Using Diagnoses to Describe Populations and Predict Costs

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The Diagnostic Cost Group Hierarchical Condition Category (DCG/HCC) payment models summarize the health care problems and predict the future health care costs of populations. These models use the diagnoses generated during patient encounters with the medical delivery system to infer which medical problems are present. Patient demographics and diagnostic profiles are, in turn, used to predict costs. We describe the logic, structure, coefficients. and performance of DCG/HCC models, as developed and validated on three important data bases (privately insured, Medicaid, and Medicare) with more than 1 million people each.

INTRODUCTION

Role of Health-Based Payment Models

Since 1985, HCFA has made capitated payments to managed care organizations that enroll Medicare beneficiaries. HCFA, using a demographic risk adjuster to calculate payments equal to 95 percent of what health maintenance organization (HMO) enrollees "would have cost" had they remained in the traditional fee-for-service Medicare program, paid less-than-average dollars for the group who originally transferred into these programs. However, HCFA still appears (on average) to have overpaid, because the early switchers into Medicare managed care were healthier than comparably aged non-switchers (Brown et al., 1993). Anticipating and responding to this problem, HCFA has sponsored much research, including development of the Diagnostic Cost Group (DCG) models, with the goal of being able to better match HMO payments to the health care needs of enrollees. Since 1984, when researchers at Boston University and Brandeis initiated this work for HCFA, DCGs have evolved into a family of methods for using administrative data collected during patient encounters to calculate health-based "expected costs" for populations (Ash et al., 1986, 1989, 1998; Ellis and Ash, 1995; Ellis et al., 1996a, 1996b; Pope et al., 1998, 1999, 2000).

DCG models use age, sex, and diagnoses generated from patient encounters with the medical delivery system to infer which medical problems are present for each individual and their likely effect on health care costs for a population. Some versions of the DCG models focus on diagnoses that form the principal reason for an inpatient admission, now called "PIP diagnoses" (Ash et al., 1989; Ellis and Ash, 1995; Pope et al., 2000). Other versions, such as the DCG/HCC models of this article, utilize the full range of diagnoses generated during all face-to-face encounters

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with clinicians (Ellis et al., 1996a, 1996b; Ash et al., 1998; Pope et al., 1998). Whereas previous publications using DCGs have calibrated models solely for Medicare samples, in this study, we contrast the ability of DCG/HCC models to predict resources in three different samples: privately insured, Medicaid, and Medicare.

Payment methods establish incentives. For example, when payments follow a "piecework" model, as in traditional fee-for-service medicine, providers are rewarded for doing more—whether the additional utilization is valuable or not. Conversely, capitated payments encourage doing less—whether through efficiency or stinting. Further, flat-rate capitated payments introduce a new perverse incentive: to enroll healthy people and to do the very little required to keep them enrolled. Models that pay each person's expected cost eliminate the incentive to "select on risk" and make efficiency the main way for a plan to achieve a competitive advantage (Van de Ven and Ellis, 2000).

Although risk-adjusted payment solves the problem of perverse patient-selection incentives, linking payments to a risk-adjustment model may lead plans to invest unproductive effort in making their enrollees "look needier" according to that model. For example, models that pay more for health care "users" encourage both appropriate and unnecessary utilization; those that identify illness only through hospitalizations encourage admissions, and those that pay more for people with more coded illnesses encourage "diagnostic discovery." This last incentive can be good to the extent that it rewards plans that keep better track of their members' chronic illnesses (Greenwald et al., 1998). The degree of imperfection in incentive-setting is one criterion in choosing among payment models. Furthermore, how much imperfection is acceptable depends upon the nature and level of problems associated with available alternatives.

Predicting Costs in a Range of Populations

The original DCG models are prospective, that is, they use baseline, or year 1, data to infer the level of need for health care in year 2 and were developed to predict costs for Medicare beneficiaries. Medical conditions (diagnoses) detected in year 1 are used to organize people into groups with similar levels of future health care need. The distribution of all members by levels of future need characterizes an enrolled group and is used to determine a health-based payment. More recently, we have developed DCG models to calculate expected concurrent expenses, that is, expenses that occur in the same year as the diagnoses used to characterize the population (Pope et al., 1998, 1999, 2000). We have also adapted both prospective and concurrent modeling frameworks for use in Medicaid and commercially insured (private) populations under the age of 65 (Ash et al., 1998).

Concurrent models may be particularly useful for provider profiling and monitoring, because knowing all the medical problems being treated during a period of time is particularly relevant for estimating the level of resources used to treat them. However, prospective models, which predict future costs, are more appropriate for creating payments to managed care organizations that assume financial risk, because they focus on the presence of illnesses, such as cancer and heart disease, that predictably make people more expensive to treat.

In this article, we describe prospective models only, as they apply to three separate populations: a national sample of

commercially insured enrollees under age 65, enrollees in Michigan's Medicaid program, and a national sample of Medicare beneficiaries. We refer to these three populations and the models that pertain to them as private, Medicaid, and Medicare. Continuing the tradition in which DCG models were originally developed, these models reflect concern for appropriate incentives in payments to health care plans and providers. All DCG/HCC models (regardless of the population or whether they are concurrent or prospective) rely on a common classification structure, which we describe later. Diversity across populations is handled by using different coefficients, different exclusions of potential predictors from payment models, and different constraints on coefficients across age or eligibility groups.

Model Criteria: Accuracy, Feasibility, and Incentives

The DCG models strive for accurate predictions in the face of limitations on the available data and concerns about incentives. The goal is to effectively predict costs from data that should be present in any health care delivery system, while limiting the rewards for undesirable behavior with respect to either treatment or reporting.

Although our descriptive system does classify all recorded diagnoses in order to create a comprehensive picture of problems seen, concerns about incentives cause us to not model some information. For example, we do not use the number of hospitalizations to predict cost, so as to avoid disadvantaging medical care organizations that are good at treating sick people with fewer hospitalizations. Nor do we count how often a diagnosis appears. Conceptually, DCG models are designed to predict higher costs when they detect additional conditions associated with elevated costs. Based on clinical judgment and concerns about incentives, we exclude some condition categories (CCs) from contributing to predictions entirely. For example, the presence of chemotherapy is noted in the diagnostic codes, and, therefore we classify it into a CC (number 115); however, our prospective models do not pay more for it. Higher payments are based on the presence of a particular type of cancer, rather than a choice of therapy.

METHODS

Populations and Data

We describe payment models for three populations whose types of health coverage span the major ways in which health care is provided in the United States today. Specifically, we use:

- A nationally dispersed, privately insured (indemnity-covered) population of 1.4 million people in 1992 and 1993 (the private data).
- One million individuals covered by Michigan's Medicaid program in 1991-1992 (Medicaid).
- Medicare's 5-percent research sample from 1991 and 1992.

The outcome variable, total program costs in year 2, is defined as total covered expenses—an amount that includes copayments, deductibles, and third-party payments—in each data set. Costs for people with less than a full year of entitlement in year 2 are annualized, based on their observed cost per month; in analyses, we treat their data as "fractional observations" (Ellis and Ash, 1995). The three populations differ substantially with respect to age and sex distributions, health care costs, and hospital experience (Table 1). In each population, most of the data are used (in a development sample) to establish the model structure and to fit

Table 1

Age, Sex, Hospital Experience, and Total Health Care Costs in Three Populations[1]

Characteristic or Statistic	Private	Medicaid	Medicare
Number	1,379,970	1,103,367	1,360,626
Prediction Year	1993	1992	1992
Percent by Age			
0-17 Years	26.7	51.4	0.0
18-44 Years	44.9	40.0	3.2
45-64 Years	28.4	8.7	5.8
65 Years or Over	0.0	0.0	91.0
Percent Female by Age			
0-17 Years	51.3	50.9	0.0
18-44 Years	44.9	29.4	36.1
45-64 Years	46.6	40.0	39.4
65 Years or Over	—	—	60.7
Total Prediction-Year Costs			
Mean	$1,592	$1,430	$3,778
Standard Deviation	8,236	5,407	10,523
Coefficient of Variation	517	378	279
Median	85	121	516
99th Percentile	25,472	23,208	57,423
Maximum	2,412,707	1,253,880	1,533,060
Percent with Zero Prediction-Year Costs	42.9	32.3	16.1
Percent Hospitalized in the Prediction Year	4.8	8.4	21.2

[1] For people with at least 1 month of eligibility in each of the baseline and prediction years.

SOURCE:(Ash et al., 1998; Pope et al., 1998.)

coefficients, while the rest of the data (the validation sample) are used for measuring model performance. Finally, regressions based upon all the data are used to produce the model coefficients in this article.

A fourth data set, consisting of 191,877 people under age 65 in a State employee benefit program (State data), is used to further validate the private model's ability to discriminate costs within important subsets of a new population, as described later.

DCG/HCC Models

The letters DCG/HCC are used to distinguish the multicondition Hierarchical Condition Category (HCC) models from the single-condition PIP-DCG model that HCFA is using to calculate payments to Medicare HMOs in the year 2000 (Ingber, 1998; Iezzoni et al., 1998; Health Care Financing Administration, 1999).

