 1,274	3.37	C3
HCC164	Major Complications of Medical Care and Trauma	1,438	18.25	1,346	16.60	1,347	3.66	
HCC174	Major Organ Transplant Status	3,790	8.55	3,702	8.37	4,523	11.13	
HCC176	Artificial Openings for Feeding or Elimination	3,810	23.84	4,054	22.39	4,523	11.13	
HCC177	Amputation Status, Lower Limb/Amputation Complications	3,965	17.86	C2 4,322	17.92	C2 1,274	3.37	C3
Disabled/Disease Interactions								
D-HCC5	Disabled Opportunistic Infections	3,965	5.49	4,047	5.52	—	—	
D-HCC44	Disabled Severe Hematological Disorders	4,649	9.98	4,580	9.72	—	—	
D-HCC51	Disabled Drug/Alcohol Psychosis	2,830	7.12	2,608	6.32	—	—	
D-HCC52	Disabled Drug/Alcohol Dependence	2,160	6.90	2,122	6.61	—	—	
D-HCC107	Disabled Cystic Fibrosis	9,691	6.70	9,547	6.63	—	—	

Refer to NOTES at end of table.

Table 2—Continued

Centers for Medicare & Medicaid Services-Hierarchical Condition Categories (CMS-HCC) Combined, Community, and Institutional Models

Variable		Models					
		Combined		Community		Institutional	
		Parameter Estimate	*t*-ratio	Parameter Estimate	*t*-ratio	Parameter Estimate	*t*-ratio
Disease Interactions							
INT1	DM-CHF1	1,265	14.62	1,296	14.46	1,064	2.91
INT2	DM-CVD	490	4.05	639	4.89	—	—
INT3	CHF-COPD	1,261	14.82	1,238	14.06	1,906	4.95
INT4	COPD-CVD-CAD	316	1.49	406	1.82	—	—
INT5	RF-CHF1	857	3.94	1,202	5.24	—	—
INT6	RF-CHF-DM1	4,185	18.48	4,433	18.71	—	—

NOTES: Beneficiaries with the three-way interaction RF-CHF-DM are excluded from the two-way interactions DM-CHF and RF-CHF. DM is diabetes mellitus (HCCs 15-19). CHF is congestive heart failure (HCC 80). COPD is chronic obstructive pulmonary disease (HCC 108). CVD is cerebrovascular disease (HCCs 95-96, 100-101). CAD is coronary artery disease (HCCs 81-83). RF is renal failure (HCC 131). "|" means coefficients of HCCs are constrained to be equal. C1, C2, and C3 denote non-contiguous constraints.

SOURCE: Pope, G.C. and Kautter, J., RTI International, Ellis, R.P. and Ash, A.S., Boston University, Ayanian, J.Z., Harvard Medical School and Brigham and Women's Hospital, Iezzoni, L.I., Harvard Medical School and Beth Israel Deaconess Medical Center, Ingber, M.J., Levy, J.M., and Robst, J., Centers for Medicare & Medicaid Services, Analysis of 1999-2000 Medicare 5% Standard Analytic File (SAF).

chest pain, $0; and ankle sprain, $0[13] (Table 2). Her total cost prediction is the sum of these increments, or $9,907.

Calibration of DCG/HCC models on several years of data reveals increasingly thorough diagnostic coding. For example, if 1999 diagnoses are used to predict expenditures with a model calibrated on 1996/1997 data, mean expenditures will be over predicted. If more complete coding over time is not accounted for, MCOs will be overpaid by the use of current diagnoses with a model calibrated on historical data. CMS makes a slight downward adjustment in HCC-predicted expenditures to account for this.

CMS-HCC Models for Subpopulations

Medicare beneficiaries differ along characteristics that are important for risk adjustment. First, they may be entitled to Medicare in one of three ways: age, disability, or ESRD. Second, some beneficiaries reside in institutions rather than in the community. Third, some enrollees are new to Medicare and do not have complete diagnostic data. Fourth, Medicare is a secondary payer for some beneficiaries. To account for the different cost and diagnostic patterns of these disparate subgroups of beneficiaries, the CMS-HCC model was adapted for Medicare subpopulations. This section describes models for subpopulations.[14]

Beneficiaries Entitled by Disability

Approximately 12 percent of Medicare beneficiaries are entitled to Medicare because they are under age 65 and have a medical condition that prevents them from working (the disabled). Models calibrated on the full Medicare population (excluding ESRD eligibles), mostly reflect cost patterns among the elderly, the other 88 percent of the population. The implications of some diagnoses might differ between the elderly and disabled. For example, a diagnosis that is disabling may be more severe, and the cost of treating a disease may vary by age. We considered allowing differences in incremental expenditure weights for some diagnoses (HCCs) for the disabled (Pope et al., 1998; 2000b).

[13] The female receives no incremental cost prediction for angina pectoris because AMI is higher-ranked in the coronary artery disease hierarchy and excludes angina. No incremental prediction is made for chest pain and ankle sprain because these diagnoses are not included in the CMS-HCC model.

[14] Risk-adjustment models for ESRD-entitled and functionally-limited beneficiaries are not described in this article.

Using Medicare's 5-percent sample FFS data (1996-1997), we estimated the DCG/HCC model separately on aged and disabled subsamples. We evaluated differences in age versus disabled parameter estimates according to their statistical significance, magnitude, clinical plausibility, and frequency of occurrence in the disabled population (Pope et al., 2000b). Based on these considerations, we chose nine diagnostic categories to receive incremental payments when they occur among disabled beneficiaries. Five of these categories remained significantly different for the disabled when the CMS-HCC model was re-estimated on 1999-2000 data: opportunistic infections, severe hematological disorders (e.g., hemophilia, sickle cell anemia), drug/alcohol psychosis, drug/alcohol dependence, and cystic fibrosis. Incremental annual payments for these conditions among the disabled (in addition to base payments for the elderly) are substantial, ranging from $2,160 to $9,691.

Other than for these five conditions, disease risk-adjustment weights are the same for the aged and disabled populations. The CMS-HCC model is estimated on a combined sample of aged and disabled beneficiaries, with disabled interactions for these five diagnostic categories. The combined aged/disabled model is shown in Table 2.

Community and Institutional Residents

Using the newly available Medicare MDS, we identified long–term nursing home residents in the current (i.e., payment) year. Long-term nursing home residence was defined as continuously residing in a nursing home for at least 90 days, as indicated by a 90-day clinical assessment reported by the nursing facility through the MDS. In our prospective risk-adjustment modeling sample of 1,337,887 beneficiaries, 65,593 beneficiaries, or 5 percent, had at least 1 month of long-term nursing facility residence in 2000.[15]

Table 3 compares sample sizes and mean expenditures by demographic categories for community and institutional residents, and shows predictive ratios from the CMS-HCC model calibrated on the combined community/institutional sample (Table 2). Nearly one-half (49 percent) of long-term nursing facility residents are age 85 or over. Facility residents are only 2 percent of the combined community plus institutional population for females age 70 to 74, but fully 37 percent of the combined population for females age 95 or over.

Overall, institutional residents are 71 percent more expensive than community residents, $8,937 in mean annualized expenditures compared to $5,213. The age profiles of expenditures are quite different. Among community residents, mean expenditures rise steadily with age in the under 65 disabled population and then again in the elderly population, except for a slight decline for the oldest females. In contrast, among the institutionalized, mean expenditures are fairly constant across all ages until they decline significantly among the oldest old. For all age/sex cells except the oldest old, mean expenditures for the institutionalized are substantially higher than for community-dwelling beneficiaries.

However, although not shown in Table 3, among beneficiaries diagnosed with particular HCCs, mean expenditures for the institutionalized are often similar to those of community residents. For example, among all beneficiaries with CHF (HCC 80), expenditures for the institutionalized are $11,719, which is $255 less than for community residents. More generally, when classifying people by the presence of

[15] Beneficiaries with both community and long-term institutional months in the same year are included in both samples, weighted by the fraction of their total months alive in the year in each status.