Each DCG model is designed to use the diagnostic codes from the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) (Public Health Service and Health Care Financing Administration, 1980) on the claims that hospitals and physicians submit to payers. (For a discussion of diagnostic coding issues, refer to Iezzoni, 1997.) Each DCG/HCC model uses the same CCs for prediction, all of which are based on diagnostic codes, rather than procedures. DCG models summarize a person's health from his or her CCs and estimate expected costs based on these profiles. Although DCG models reward medical-problem identification, not all CCs are or should be used to modify payments to plans. In designing DCG models, we have anticipated "DCG creep" (changes in diagnostic coding for the purpose of increasing DCG-based payments) by making the models less sensitive

to expected changes. In particular, our models exclude some CCs and impose hierarchies to reduce the sensitivity of predicted costs to three things: (1) variations in coding practice; (2) intentional coding proliferation with the aim of improving provider reimbursement (gaming); and (3) inconsistent coding of less serious or vague conditions.

Diagnostic Groups (DxGROUPs)

With more than 15,000 codes, the distinctions created by ICD-9-CM are too fine to be used directly as a payment classification system. Therefore, we group ICD-9-CM codes into 543 categories, called "DxGROUPs," which are the building blocks of DCG/HCC models. Each DxGROUP has a two-level numerical label and a short, clinically informative text name. All DxGROUPs with the same "whole number" stem are clinically related. For example, the "4.xy" series refers to infectious diseases, with 4.01 being bacterial enteritis, 4.02 viral enteritis, 4.03 other intestinal infections, 4.04 tuberculosis, and so on.

Each recognized ICD-9-CM code maps to a unique DxGROUP; each DxGROUP encompasses diagnostic codes that describe very similar medical problems. We place in the same DxGROUP alternative codes that can be used for the medical conditions that clinicians generally think of together (such as congestive heart failure and cardiomyopathy or deep vein thrombosis and deep vein thrombosis in pregnancy) or codes for medical conditions that are not easily distinguished (such as chronic bronchitis and emphysema).

Condition Categories

DxGROUPs are clustered in a CC when they contain medically related problems with similar expected costs. We created the 118 diagnosis-based CCs used for modeling in each population using a mix of clinical judgment and empirical cost data. The core physician panel making these judgments consisted of four internists experienced in health services research. Specialist consultants assisted in several areas including pediatrics, HIV/AIDS (human immunodeficiency virus/acquired immunodeficiency syndrome), pediatric surgery, obstetrics, and neonatology.
Although we sought to create CCs with at least 500 cases in our private sample of around 1 million people, that goal is subordinated to the objective of clinical homogeneity. For a few conditions (such as mental retardation, quadriplegia, and underweight neonates), we accept significantly smaller numbers.

We eliminate logical inconsistencies in diagnostic coding that can be identified by comparing with age and sex. For example, we drop a diagnosis of uterine disorder in a male. However, we do not drop neonatal codes found in the records of non-infant females. When an infant dies shortly after birth, insurance companies sometimes do not create a separate eligibility record but rather assign the neonatal codes to the mother. Currently, two CCs are used to classify neonatal codes assigned to mothers.

The CCs are organized in broad system groups (such as four CCs for infections, eight for neoplasms, and three each for diabetes and metabolic disorders). Short names (such as Infection1, Diabetes3) denote such CC groups; numbering within a short-name series generally indicates decreasing expected costs (e.g., Neoplasm1 contains metastatic cancers, Neoplasm2 contains high-cost site-specific cancers, Neoplasm3 has moderate-cost cancers, on down to Neoplasm8, benign neoplasms).

Table A in the Technical Note shows for each CC, its number, long name, short name and the CCs that it donimates in the

model hierarchy explained in the following section. A complete list of the individual DxGROUPs indicating their organization into CCs is available at www.dxcg.com under the heading "DCG Clinical Classification System in Detail." (This information can also be obtained by contacting the lead author.)

CC Hierarchies

A payment model should not be sensitive to every diagnostic code recorded because this will result in poorly specified coefficients and unstable estimates of the relative risk of populations. For example, a female who has metastatic cancer (CC 5) could also be coded with cancer in two or more specific body sites, such as the liver (CC 6) or connective and soft tissue (CC 7). She may also have been tested for other "uncertain" (CC 10) or "benign" cellular changes (CC 12). A regression model that separately assigns credit for each of these diagnoses will have confounded parameter estimates, because the costs of people with only the simpler problems get averaged in, or confounded, with costs for people with both simple and more consequential conditions. Also, such models reward most the plans that capture as many codes as can be legitimately defended in an audit—a behavior with little social value. To dampen these incentives, we use hierarchies to constrain CC assignment as follows: a person classified into a CC is not also classified into a lower ranked CC in the same hierarchy. An important feature of an HCC model is that the hierarchies are not imposed across unrelated medical problems. For example, for a female with both cancer and diabetes, hierarchies are used to retain only the "worst" evidence of each disease, but both cancer and diabetes CCs are used in predicting her costs next year.

Hierarchies are identified for each CC in the rightmost column of Table A by indicating which CCs are dominated; dominated CCs are zeroed out for a person when a dominating CC is present.

The CC hierarchies capture both chronic and serious acute manifestations of particular disease processes, as well as their seriousness in terms of expected costs. Some hierarchies, such as neoplasm, are simple; CC 5 dominates CC 6, which dominates CC 7, all the way down to CC 12. Other hierarchies, such as gastrointestinal, are more complex, as illustrated in Figure 1. A person may be classified with either, or both, acute and chronic high-cost gastrointestinal problems; however, if either of these is coded, information about moderate or lower cost GI disorders is ignored.

Clinically, hierarchies reduce the sensitivity of predicted payments to the coding of less serious manifestations of the same condition; statistically, they make explanatory variables more nearly orthogonal, increasing statistical precision. Imposing hierarchies typically increases the estimated coefficients and t-ratios of serious condition categories.

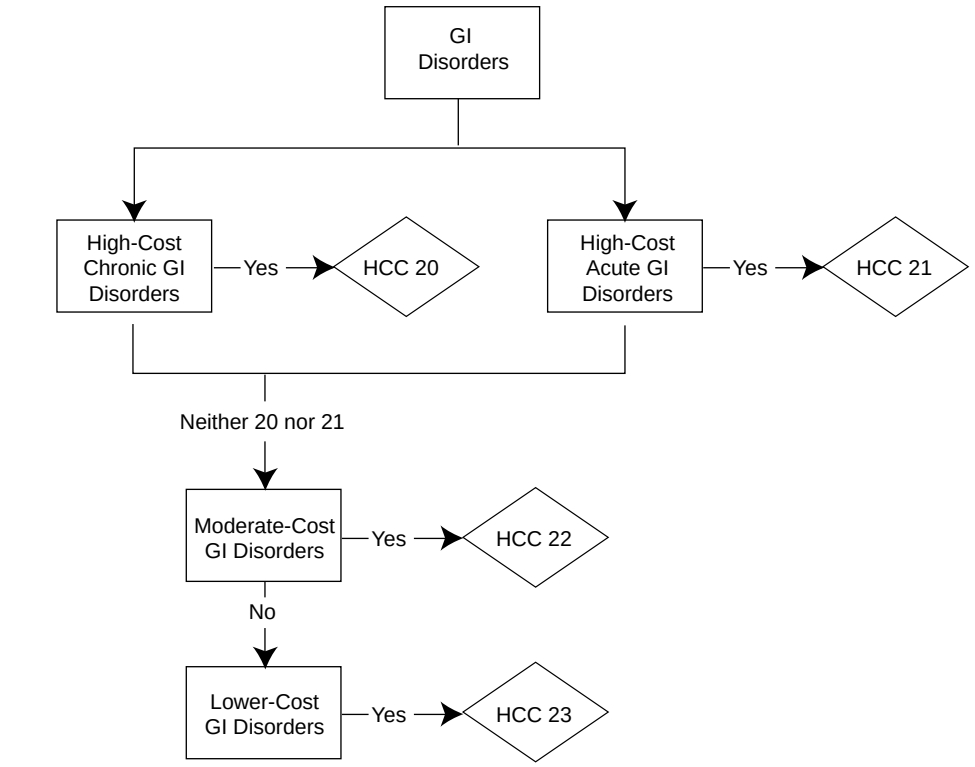
Excluded Condition Categories

We also exclude some CCs from the models entirely, by constraining their coefficients to be zero; the result is that the presence of that condition for an individual will not increase his or her predicted cost. Money that "disappears" from the prediction when a positive coefficient is constrained to zero is redistributed—generally reappearing as slight increments to demographic variables. Each model still accounts for the costs of treating all conditions.

The most common reason for exclusion is the a priori medical judgment that a current problem triggering this CC this year should have little effect on next-year costs.

Figure 1

Sample of a Condition Category Hierarchy: Gastrointestinal (GI) Disorders



NOTE: HCC is Hierarchical Condition Category.

SOURCE: (Ash et al., 1998.)

Examples are (non-melanoma) skin cancers; benign cancers; lower cost ear, nose, and throat disorders; minor injuries; and screening (for example, presence of a routine checkup).