Table 3

Descriptive Statistics for Community and Institutionalized Residents

Variable	Community			Institutional		
	Observations	Mean Annualized Expenditures	Predictive Ratio[1]	Observations	Mean Annualized Expenditures	Predictive Ratio[1]
Overall	1,291,308	5,213	0.99	65,593	8,937	1.12
Demographics						
Female						
0-34 Years	7,007	3,623	1.00	49	9,251	0.99
35-44 Years	15,566	4,332	1.00	199	9,395	0.94
45-54 Years	22,077	4,692	1.00	473	8,869	1.07
55-59 Years	14,023	5,254	1.00	343	10,168	0.91
60-64 Years	15,793	5,993	1.00	501	9,906	1.04
65-69 Years	129,970	3,714	1.00	1,380	10,961	0.99
70-74 Years	171,775	4,372	1.00	3,098	10,901	0.97
75-79 Years	157,586	5,260	1.00	6,260	9,458	1.08
80-84 Years	111,303	6,101	0.99	9,801	8,797	1.13
85-89 Years	66,301	6,882	0.97	12,294	8,054	1.19
90-94 Years	26,852	7,606	0.92	9,535	7,146	1.29
95 Years or Over	8,074	7,338	0.83	4,729	5,734	1.42
Male						
0-34 Years	10,272	2,868	1.00	106	10,622	0.95
35-44 Years	22,913	3,666	1.00	384	9,596	0.92
45-54 Years	29,377	3,968	1.00	606	10,186	0.91
55-59 Years	16,391	4,651	1.00	438	10,340	0.96
60-64 Years	18,581	5,214	1.00	588	10,486	1.00
65-69 Years	105,856	4,018	1.00	1,132	12,432	0.88
70-74 Years	128,874	5,014	1.00	1,921	11,501	0.99
75-79 Years	106,402	6,207	1.00	2,842	11,411	1.04
80-84 Years	64,263	7,083	1.00	3,404	11,049	1.06
85-89 Years	30,765	8,144	0.99	3,116	10,754	1.08
90-94 Years	9,343	8,731	0.97	1,783	9,489	1.20
95 Years or Over	1,944	9,062	0.92	611	8,096	1.37
Medicaid	196,604	6,523	0.97	33,074	8,895	1.17
Originally-Disabled	81,894	7,614	0.99	7,415	10,606	1.11

[1] Ratio of mean expenditures predicted by the Centers for Medicare & Medicaid Services - Hierarchical Condition Categories (CMS-HCC) model for combined community/institutional samples to mean actual expenditures.

SOURCE: Pope, G.C. and Kautter, J., RTI International, Ellis, R.P. and Ash, A.S., Boston University, Ayanian, J.Z., Harvard Medical School and Brigham and Women's Hospital, Iezzoni, L.I., Harvard Medical School and Beth Israel Deaconess Medical Center, Ingber, M.J., Levy, J.M., and Robst, J., Centers for Medicare & Medicaid Services, Analysis of 1999-2000 Medicare 5% Standard Analytic File (SAF).

a single diagnosis, expenditures for the institutionalized may be higher, lower, or about the same.

Thus, the main reason that people in facilities cost more is that they have more medical problems, a distinction that is fully accounted for by the HCCs. In fact, the predictive ratios from the combined CMS-HCC model for community and institutional beneficiaries are, respectively, 0.99 and 1.12 (Table 3). This means that the combined model, on average, under predicts expenditures for community residents by 1 percent, and over predicts expenditures for long–term nursing home residents by 12 percent. Lower expenditures among facility residents adjusting for disease burden could result from substituting non-Medicare for Medicare-reimbursed services; since most nursing home service are not reimbursed by Medicare. Also, greater monitoring of nursing home than community residents may identify and prevent problems leading to hospitalization. The under-prediction for community residents and over-prediction for facility residents is most severe for the oldest age groups, most likely due to decisions to limit

aggressive care for very old residents in nursing homes. The over-prediction of the costs of the institutionalized, together with their different cost patterns by age and diagnosis, led us to consider differentiating the CMS-HCC model for community and institutional populations.