A second reason for exclusion is that a CC does not add to expected costs (either its coefficient in our modeling sample is actually negative or it is not statistically significantly positive). Reassuringly, these are generally the same CCs clinically thought to have little effect on future costs. Excluding CCs that would subtract from the payment preserves the monotonic character of the model. To ensure that adding a code does not reduce predicted costs, each CC with a non-positive coefficient is excluded or constrained, even if it might seem that the CC should be in the model.

A final reason for exclusion is concern over "gaming," that is, a perverse health plan response to the incentives created by the model. Thus, the models do not pay for the often vague or discretionary conditions included in CCs such as moderate and other endocrine disorders (CCs 17 and 18), and lower cost mental disorders (CC 35). Such exclusions improve the models' attractiveness for setting payments, at the cost of some loss in accuracy.

Coefficient Constraints

Especially for conditions that are rare (such as mental retardation, ranging from mild to profound, in an employed population), unconstrained models can lead to higher payments for less serious condi-

tions. Thus, in a few cases, we impose restrictions across sets of CCs, forcing predictions for conditions that are higher in a hierarchy to be at least as large as predictions for conditions that they dominate (as "profound mental retardation" dominates "mild mental retardation"). These restrictions avoid plans receiving higher payments for "downcoding." We also do not modify some surprisingly low-cost coefficients that appear to be real artifacts of the coverage or delivery systems to which they apply, in the sense that they capture all costs covered by the program that collected the data but do not reflect expenditures from other sources. An example of this is the relatively low cost for people with renal failure in Medicaid because Medicare is likely to be the primary payer for most of the very high treatment costs for these people.

Clinical Refinements, Including Interactions with Age

The DCG classification system, originally focused on chronic conditions of the elderly, now handles distinctions for a full age and population spectrum. There are 21 DxGROUPs organized into 5 CCs for neonates (ages 0 to 1). Additional new CCs include four for the mentally retarded (common only in Medicaid), five for mental health and substance abuse, five for accidents and injuries, seven for pregnancy, and four for congenital and/or distinctly pediatric problems.

Ultimately, a single comprehensive classification system, with 543 DxGROUPs organized into 118 CCs and a common set of imposed hierarchies, is used to profile the medical problems present for any person, regardless of age, sex, or type of insurance. However, the cost consequences of a given diagnostic profile can be affected by demographics. For example, some CCs are separately priced for pediatric populations (age under 18), in the private or Medicaid populations, when clinical judgment and empirical evidence find substantial differences in utilization by age (e.g., CC 70, asthma, adds $1,513 for adults and only $825 for children in the private data.) The Medicare model also recognizes age/medical interactions for a few conditions (such as HIV and aplastic anemia). For people with such conditions, certain costs are associated with it in elderly persons (those age 65 or over), but additional dollars are associated with costs of care among the disabled (younger persons whose Medicare entitlement derives from disability).

Demographic Variables

In a given year, healthy people, whether they are age 8 or 80, incur few medical expenses. However, average health care costs differ dramatically by age and somewhat by sex. Much of this is driven by differences in disease prevalence because, for example, most children 8 years of age are fully healthy, while most persons age 80 have one or more chronic conditions requiring medical attention. Some of the cost difference is attributable to differences in the nature of certain diseases (or how they are treated) in children, young adults, or seniors. Additionally, however, even among those with no medical problems this year, demographically defined subgroups, such as females of childbearing age, or the oldest old, have different average costs next year. In a prospective model, even after accounting for the medical problems present, the additional effects of age and sex on expected costs remain important.

The three models (private, Medicaid, and Medicare) recognize three key age groups: 0-17 years, 18-64 years, 65 years or

over, either by allowing some distinct CC coefficients for those under as opposed to over age 18 in the younger populations or by using distinct Medicare coefficients for those 65 or over.

The private and Medicaid models contain 16 indicators that place people within same-sex, similar-age groups (ages 0-5, 6-12, 13-17, 18-24, 25-34, 35-44, 45-54, and 55-64). The Medicare model constrains coefficients among its disabled enrollees under age 65 to distinguish only ages 0-34 and 35-64; it then makes 5-year breaks between 65 and 94 years of age; the highest age category is 95 or over.

Eligibility Categories

In addition to age and sex categories, the Medicaid model incorporates nine additional variables that distinguish among five distinct groups of enrollees: (1) the blind and disabled (11 percent); (2) those eligible because of other medical problems (8 percent); (3) pregnant women (2 percent); (4) those with poverty-related entitlement (71 percent); and (5) others (9 percent). We assign each person to one of the categories based on reason for entitlement during his or her earliest month of enrollment in year 1. Observed annual expenditures per person in year 2 averaged $1,430 and differed substantially by category. The blind and disabled are by far the most expensive, at $5,585 annually in year 2. Pregnant women cost about twice the average ($2,708); the "other medical" and "other" groups are about average ($1,281 and $1,500, respectively) and the non-medical, poverty-related group, consisting mainly of children enrolled under Aid to Families with Dependent Children, cost about one-half the average ($731).

Four of the new variables are indicators (yes-no variables) that distinguish Medicaid's other subpopulations from the least expensive, poverty-related subgroup. The remaining five additional demographic variables in the model are interactions of eligibility category and duration of (year 1) Medicaid enrollment. These variables allow the model to reflect the fact that recent entrants to the Medicaid program cost more than longer term "stayers," and that the "premium" for recent entry varies not only by duration of enrollment but by eligibility type. These five variables each have the form:

(Eligibility type) * (Amount added per missing year-1 month)

How all this works is best illustrated with examples, as shown in the following section.

Sample Calculations of Expected Costs

Each HCC model prediction is the sum of a demographic part and a health-status part. We illustrate this in Figure 2 for two privately insured females 58 years of age. The numbers here are private-model coefficients, shown in the first column of Table 2. Both patients' estimated costs begin with a demographic component of $1,730, which is the final prediction for any fully healthy, privately insured female between the ages of 55 and 64. Each of these patients, however, also has medical conditions with expected consequences for future health care costs.

Figure 2 shows how the model organizes each patient's ICD-9-CM data into a clinical profile that leads to the health-status part of her prediction. For patient 1, her breast cancer diagnosis adds $2,372; her hypertension, a distinct medical problem, adds another $915, for a total of $5,017. Patient 2 has breast cancer, too, but her cancer has metastasized and is coded at

Figure 2

Sample Information Used to Predict Next Year's Expenses for Privately Insured Patients

Patient 1

Prediction for Year 2	Information from Year 1
$1,730	Base: Female Age 58
2,372	CC 8:Neoplasm4 (Lower Cost Cancers/Tumors) DxGROUP: 11.01 (Breast Cancer) ICD-9-CM:174.9 (Malignant Neoplasm Breast, NOS)
915	CC 57: Hypertension DxGROUP: 70.04 (Secondary Hypertension) ICD-9-CM: 405.19 (Other, Benign, Secondary Hypertension)
5,017	Total of All Scores

Patient 2

Prediction for Year 2	Information from Year 1
$1,730	Base: Female Age 58
21,884	CC 5:Neoplasm1 (Metastatic Cancer) DxGROUP: 19.02 (Secondary Cancer, Respiratory/Digestive System) ICD-9-CM:197.0 (Secondary Malignant Neoplasm Lung) ICD-9-CM:197.7 (Secondary Malignant Neoplasm Liver) DxGROUP: 19.03 (Secondary Cancer of Other Site) ICD-9-CM: 198.5 (Secondary Malignant Neoplasm Bone)
0	CC 8:Neoplasm4 (Lower Cost Cancers/Tumors) DxGROUP: 11.01 (Breast Cancer) ICD-9-CM:174.9 (Malignant Neoplasm Breast, NOS)
$23,614	Total of All Scores

NOTES:CC is Condition Category. DxGROUP is Diagnostic Group. ICD-9-CM is *International Classification of Diseases, 9th Revision, Clinical Modification*. NOS is not elsewhere specified.

SOURCE:(Ash et al., 1998.)

multiple sites (lung, liver, and bone). Note the different ways that additional information about cancer is reflected in the classification: in one, distinct but related diagnoses are classified into the same DxGROUP; in another, related DxGROUPs are classified into the same CC; in a third, one CC is ranked higher than another. In the end, only a single payment amount ($21,884) is calculated for metastatic cancer; any additional codes pertaining to benign or malignant neoplasms are ignored.

Another example clarifies how the Medicaid demographic/eligibility variables work. This time the numbers are drawn from the Medicaid column of Table 2. We compute the predicted cost for a female age 20 with no medical problems and a full year 1 of poverty-related Medicaid by adding $560 (the "female, age 18-24" base amount) to $476 (poverty-related eligibility) for a total of $1,036. If the female had been present for only 10 months in year 1, we add another $112, that is, $56 for each of the two missing year-1 months, for a total of $1,148. If she were present for only 2 months in year 1, we would add 10 x 56 to $1,036, for a total of $1,596. In contrast, consider a female of the same age and present for 10 months in year 1 but who is eligible for Medicaid because of disability rather than poverty. We add three numbers to arrive at the demographic part of

Table 2

Statistics for Private, Medicaid, and Medicare Prospective Payment Models

Statistic or Variable			Private	Medicaid	Medicare
Number of Observations			1,379,023	1,103,367	1,360,626
Prediction Year Mean Total Costs			1,593	1,430	3,778
Number of Model Parameters			102	136	96
R^2 x 100			9.4	21.1	8.8
Validated R^2 x 100			9.1	23.1	8.5
Standard Error			7,843	4,802	9,963
Age/Sex Groups				Model Coefficients	
Female					
0-5 Years			295	-6	1,324
6-12 Years			241	0	1,324
13-17 Years			479	270	1,324
18-24 Years			613	560	1,324
25-34 Years			1,187	337	1,324
35-44 Years			1,120	345	1,155
45-54 Years			1,401	446	1,202
55-64 Years			1,730	537	1,698
65-69 Years			‡	‡	1,042
70-74 Years			‡	‡	1,318
75-79 Years			‡	‡	1,675
80-84 Years			‡	‡	1,962
85-89 Years			‡	‡	2,161
90-94 Years			‡	‡	2,258
95 Years or Over			‡	‡	1,897
Male					
0-5 Years			312	87	955
6-12 Years			271	113	955
13-17 Years			473	334	955
18-24 Years			370	86	955
25-34 Years			574	132	955
35-44 Years			778	392	904
45-54 Years			1,218	571	887
55-64 Years			2,126	526	1,403
65-69 Years			‡	‡	1,428
70-74 Years			‡	‡	1,743
75-79 Years			‡	‡	2,215
80-84 Years			‡	‡	2,426
85-89 Years			‡	‡	2,725
90-94 Years			‡	‡	3,027
95 Years or Over			‡	‡	2,980
Medicaid Eligibility Categories					
Blind/Disabled			‡	1,449	‡
Other Medical			‡	429	‡
Poverty-Related			‡	476	‡
Pregnant Women			‡	96	‡
Other			‡	-263	‡
Medicaid Amount Added per Missing Base Year Month for					
Blind/Disabled			‡	179	‡
Other Medical			‡	71	‡
Poverty-Related			‡	56	‡
Pregnant Women			‡	296	‡
Other			‡	100	‡
Condition Categories[2]					
1	Infection1	HIV/AIDS	22,580	5,284	1,076
2	Infection2	Septicemia (Blood Poisoning)/Shock	8,677	3,663	3,253
3	Infection3	Central Nervous System Infections	4,658	†	760
5	Neoplasm1	Metastatic Cancer	21,884	6,331	6,185
6	Neoplasm2	High-Cost Cancer	11,967	3,278	3,905
7	Neoplasm3	Moderate-Cost Cancer	5,863	1,288	2,128
8	Neoplasm4	Lower Cost Cancers/Tumors	2,372	550	873
13	Diabetes1	Diabetes with Chronic Complications	7,726	3,686	3,582
14	Diabetes2	Diabetes with Acute Complications/ Non-Proliferative Retinopathy	3,806	2,392	2,396

See footnotes at end of table.

Table 2—Continued

Statistics for Private, Medicaid, and Medicare Prospective Payment Models

Statistic	or Variable		Private	Medicaid	Medicare
15	Diabetes3	Diabetes with No or Unspecified Complications	1,961	369	1,147
16	Metabolic1	Protein-Calorie Malnutrition	13,639	5,012	3,594
19	Liver	Liver Disease	5,700	4,007	3,028
20	GI1	High-Cost Chronic Gastrointestinal Disorders	4,312	2,944	1,336
21	GI2	High-Cost Acute Gastrointestinal Disorders	2,087	1,213	1,329
22	GI3	Moderate-Cost Gastrointestinal Disorders	1,432	748	730
24	MSK1	Bone/Joint Infections/Necrosis	3,653	3,563	2,070
25	MSK2	Rheumatoid Arthritis and Connective Tissue Disease	2,380	870	1,218
27	Blood1	Aplastic and Acquired Hemolytic Anemias	9,801	6,562	4,035
28	Blood2	Blood/Immune Disorders	4,248	3,637	709
30	Dementia	Dementia	4,822	1,324	438
31	Mental1	Drug/Alcohol Dependence/Psychoses	3,568	2,223	1,122
32	Mental2	Psychosis and Other Higher Cost Mental Disorders	3,092	3,599	1,288
33	Mental3	Depression and Other Moderate-Cost Mental Disorders	2,171	834	540
34	Mental4	Anxiety Disorders	1,788	771	511
36	MR1	Profound Mental Retardation	2,544	22,370	†
37	MR2	Severe Mental Retardation	2,544	16,064	†
38	MR3	Moderate Mental Retardation	2,544	11,677	†
39	MR4	Mild/Unspecified Mental Retardation	2,544	5,508	†
40	Neuro1	Quadriplegia	12,506	5,632	5,686
41	Neuro2	Paraplegia	12,506	3,467	5,788
42	Neuro3	Higher Cost Neurological Disorders	3,939	1,452	1,851
43	Neuro4	Moderate-Cost Neurological Disorders	1,936	1,037	1,261
45	Arrest1	Respirator Dependence/Tracheostomy Status	41,465	24,247	9,117
46	Arrest2	Respiratory Arrest	13,396	3,538	8,087
47	Arrest3	Cardio-Respiratory Failure and Shock	3,416	2,673	2,809
48	Hrt_CHF	Congestive Heart Failure	5,114	2,714	2,069
49	Hrt_ARR	Heart Arrhythmia	1,872	928	670
50	Hrt_AMI	Acute Myocardial Infarction	4,723	3,792	1,778
51	Hrt_CAD1	Other Acute Ischemic Heart Disease	3,442	1,639	1,807
52	Hrt_CAD2	Chronic Ischemic Heart Disease	2,871	511	883
53	Hrt_VHD	Valvular and Rheumatic Heart Disease	1,128	741	938
54	Hrt_HTN	Hypertensive Heart Disease	1,346	436	347
57	HTN	Hypertension (High Blood Pressure)	915	312	216
58	Stroke1	Higher Cost Cerebrovascular Disease	3,902	1,523	1,919
59	Stroke2	Lower Cost Cerebrovascular Disease	1,795	645	835
60	Vascular1	High-Cost Vascular Disease	2,486	1,420	1,268
61	Vascular2	Thromboembolic Vascular Disease	2,505	2,316	1,429
64	Lung1	Chronic Obstructive Pulmonary Disease	2,633	1,034	1,669
65	Lung2	Higher Cost Pneumonia	8,092	3,455	4,037
66	Lung3	Moderate-Cost Pneumonia	3,411	492	1,229
68	Lung5	Pulmonary Fibrosis and Other Chronic Lung Disorders	3,254	936	829
69	Lung6	Pleural Effusion/Pneumothorax	2,239	2,506	1,456
70	Lung7	Asthma	1,513	409	624
72	Eye1	Higher Cost Eye Disorders	783	1,110	242
74	ENT1	Higher Cost Ear, Nose, and Throat Disorders	685	620	147
76	Urinary1	Dialysis Status	37,287	3,693	6,821
77	Urinary2	Kidney Transplant Status	10,333	215	6,468
78	Urinary3	Renal Failure	17,834	5,742	3,107
79	Urinary4	Nephritis	1,050	1,026	1,627
81	Genital1	Female Infertility	2,242	455	†
82	Genital2	Moderate-Cost Genital Disorders	889	345	89
84	Preg1	Ectopic Pregnancy	1,957	951	†
85	Preg2	Miscarriage/Abortion	1,892	1,064	†
86	Preg3	High-Cost Completed Pregnancy	572	262	†
87	Preg4	Moderate-Cost Completed Pregnancy	572	262	†
88	Preg5	Normal Delivery	572	262	†
89	Preg6	Higher Cost Pregnancy without Completion	4,060	1,674	1,634
90	Preg7	Lower Cost Pregnancy without Completion	4,060	1,674	1,634
91	Skin1	Chronic Ulcer of Skin	3,756	2,468	2,473
93	Injury1	Vertebral Fractures and Spinal Cord Injuries	2,992	546	1,289
94	Injury2	Hip Fracture/Dislocation	1,280	463	993
95	Injury3	Head Injuries	763	95	428
96	Injury4	Drug Poisoning, Internal Injury, Traumatic Amputation, Burn	1,588	932	1,256
98	Complic	Complications of Care	2,369	1,380	798

See footnotes at end of table.