Within a multiple regression model estimation framework, we investigated alternative approaches to allowing differences in the model between community and institutional residents, ultimately choosing to estimate separate models. This properly calibrates the prediction of each group's costs, while allowing all demographic and disease coefficients to differ between community and institutional populations.

In addition to the combined model, Table 2 shows the CMS–HCC community and institutional models. Not surprisingly, the community model R^2 and most of the demographic and disease coefficients are very similar to the combined model, because community residents comprise 95 percent of the combined sample. A few coefficients show greater differences. The community coefficients for the oldest age cells are significantly larger than the combined model coefficients because the lower-cost very old institutionalized have been removed from these cells. The community coefficients for the aged enrolled in Medicaid are also significantly higher, as are several HCC coefficients.

The institutional model R^2 is considerably lower than the community model. But some of the community model's predictive power comes from distinguishing beneficiaries who are healthy (no diagnoses) versus sick (with diagnoses), while the institutional model is explaining cost variations among a population comprised entirely of impaired individuals. Diagnoses help explain why someone might be institutionalized (i.e., distinguish healthy from sick), but are not as powerful in explaining expenditure differences among the institutionalized. Disease (HCC) coefficients tend to be smaller in the institutional model than in the community model (Table 2). Diagnoses are less predictive of incremental costs among the more uniformly expensive institutional population than they are among the community population.

We constrained certain groups of demographic and diagnostic coefficients in the institutional model to be equal (Table 2), because the small available sample of institutionalized beneficiaries resulted in their low prevalence in some diagnostic categories (HCCs) and made it difficult to obtain stable estimates of each separate parameter. For the same reason, we included no disabled interaction terms, and only two of the disease interaction terms in the institutional model. Also, HCC 158 Hip Fracture/Dislocation was excluded because its coefficient was negative.

The age/sex coefficients for the institutionalized are much higher than for community residents except for the oldest ages. This implies that institutionalized beneficiaries are predicted to be expensive regardless of their diagnostic profile (e.g., even lacking any of the diagnoses included in the CMS-HCC model), whereas community residents are predicted to be expensive only if diagnosed with at least one of the serious diseases included in the CMS-HCC model. This makes sense since institutionalization itself is a marker of poor health, aside from diagnostic profile, but the institutionalized age/sex coefficients decline for the oldest ages, and fall below the community coefficients. Medical treatment may be less aggressive for old, frail beneficiaries who are institutionalized.

Among the institutional population, the coefficient for Medicaid was negative and the coefficients for originally disabled was statistically insignificant. These variables

were excluded from the institutional model. Beneficiaries often qualify for Medicaid after spending down their personal assets to pay for a lengthy nursing home stay. Thus, Medicaid may be a proxy for beneficiaries in the later portion of their stays, when they are less expensive than in the earlier, post-acute phase of their nursing home tenure.

New Medicare Enrollees

The CMS–HCC model requires a complete 12-month base year diagnostic profile to predict the next year's expenditures. Beneficiaries without 12 months base year Medicare enrollment, but at least 1 month of prediction year enrollment, are defined as new enrollees. About two–thirds of new enrollees are age 65.[16] New enrollees may be under age 65 if they become eligible for Medicare by disability; they may be over age 65 if they delay Medicare enrollment or are not originally enrolled in both Parts A and B.[17] We developed a demographic model to predict expenditures for new enrollees who lack the data needed to apply the CMS-HCC model.