Table 2—Continued

Statistics for Private, Medicaid, and Medicare Prospective Payment Models

Statistic or Variable			Private	Medicaid	Medicare
101	Peds	Very-High-Cost Pediatric Disorders	5,901	2,067	†
102	Cong1	Higher Cost Congenital/Pediatric Disorders	4,948	710	2,081
103	Cong2	Moderate-Cost Congenital Disorder	1,603	355	532
104	Cong3	Lower Cost Congenital Disorder	829	334	348
105	Baby1	Extremely-Low-Birthweight Neonates	13,238	1,852	†
106	Baby2	Very-Low-Birthweight Neonates	13,238	1,163	†
107	Baby3	Serious Perinatal Problem Affecting Newborn	1,010	323	†
108	Baby4	Other Perinatal Problem Affecting Newborn	145	78	†
109	Baby5	Normal, Single Birth	332	78	†
110	Transplant1	Heart, Lung, Liver Transplant Status	26,576	5,312	3,552
112	Openings	Artificial Opening Status/Attention	5,588	4,317	2,696
Age-Interacted Condition Category[3]					
AI-1	Infection1	HIV/AIDS	†	†	8,735
AI-2	Infection2	Septicemia (Blood Poisoning)/Shock	†	-2,615	†
AI-15	Diabetes3	Diabetes with No or Unspecified Complications	†	-157	†
AI-20	GI1	High-Cost Chronic Gastrointestional Disorders	†	-924	4,241
AI-21	GI2	High-Cost Acute Gastrointestional Disorders	1,406	-313	†
AI-22	GI3	Moderate-Cost Gastrointestinal Disorders	-1,044	-460	†
AI-24	MSK1	Bone/Joint Infections/Necrosis	†	-3,047	†
AI-25	MSK2	Rheumatoid Arthritis and Connective Tissue Disease	†	-812	†
AI-27	Blood1	Aplastic and Acquired Hemolytic Anemias	†	-4,872	3,365
AI-28	Blood2	Blood/Immune Disorders	†	-2,108	2,019
AI-30	Dementia	Dementia	†	373	†
AI-31	Mental1	Drug/Alcohol Dependence/Psychoses	†	-1,135	3,315
AI-32	Mental2	Psychosis and Other Higher Cost Mental Disorders	346	3,842	1,204
AI-33	Mental3	Depression and Other Moderate Cost Mental Disorders	†	1,876	†
AI-36	MR1	Profound Mental Retardation	†	-4,752	†
AI-37	MR2	Severe Mental Retardation	†	-6,924	†
AI-38	MR3	Moderate Mental Retardation	†	-5,056	†
AI-39	MR4	Mild/Unspecified Mental Retardation	†	-1,717	†
AI-42	Neuro3	Higher Cost Neurological Disorders	†	1,377	†
AI-43	Neuro4	Moderate-Cost Neurological Disorders	-929	-224	†
AI-58	Stroke1	Higher Cost Cerebrovascular Disease	†	-1,450	†
AI-59	Stroke2	Lower Cost Cerebrovascular Disease	†	1,417	†
AI-64	Lung1	Chronic Obstructive Pulmony Disease	-1,904	-734	†
AI-65	Lung2	Higher Cost Pneumonia	†	365	†
AI-70	Lung7	Asthma	-688	†	†
AI-82	Genital2	Moderate-Cost Genital Disorders	348	364	†
AI-88	Preg5	Normal Delivery	†	395	†
AI-90	Preg7	Lower Cost Pregnancy without Completion	†	472	†
AI-94	Injury2	Hip Fracture/Dislocation	†	245	†
AI-96	Injury4	Drug Poisoning, Internal Injury, Traumatic Amputation, Burn	-1,336	-554	†
AI-98	Complic	Complications of Care	†	-710	†
AI-102	Cong1	Higher Cost Congenital/Pediatric Disorders	†	2,757	†
AI-103	Cong2	Moderate-Cost Congenital Disorder	1,383	911	†

† Indicates a coefficient constrained to zero.

‡ Indicates a variable that is not relevant for a particular model.

[1] The Medicare model combines age/sex categories 0-34 years for each of females and males.

[2] Lines for CCs that are zeroed out in all three prospective models are not listed in this table.

[3] Values are increments or decrements for younger persons in this CC (under 18 for private and Medicaid;under 65 for Medicare) after receiving the basic CC payment coefficient listed in this table.

NOTES:Coefficients joined by a brace are constrained to be the same. CC is condition category. HIV is human immunodeficiency virus. AIDS is acquired immunodeficiency syndrome.

SOURCE:(Ash et al., 1998; Pope et al., 1998.)

this female's prediction: $560 for age and sex, $1,449 for disability entitlement, and $179 x 2 for her two missing year-1 months as a disability-entitled person. The demographic part of this female's expected cost next year is then $2,367; in computing her total expected costs, dollars for the future cost implications of her year-1 medical conditions are added to $2,367.

We include one final example to illustrate how health-status information can interact with age. Consider the payment for a Medicare-entitled male 66 years of age, under treatment for drug dependence (CC 31) but with no other recorded illness. His predicted cost is $2,540, computed as the sum of $1,428 for the demographic part (the same for all males between ages 65 and 69) and a $1,122 contribution for CC 31. Consider, however, a second male, also drug-dependent, but only 30 years of age and entitled to Medicare through disability. Here, there is a $5,392 total prediction, the sum of a $955 demographic part (the same for any male under age 35) and $4,437 for drug dependence. The latter number is computed by adding a $3,315 age-interaction for a Medicare enrollee under age 65 in CC 31 to the $1,122 basic payment for any Medicare enrollee in CC 31. The number $3,315 is in the last column of Table 2 in the row labeled AI-31; drug problems cost, on average, $3,315 more to treat in younger (disabled) Medicare enrollees than in the elderly.

Models

Table 2 shows the complete detail (summary statistics and all coefficients for all variables) for the three DCG/HCC models. The models are distinguished in several ways by: (1) which CCs are excluded, (2) which coefficients are constrained, (3) which demographic variables and demographic-medical interactions are included, and (4) what the model coefficients are. We discuss each of these in turn.

Exclusions, which result in coefficients being set to zero, were made for reasons previously described. The lines for the 33 CCs that are excluded from all three models are omitted from Table 2. Exclusions used in specific models appear in Table 2 as omitted coefficients (†). The private model has no model-specific exclusions, Medicaid has one (CC3 central nervous system infections) and Medicare has 16, most of them related to maternity, neonatal and pediatric conditions that are extremely rare in Medicare's predominantly elderly population.

We indicate coefficients that are constrained to be equal by connecting them with a brace. For example, because only 165 people were classified in the 4 mental retardation categories (CCs 36 through 39) in the private model, these 4 coefficients are constrained to a common value of $2,544. The three models differ in the number of constraints imposed across sets of CC coefficients, with the private model employing the most (five) and the Medicare model, the least (one).

A third difference is in the variables included in addition to the age/sex and CC predictors that characterize prospective DCG/HCC models. The Medicaid model has the most: including eligibility categories, missing-months variables, and 31 coefficients for selected age-medical interactions (labeled as AI-2, AI-15, and so on, where the AI number indicates an associated condition category). The private model includes 9 AI variables and the Medicare model, 6. The AI coefficients shown at the end of Table 2 are the increments (decrements, for negative numbers) to the basic CC payments for a younger person with those particular medical problems.

"Younger" means under age 65 in Medicare and under age 18 in the other two populations.

Finally, the models differ in the values of their coefficients. A striking feature of Table 2 is the similarity between the CC coefficients in Medicare and Medicaid, estimated to within 20-30 percent for about one-half of the categories; also, for any particular CC, the larger coefficient is about equally likely to be found in either model. Thus, even though average costs are much higher in Medicare than in Medicaid, the incremental costs of treating particular conditions do not differ systematically. Although one source of higher expected costs next year in Medicare is larger age/sex coefficients, the more important explanation is greater disease prevalence. For example, 1.3 percent of the Medicare population has metastatic cancer (CC 5) but only 0.2 percent of the Medicaid population; for chronic complications of diabetes (CC 13), the rates are 1.6 percent versus 0.2 percent; for congestive heart failure (CC 48), 9.8 percent versus 1.1 percent; for acute myocardial infarction (CC 50), 4.2 percent versus only 8 in 10,000.

Medicaid and Medicare coefficients, although similar to each other, are almost always much smaller than coefficients in the private model. Typically, they are not even one-half as large as the private model coefficients. For only a handful of CCs, the Medicaid coefficient exceeds the private model coefficient: CC 32—depression and other moderate-cost mental illness; the four mental retardation CCs—36 through 39; CC 69—pleural effusion/pneumothorax; and CC 72—high-cost eye disorders. In only one instance, CC 79—nephritis, is the Medicare coefficient greater than the private one. We have no explanation for this unusual finding. It is encouraging that the private and Medicaid models are similar in terms of the age-interacted coefficients estimated for the pediatric conditions. Of the eight AI parameters present in both models, seven are of the same sign. Most of the pediatric coefficients, which were identified in the development samples, remain highly significant in these full-data re-estimated models.

In considering the plausibility of particular model coefficients, we note that each coefficient for a CC reflects the increment to expected costs that is independently associated with having the condition. An HIV-positive male's prediction, for example, is the sum of the CC 1 coefficient, all coefficients associated with his other medical problems, and any relevant demographic coefficients. If this male has multiple medical problems, his predicted total costs will be much larger than the coefficient for CC 1 alone. This feature is an important strength of the DCG/HCC multiple-condition model structure (in contrast to single-condition models, such as PIP-DCG), because, in fact, people who are HIV-positive differ widely in the range of medical problems they experience and how expensive they are to treat. This model does not simply pay more for HIV but rather establishes appropriately different payment amounts within the community of people living with HIV by recognizing comorbid conditions.

Measuring Model Performance

Because implementing a risk-adjustment model has serious consequences, we must understand how well the models work. The one universally reported, single-number summary performance measure for risk-adjustment payment models is the R^2, or the proportion of variance in costs that the model explains. For reference, demographic payment models in private and Medicare populations have R^2 values of less than 2 percent, and the R^2 for a demo-

graphic/eligibility model in our Medicaid data is 7 percent (Greenwald et al., 1998; Ash et al., 1998; Pope et al., 1998).

Our Medicaid model has the highest explanatory power, with a validated R^2 of more than 20 percent, compared with 8 to 9 percent in the other two populations (refer to the fifth row of Table 2). The better fit in Medicaid is attributable to several factors. For one, the distribution of the outcome variable, cost, has a less extreme upper tail (virtually no million-dollar cases) in Medicaid. Additionally, many people with Medicaid coverage are eligible for medical reasons (such as pregnancy or disability), and expenditures within medically defined groups are more predictable than among populations with many non-users (Kronick et al., 1996). Medicaid eligibility categories also distinguish groups (such as children in poor families) that have predictably lower medical costs because they are basically healthy. Finally, the "months out" variables capture the higher expected costs of recent entrants, an important factor in a system with sporadic entitlement.

All three prospective DCG/HCC models rely upon age and sex in addition to diagnostic information, and costs in these populations do differ substantially by age. For example, in the Medicaid and private samples, annual costs are each about $3,500 more for males age 60 than for females age 5; in Medicare, there is a similar difference in annual costs for males age 90 versus females age 65. However, after accounting for differences in the prevalence of medical problems, the demographic coefficients in our models differentiate less. (The disease-adjusted differences are about $1,400 for males age 60 than for females age 5 among the privately insured, about $500 for a similar demographic difference in Medicaid, and $2,000 for males age 90 versus females age 65 in Medicare.) Although age and sex coefficients remain highly statistically significant in each model, information about the presence of serious, chronic disease groups, such as diabetes and renal insufficiency, is far more useful for predicting costs.

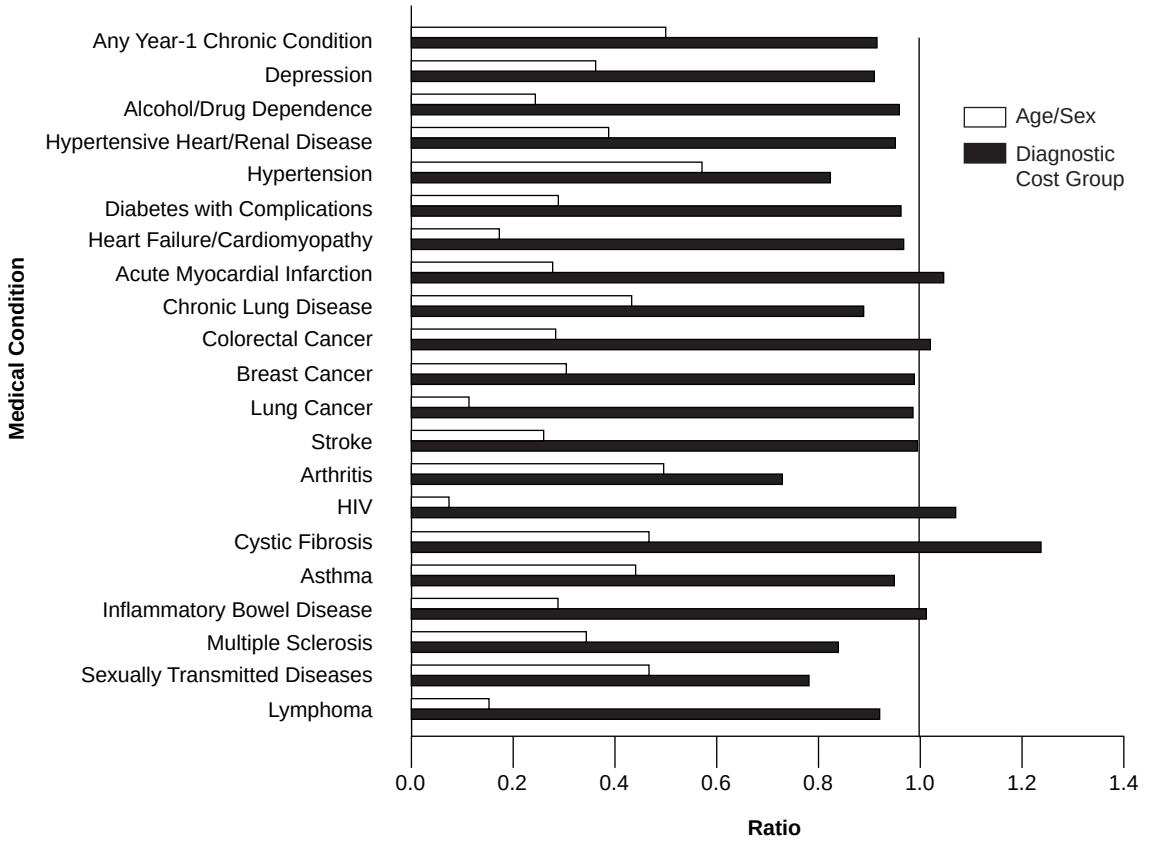
Average Costs for Important Subgroups

Although R^2 values are always reported, other ways of examining model performance may be more useful in assessing the value of a payment model (Ash and Byrne-Logan, 1998). We use some of these to examine the private DCG/HCC model's performance in a fourth, entirely new data set (a State employee health insurance plan). The methodology is to compare predicted versus actual year-2 average costs within significant subgroups. A predictive ratio (PR) for a model applied to a subgroup of people is formed by dividing the model-predicted costs for the group by their actual costs. Thus, for example, when an age/sex model is used to predict costs for a group of sick people, the PR is likely to be much less than 1.00. Alternatively, when people are identified retrospectively as a group whose costs turned out to be very low, PRs for any prospective model will be much larger than 1.00. Prospective models should never predict zero costs, because no one has zero expected future health care costs.

Figure 3 shows PRs for several clinically defined groups of people in the State data, as predicted by the private DCG/HCC model and by an age/sex model. The medical condition groups were defined by an outside panel convened by HCFA, and membership in each group is contingent upon the presence (during year 1) of at least one panel-specified ICD-9-CM code. Although the age/sex prediction is never more than one-half the actual costs for any of these groups (all PRs are 0.50 or less),

Figure 3

Predictive Ratios for the Private Validation Sample, by Presence of Medical Condition



NOTES: *n* = 191,877. Predictive ratio equals average predicted costs divided by average actual costs. Condition groups contained at least 500 persons, except as follows: Lymphoma (260), Sexually Transmitted Diseases (366), Multiple Sclerosis (268), Inflammatory Bowel Disease (463), Cystic Fibrosis (126), HIV (86), Lung Cancer (192), and Colorectal Cancer (335). HIV is human immunodeficiency virus.

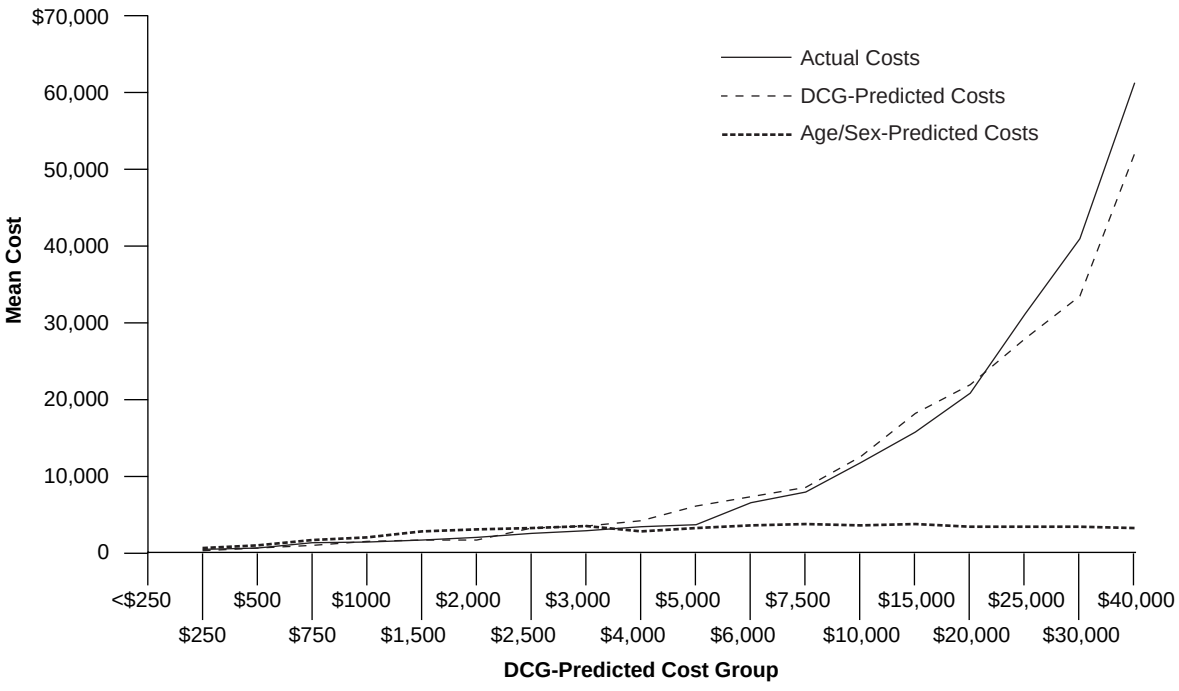
SOURCE: (Ash et al., 1998.)