Table 4 presents frequencies and mean annualized expenditures from the 5-percent FFS sample data for new enrollees and continuing enrollees. Continuing enrollees are defined as beneficiaries having 12 months of Parts A and B Medicare enrollment in the base year and at least 1 month in the prediction year. For female and male new enrollees age 65, mean annualized expenditures are $2,729 and $2,900, respectively, less than one-half of costs of continuing enrollees ($6,952 for female and $6,055 for male). For almost all new enrollees age 65, the original reason for Medicare entitlement is age.[18] In contrast, continuing enrollees age 65 were originally entitled to Medicare by disability, and hence are much more expensive. For other ages, mean expenditures of new and continuing enrollees are much more similar. To achieve sufficient sample sizes in all age ranges to calibrate the new enrollees model, we merged the new and continuing enrollees samples, which resulted in a sample size of 1,495,225 with mean expenditures of $5,184. For age 65, actual new enrollees dominate the combined sample, and the cost weight reflects their (low) relative costs. Continuing enrollees age 65 are included in the sample to calibrate the originally disabled coefficient for age 65. For other than age 65, the sample is dominated by continuing enrollees, but their costs appear to proxy actual new enrollee costs reasonably well for younger or older ages.

Beneficiaries for Whom Medicare is a Secondary Payer

Working aged beneficiaries are Medicare beneficiaries, age 65 or over, with private group health insurance coverage from their or their spouse's employer. By law, Medicare is a secondary payer for these beneficiaries. The primary private health plan must pay for medical expenses to the extent of its defined benefits. Only if Medicare covers services not covered by the private plan, or has more generous coverage (e.g., lower deductibles or copayments) for Medicare-covered services, is Medicare responsible for payment, and then only to the extent of the difference in

[16] To simplify the new enrollees model, we recoded new enrollees age 64 on February 1 with an original reason for Medicare entitlement of aged to age 65. Thus, the age 65 cell in the new enrollees model combines new enrollees ages 64 and 65 on February 1 of the prediction year whose original reason for entitlement is aged.

[17] For example, a beneficiary might be entitled to Part A (hospital insurance) by age at age 65 or over, but might not pay Part B (physician insurance) premium until an older age.

[18] Some age 65 new enrollees might have originally been entitled to Medicare by disability when under age 65, but then have rejoined the work force and lost their Medicare eligibility, only to re-enroll at age 65.

Table 4

Descriptive Statistics for New and Continuing Medicare Enrollees[1]

Age/Sex Category	New Enrollees[2] Observations	New Enrollees[2] Mean Annualized Expenditures	Continuing Enrollees[3] Observations	Continuing Enrollees[3] Mean Annualized Expenditures
Female				
0-34 Years	2,540	3,532	7,037	3,653
35-44 Years	3,685	4,341	15,717	4,385
45-54 Years	5,891	4,814	22,431	4,767
55-59 Years	4,029	4,903	14,277	5,354
60-64 Years	3,310	5,705	16,159	6,094
65 Years	58,946	2,729	3,336	6,952
66 Years	1,448	3,319	29,534	3,401
67 Years	845	3,349	31,560	3,684
68 Years	531	3,116	32,578	3,740
69 Years	504	3,608	33,893	3,905
70-74 Years	1,311	4,672	173,829	4,461
75-79 Years	471	5,063	161,843	5,387
80-84 Years	200	6,043	118,144	6,276
85-89 Years	95	8,111	75,186	7,035
90-94 Years	46	5,931	34,135	7,500
95 Years or Over	15	6,457	11,886	6,795
Male				
0-34 Years	3,434	3,089	10,342	2,934
35-44 Years	4,281	3,690	23,172	3,746
45-54 Years	5,820	4,099	29,814	4,074
55-59 Years	4,120	4,603	16,677	4,772
60-64 Years	4,196	4,775	18,986	5,346
65 Years	46,262	2,900	3,940	6,055
66 Years	1,546	3,205	24,472	3,644
67 Years	872	2,976	25,279	3,933
68 Years	570	3,501	25,915	4,145
69 Years	490	3,638	27,009	4,295
70-74 Years	1,223	5,700	130,148	5,087
75-79 Years	429	6,476	108,214	6,307
80-84 Years	144	5,916	66,505	7,231
85-89 Years	63	8,028	32,848	8,326
90-94 Years	19	13,027	10,601	8,827
95 Years or Over	2	3,221	2,420	8,867

[1] Aged and disabled beneficiaries. Excludes working aged and ESRD beneficiaries.

[2] Enrollees with less than 12 months of base year eligibility.

[3] Enrollees with 12 months of base year eligibility.

SOURCE: Pope, G.C. and Kautter, J., RTI International, Ellis, R.P. and Ash, A.S., Boston University, Ayanian, J.Z., Harvard Medical School and Brigham and Women's Hospital, Iezzoni, L.I., Harvard Medical School and Beth Israel Deaconess Medical Center, Ingber, M.J., Levy, J.M., and Robst, J., Centers for Medicare & Medicaid Services, Analysis of 1999-2000 Medicare 5% Standard Analytic File (SAF).

coverage. Medicare expenditures for working aged beneficiaries are lower for this reason, as well as because working may be a proxy for better health.[19] Estimation of a separate model for the working aged is not feasible with the sample sizes available from the Medicare's 5-percent FFS sample. A simple adjustment to CMS–HCC model predictions is a multiplier that scales cost predictions to be lower for these beneficiaries.

We defined the working aged as beneficiaries otherwise satisfying the requirements of our 1999-2000 aged/disabled prospective modeling sample who had at least 1 month of working aged status in the prediction year (2000). There are 19,057 beneficiaries in our working aged sample, or about 1.4 percent as many individuals as in our aged/disabled sample. The mean annualized expenditures of the working aged are $966, less than one-fifth as much as for the aged/disabled community sample ($5,213). The CMS–HCC community

[19] Throughout this section, we use the terms working and working aged to include both those who are actually working, and the spouses of those who are working.

model over-predicts mean working aged expenditures by a factor of 3.66. Essentially, we define the working aged multiplier as the ratio of mean actual to mean predicted expenditures for the working aged sample, where expenditures are predicted by the CMS-HCC community model. With an adjustment for beneficiaries who have a mixture of working aged and non-working-aged months in the payment year, the working aged multiplier is 0.215.

CONCLUSIONS

CMS' adaptation of the DCG/HCC model makes substantially more accurate predictions of medical costs for M+C enrollees than has previously been possible. Its use is intended to redirect money away from MCOs that cherry-pick the healthy, while providing the MCOs that care for the sickest patients the resources to do so. The ultimate purpose of the CMS-HCC payment model is to promote fair payments to MCOs that reward efficiency and encourage excellent care for the chronically ill. The CMS-HCC model will continue to evolve. Additional diagnoses may be needed to predict drug expenditures incurred under the drug benefit enacted by MMA (2003). The model may need to be recalibrated to reflect new treatment patterns and disease prevalence. Diagnosis-based risk adjustment may need to be coordinated with disease management programs and incentives for quality of care.

The model has evolved over two decades of research,[20] with careful attention to clinical credibility, real-world incentives and feasibility tradeoffs. Continuous feedback between government technical staff and policymakers at CMS on the one hand, and research organization and academic researchers on the other, has shaped the CMS-HCC model. Much of the recent research reported in this article has related to adapting the model for Medicare subpopulations. The use of a single modeling framework—the CMS-HCC model—provides unity and organization to the subgroup models with the unique features specific to certain types of beneficiaries. Comprehensive risk adjustment, based on ambulatory as well as inpatient diagnoses, is just beginning to be implemented. Thus, it is too early to tell whether it will achieve its goals. As risk adjustment continues to be incorporated in Medicare payments to MCOs, it will be important to evaluate its impact on these organizations and the beneficiaries they serve, especially organizations that care for the chronically ill and their enrollees. This will tell us a great deal about the feasibility and consequences of matching health care resources to needs.

[20] The DCG line of risk-adjustment research dates back to the report by Ash et al. (1989), based on research begun in 1984.

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Reprint Requests: Gregory C. Pope, RTI International, 411 Waverly Oaks Road, Suite 330, Waltham, MA 02452. E-mail address: gpope@rti.org