the DCG prediction is commonly between 0.95 and 1.05. The DCG model underpredicts most seriously in arthritis, where nearly 4,000 people predicted to cost around $4,300 actually cost nearly $5,800 (PR = 0.74). This is because the panel-identified arthritis subgroup includes anyone with any arthritis code regardless of its specificity, but the DCG model identifies only a smaller, sicker subgroup. The model does pay $2,357 for the presence of a well-defined, systemic rheumatoid disease, such as rheumatoid arthritis (ICD-9-CM 714); however, it does not add dollars for vague codes, such as ICD-9-CM 713 (other arthropathy, joint disorders, derangements, joint pain/stiffness). When a model excludes payment for vague codes associated with real costs, it becomes less accurate; in particular, this model underpays for people with low-level or non-specific joint disorders, even though these disorders can result in significant disability.

In another illustration of the predictive value of DCG/HCC models, we divide the private validation sample into 18 groups based on predicted cost levels specified by the DCG/HCC model. The healthiest group, with predicted costs between $250 and $500, contains 21,650 people, or 11.3

Figure 4

Means of Actual and Predicted Costs for the Private Validation Sample, by DCG-Prediction Group



NOTES: DCG is Diagnostic Cost Group. Data for this figure are shown in Table 3

SOURCE: (Ash and Byrne-Logan, 1998.)

percent of the population. (The model does not predict costs of less than $250 for anyone.) The next group, with predicted costs of at least $500 but less than $750, contains another 21.6 percent of people. At the other end of the spectrum, the model predicts costs of $5,000 or more for 5.6 percent of people; among these, just 74 (4/100 of 1 percent) fall into our highest cost prediction group ($40,000 and over). Within each group, we calculate mean actual costs, as well as the means for DCG/HCC-predicted costs and age/sex predicted costs. At the high end, for those with predicted costs over $5,000, the DCG/HCC-predicted amounts track actual costs quite well (meaning that PRs within these groups are not far from 1.00), while the age/sex predicted costs plateau at about $3,300. Figure 4, in which average actual costs, age-sex predicted costs, and DCG-predicted costs are plotted for people in each of these 18 prediction groups, illustrates these points. The data for Figure 4 are in Table 3.

In summary, the private model, which was built on a large national data set, predicts costs well within a new population of State employees. It not only distinguishes groups of high- and low-cost individuals but also even identifies a high-cost tail, with small numbers of very expensive people.

The Medicaid and Medicare DCG/HCC models work similarly well (and demographic-only models, similarly poorly) in analogous comparisons of actual and predicted costs in out-of-sample validation data sets (Ash et al., 1998; Pope et al., 1998).

Table 3

Means of Actual and Predicted Cost for the Private Validation Sample, by DCG-Prediction Group

Predicted Cost Group[1]	Actual Costs	DCG-Predicted Costs	Age/Sex Predicted Costs	Counts
Less than $250	—	—	—	0
250	$510	$417	$570	21,650
500	672	620	855	41,384
750	931	867	1,262	22,649
1,000	1,391	1,347	1,915	28,782
1,500	1,707	1,714	2,335	30,786
2,000	2,295	2,242	3,140	16,100
2,500	2,510	2,779	3,195	5,828
3,000	3,373	3,406	3,332	9,086
4,000	3,993	4,451	2,695	4,944
5,000	4,734	5,485	2,859	3,474
6,000	6,478	6,624	2,951	2,747
7,500	8,025	8,557	3,012	1,980
10,000	11,415	11,939	3,006	1,314
15,000	15,741	17,042	3,217	441
20,000	20,426	22,377	2,853	257
25,000	31,804	27,181	2,929	227
30,000	40,559	34,087	3,010	154
40,000	61,380	52,026	2,926	74

[1] Each predicted cost group contains all people whose DCG-predicted dollar cost are at least this great but less than the next higher number.

NOTES:DCG is Diagnostic Cost Group. *n* = 191,877.

SOURCE:(Ash and Byrne-Logan, 1998.)

CONCLUSION

We have extracted disease profiles of individual patients and groups of patients from the kinds of administrative records that many providers have been supplying to health care payers for years. Until now, few plans have used these data to construct a solid "information backbone" for managing care. The unified, multiple-condition DCG modeling framework characterizes individual health status and the disease burden of populations, as well as predicting future levels of resource need. When comparing physicians' practices, patient profiles can be aggregated to describe the various mixes of medical problems that providers handle, at the same time that the model's predictions can help establish fair (risk-adjusted) resource allocations.

Although the original purpose of these models was to enable health care purchasers, such as HCFA, to identify an efficient capitation price, the models actually provide detailed information on the prevalence of disease. Such information helps explain why some providers and plans use more-than-average resources. The DCG/HCC health profiles and the model predictions can be used together to routinely identify patients who are likely to be very costly and to find the particular medical problems that contribute to this expectation. Such information is invaluable for identifying opportunities for selecting, implementing, and evaluating the effectiveness of disease management programs.

Table A

Condition Category (CC) Numbers, Long Names, Short Names, and Hierarchies

CC Number	CC Long Name	CC Short Name	Dominated CCs
1	HIV/AIDS	Infection1	None
2	Septicemia (Blood Poisoning)/Shock	Infection2	None
3	Central Nervous System Infections	Infection3	None
4	Other Infectious Disease	Infection4	None
5	Metastatic Cancer	Neoplasm1	6, 7, 8, 9, 10, 11, 12
6	High-Cost Cancer	Neoplasm2	7, 8, 9, 10, 11, 12
7	Moderate-Cost Cancer	Neoplasm3	8, 9, 10, 11, 12
8	Lower Cost Cancers/Tumors	Neoplasm4	9, 10, 11, 12
9	Carcinoma in Situ	Neoplasm5	10, 11, 12
10	Uncertain Neoplasm	Neoplasm6	11, 12
11	Skin Cancer, Except Melanoma	Neoplasm7	12
12	Benign Neoplasm	Neoplasm8	None
13	Diabetes with Chronic Complications	Diabetes1	14,15
14	Diabetes with Acute Complications/Non-Proliferative Retinopathy	Diabetes2	15
15	Diabetes with No or Unspecified Complications	Diabetes3	None
16	Protein-Calorie Malnutrition	Metabolic1	None
17	Moderate-Cost Endocrine/Metabolic/Fluid-Electrolyte Disorders	Metabolic2	None
18	Other Endocrine, Metabolic, Nutritional Disorders	Metabolic3	None
19	Liver Disease	Liver	None
20	High-Cost Chronic Gastrointestinal Disorders	GI1	22, 23
21	High-Cost Acute Gastrointestinal Disorders	GI2	22, 23
22	Moderate-Cost Gastrointestinal Disorders	GI3	23
23	Lower Cost Gastrointestinal Disorders	GI4	None
24	Bone/Joint Infections/Necrosis	MSK1	None
25	Rheumatoid Arthritis and Connective Tissue Disease	MSK2	26
26	Other Musculoskeletal and Connective Tissue Disorders	MSK3	None
27	Aplastic and Acquired Hemolytic Anemias	Blood1	28, 29
28	Blood/Immune Disorders	Blood2	29
29	Iron Deficiency and Other/Unspecified Anemias	Blood3	None
30	Dementia	Dementia	None
31	Drug/Alcohol Dependence/Psychoses	Mental1	32, 33, 34, 35
32	Psychosis and Other Higher Cost Mental Disorders	Mental2	33, 34, 35
33	Depression and Other Moderate-Cost Mental Disorders	Mental3	34, 35
34	Anxiety Disorders	Mental4	35
35	Lower Cost Mental Disorders/Substance Misuse	Mental5	None
36	Profound Mental Retardation	MR1	37, 38, 39
37	Severe Mental Retardation	MR2	38, 39
38	Moderate Mental Retardation	MR3	39
39	Mild/Unspecified Mental Retardation	MR4	None
40	Quadriplegia	Neuro1	41, 42, 43, 44
41	Paraplegia	Neuro2	42, 43, 44
42	Higher Cost Neurological Disorders	Neuro3	43, 44
43	Moderate-Cost Neurological Disorders	Neuro4	44
44	Lower Cost Neurological Disorders	Neuro5	None
45	Respirator Dependence/Tracheostomy Status	Arrest1	46, 47
46	Respiratory Arrest	Arrest2	47
47	Cardio-Respiratory Failure and Shock	Arrest3	None
48	Congestive Heart Failure	Hrt_CHF	55, 56, 57
49	Heart Arrhythmia	Hrt_ARR	55, 56, 57
50	Acute Myocardial Infarction	Hrt_AMI	51, 52, 55, 56, 57
51	Other Acute Ischemic Heart Disease	Hrt_CAD1	52, 55, 56, 57
52	Chronic Ischemic Heart Disease	Hrt_CAD2	55, 56, 57
53	Valvular and Rheumatic Heart Disease	Hrt_VHD	55, 56, 57
54	Hypertensive Heart Disease	Hrt_HTN	55, 56, 57
55	Other Heart Diagnoses	Hrt_Misc	56
56	Heart Rhythm and Conduction Disorders	Hrt_Rhythm	None
57	Hypertension (High Blood Pressure)	HTN	None
58	Higher Cost Cerebrovascular Disease	Stroke1	59
59	Lower Cost Cerebrovascular Disease	Stroke2	None
60	High-Cost Vascular Disease	Vascular1	62, 63
61	Thromboembolic Vascular Disease	Vascular2	62, 63
62	Atherosclerosis/Unspecified	Vascular3	None
63	Other Circulatory Disease	Vascular4	None

See footnotes at end of table.

Table A—Continued

Condition Category (CC) Numbers, Long Names, Short Names, and Hierarchies

CC Number	CC Long Name	CC Short Name	Dominated CCs
64	Chronic Obstructive Pulmonary Disease	Lung1	70, 71
65	Higher Cost Pneumonia	Lung2	66, 67, 69, 71
66	Moderate-Cost Pneumonia	Lung3	67, 69, 71
67	Lower Cost Pneumonia	Lung4	71
68	Pulmonary Fibrosis and Other Chronic Lung Disorders	Lung5	70, 71
69	Pleural Effusion/Pneumothorax	Lung6	71
70	Asthma	Lung7	71
71	Other Lung Disease	Lung8	None
72	Higher Cost Eye Disorders	Eye1	73
73	Lower Cost Eye Disorders	Eye2	None
74	Higher Cost Ear, Nose, and Throat Disorders	ENT1	75
75	Lower Cost Ear, Nose, and Throat Disorders	ENT2	None
76	Dialysis Status	Urinary1	77, 78, 79, 80
77	Kidney Transplant Status	Urinary2	78, 79, 80
78	Renal Failure	Urinary3	79, 80
79	Nephritis	Urinary4	80
80	Other Urinary System Disorders	Urinary5	None
81	Female Infertility	Genital1	82, 83
82	Moderate-Cost Genital Disorders	Genital2	83
83	Low-Cost Genital Disorders	Genital3	None
84	Ectopic Pregnancy	Preg1	85, 89, 90
85	Miscarriage/Abortion	Preg2	89, 90
86	Completed Pregnancy with Major Complications	Preg3	87, 88, 89, 90
87	Completed Pregnancy with Complications	Preg4	88, 89, 90
88	Completed Pregnancy Without Complications (Normal Delivery)	Preg5	89, 90
89	Uncompleted Pregnancy with Complications	Preg6	90
90	Uncompleted Pregnancy with No or Minor Complications	Preg7	None
91	Chronic Ulcer of Skin	Skin1	92
92	Other Dermatological Disorders	Skin2	None
93	Vertebral Fractures and Spinal Cord Injuries	Injury1	97
94	Hip Fracture/Dislocation	Injury2	97
95	Head Injuries	Injury3	97
96	Drug Poisonings, Internal Injuries, Traumatic Amputations, Burns	Injury4	97
97	Other Injuries and Poisonings	Injury5	None
98	Complications of Care	Complic	None
99	Major Symptoms	Symptom1	None
100	Minor Symptoms, Signs, Findings	Symptom2	None
101	Very-High-Cost Pediatric Disorders	Peds	20, 22, 23, 28, 29, 43, 44, 68, 70, 71
102	Higher Cost Congenital/Pediatric Disorders	Cong1	104
103	Moderate-Cost Congenital Disorder	Cong2	104
104	Lower Cost Congenital Disorder	Cong3	None
105	Extremely-Low-Birthweight Neonates	Baby1	106, 107, 108, 109
106	Very-Low-Birthweight Neonates	Baby2	107, 108, 109
107	Serious Perinatal Problem Affecting Newborn	Baby3	109
108	Other Perinatal Problems Affecting Newborn	Baby4	109
109	Normal, Single Birth	Baby5	None
110	Heart, Lung, Liver Transplant Status	Transplant1	None
111	Other Organ Transplant/Replacement	Transplant2	None
112	Artificial Opening Status/Attention	Openings	None
113	Elective/Aftercare	Surgery	None
114	Radiation Therapy	Radiation	None
115	Chemotherapy	Chemo	None
116	Rehabilitation	Rehab	None
117	Screening/Observation/Special Exams	Screening	None
118	History of Disease	History	None

NOTES:HIV is human immunodeficiency virus. AIDS is acquired immunodeficiency syndrome.

SOURCE:(Ash et al., 1998.)

REFERENCES

Ash, A., Porell, F., Gruenberg, L., et al.: An Analysis of Alternative AAPCC Models Using Data from the Continuous Medicare History Sample. Final Report to the Health Care Financing Administration. Health Policy Research Consortium. Brandeis/Boston Universities. Boston. September 1986.

Ash A., Porell, F., Gruenberg, L., et al.: Adjusting Medicare Capitation Payments Using Prior Hospitalization. Health Care Financing Review 10(4):17-29, 1989.

Ash, A., Ellis, R.P., Yu, W., et al.: Risk Adjusted Payment Models for the Non-Elderly. Final Report to the Health Care Financing Administration under Contract Number 18-C-90462/1-02. Boston University. Boston. June 1998.

Ash, A., and Byrne-Logan, S.: How Well Do Models Work? Predicting Health Care Costs. Proceedings of the Section on Statistics in Epidemiology of the American Statistical Association. Dallas. 1998.

Brown, R., Clement, D.C., Hill, J.W., et al.: Do Health Maintenance Organizations Work for Medicare? Health Care Financing Review 15(1): 7-23, 1993.

Ellis, R.P., and Ash, A.: Refinements to the Diagnostic Cost Group Model. Inquiry 32(4):1-12, Winter 1995.

Ellis, R. P., Pope, G.C., Iezzoni, L.I., et al.: Diagnostic Cost Group (DCG) and Hierarchical Coexisting Conditions and Procedures (HCCP) Models for Medicare Risk Adjustment. Final Report to the Health Care Financing Administration. Baltimore, MD. April 1996a.

Ellis, R.P., Pope, G.C., Iezzoni, L.I., et al.: Diagnosis-Based Risk Adjustment for Medicare Capitation Payments. Health Care Financing Review 17(3):101-128, Spring 1996b.

Greenwald, L.M., Esposito, A., Ingber, M.J., and Levy, J.M.: Risk Adjustment for the Medicare Program: Lessons Learned from Research and Demonstrations. Inquiry 35(2):193-209, 1998.

Health Care Financing Administration, Office of Strategic Planning: Report to Congress: Proposed Method of Incorporating Health Status Risk Adjusters into Medicare+Choice Payments. Baltimore, MD. March 1999.

Iezzoni L.I., ed.: Risk Adjustment for Measuring Health Care Outcomes. Health Administration Press. Ann Arbor, Michigan. 1997.

Iezzoni, L.I., Ayanian, J.Z., Bates, D.W., and Burstin, H.R.: Paying More Fairly for Medicare Capitated Care. New England Journal of Medicine 339(26): 1933-1938, December 24, 1998.

Ingber, M.J.: The Current State of Risk Adjustment Technology for Capitation. Journal of Ambulatory Care Management 21(4):1-28, 1998.

Kronick, R., Dreyfus, T., Lee, L., and Zhou, Z.: Diagnostic Risk Adjustment for Medicaid: The Disability Payment System. Health Care Financing Review 17(3):7-33, 1996.

Pope, G.C., Ellis, R.P., Liu, C.F., et al.: Revised Diagnostic Cost Group (DCG)/Hierarchical Coexisting Conditions (HCC) Models for Medicare Risk Adjustment. Final Report to the Health Care Financing Administration under Contract Number 500-95-048. Waltham, MA. Health Economics Research, Inc. February 1998.

Pope, G.C., Liu, C.F., Ellis, R.P., et al.: Principal Inpatient Diagnostic Cost Group Models for Medicare Risk Adjustment. Final Report to the Health Care Financing Administration. Waltham, MA. Health Economics Research, Inc. February 1999.

Pope, G.C., Ellis, R.P., Ash, A.S., et al.: Principal Inpatient Diagnostic Cost Group Models for Medicare Risk Adjustment. Health Care Financing Review. 21(3):93-118, Spring 2000.

Public Health Service and Health Care Financing Administration: International Classification of Diseases, 9th Revision, Clinical Modification. U.S. Department of Health and Human Services. U.S. Government Printing Office. Washington, DC. September 1980.

Van de Ven, W.P.M.M., and Ellis, R.P.: Risk Adjustment in Competitive Health Plan Markets. In Culyer, A.J., and Newhouse, J.P., eds.: Handbook in Health Economics. North Holland. 2000.

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