Clinical Risk Groups (CRGs)

A Classification System for Risk-Adjusted Capitation-Based Payment and Health Care Management

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Objective: To develop Clinical Risk Groups (CRGs), a claims-based classification system for risk adjustment that assigns each individual to a single mutually exclusive risk group based on historical clinical and demographic characteristics to predict future use of healthcare resources.

Study Design/Data Sources: We developed CRGs through a highly iterative process of extensive clinical hypothesis generation followed by evaluation and verification with computerized claims-based databases containing inpatient and ambulatory information from 3 sources: a 5% sample of Medicare enrollees for years 1991–1994, a privately insured population enrolled during the same time period, and a Medicaid population with 2 years of data.

Results: We created a system of 269 hierarchically ranked, mutually exclusive base-risk groups (Base CRGs) based on the presence of chronic diseases and combinations of chronic diseases. We subdivided Base CRGs by levels of severity of illness to yield a total of 1075 groups. We evaluated the predictive performance of the full CRG model with R^2 calculations and obtained values of 11.88 for a Medicare validation data set without adjusting predicted payments for persons who died in the prediction year, and 10.88 with a death adjustment. A concurrent analysis, using diagnostic information from the same year as expenditures, yielded an R^2 of 42.75 for 1994.

Conclusion: CRGs performance is comparable to other risk adjustment systems. CRGs have the potential to provide risk adjustment for capitated payment systems and management systems that support care pathways and case management.

Key Words: capitation, risk adjustment, health care costs, patients, classification

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The push for capitation-based payment for health care waned in the 1990s in response to dissatisfied patients, resentful doctors, and a booming economy. However, the more recent combination of a faltering economy and the return of surging health costs may bring renewed emphasis on incentive-based payment systems such as capitation. Capitation-based contracts provide strong incentives for health plans to maximize the efficiency and cost effectiveness of their services. Unfortunately, they also provide even stronger incentives to avoid caring for the sickest and most expensive patients. In any year, most illness, and therefore most spending, is concentrated in a minority of the population. The distribution of Medicare expenditures bears this out: in 1998, the healthiest 76.3% of Medicare beneficiaries consumed only 14.0% of program expenditures, while the sickest 15.3% consumed 75.7% of expenditures.[1] If the most severely ill patients are to be treated adequately, there will need to be mechanisms to provide adequate compensation to those physicians and organizations caring for them.

In response to these concerns, a number of risk-adjustment systems, based on computerized clinical and demographic data, have been created for capitation-based health care plans.[2–7] The purpose of these systems is to predict total yearly health costs, arising from both the inpatient and outpatient settings, for large groups of patients. These systems stratify patients based on their expected resource consumption, usually measured as expected expenditures for a future year. If the risk-adjusted payment more closely matches

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actual expenditures, the health plan will not be penalized for enrolling complicated, expensive patients. Thus, the incentive for risk selection will be reduced.

Existing risk adjustment methods employ 1 of 2 approaches for predicting future year expenditures: one is to generate an additive score based on the regression coefficients of predictor variables[2–4]; a second approach is to categorize patients into mutually exclusive risk groups, or cells.[5,6] We chose the latter strategy to develop Clinical Risk Groups (CRGs),[8,9] a proprietary system of mutually exclusive risk categories for stratifying individuals according to their expected use of healthcare resources in a future year.

Purpose

We designed CRGs to have several important characteristics, including that they (1) be based on readily available computerized claims data so that there was no need for chart abstraction; (2) make explicit recognition of the interaction of 2 or more chronic health conditions and the gradations of severity of illness within the underlying conditions; (3) be transparent, with a complete specification of the CRG logic available to physicians, managers, and other licensees in a definitions manual, permitting them to assess its clinical validity independently; and (4) employ a separate method for computing the risk group payment weight, or expected costs, thus allowing payers the option to compute their own payment weights or to adjust them in response to local conditions. With these characteristics, the system could not only serve as a basis for adjusting capitation payments but also serve as a method to adjust physician compensation within an organization, provide a means of predicting future need for health services for a population, serve as a basis for case management systems, and permit more accurate comparisons of effectiveness of care by provider groups or health care organizations. This paper describes the CRG system's development, its operational logic and some aspects of its predictive performance.

MATERIALS AND METHODS

Data Sources

Development of CRGs used data sets from 3 US sources: Medicare, Medicaid, and a privately insured population. Data for the Medicare component of the development and validation of CRGs used a 5% sample of beneficiaries who were enrolled in both parts A and B of Medicare during the period 1991–1994. The development data set contained individuals who were enrolled continuously throughout 1991–1993, including those who died at any time in 1993. The validation set contained all beneficiaries enrolled for all of 1992 through 1994, including those who died any time in 1994. Enrollees who were permanently institutionalized or joined an HMO during those years were excluded. The data set contained all claims for inpatient care, hospital-based outpatient care, hospice care, skilled nursing facility, physician office, and ancillary services. All data were linkable at the beneficiary and provider level. The analysis database included a total of almost 1.3 million beneficiaries. The dependent variable was actual Medicare payments in 1993 or 1994. In addition to the Medicare data, we used a 4-year privately insured database containing 246,186 individuals and a 2-year Medicaid database containing 242,816 individuals. These data sets also contained information on diagnoses and procedures from inpatient and outpatient hospital settings, as well as demographic data and professional and ancillary claims.

Analysis

The analyses presented in this report are limited to the Medicare data set. We used the first 3 years of Medicare data for the development of CRGs (ie, 1991–1993), using 1991 and 1992 data to develop risk groups, with 1993 expenditures as the dependent variable. Having developed the CRG model, we then evaluated overall performance using data from 1992–1994. First we used data from 1992 to assign risk groups, and then calibrated the model by calculating payment weights for each risk group using 1993 expenditures for 1,285,549 Medicare beneficiaries. Then for validation purposes, we reassigned individuals to risk groups, this time using 1993 data, and, using the payment weights derived from 1992 and 1993 data in the previous step, predicted 1994 expenditures for the 1,286,574 beneficiaries who were enrolled for the entire year or died during the year. For patients who died in either of the prediction years, we prorated predicted expenditures for the number of months the patient was alive. We also examined the ability of CRGs to categorize individuals using a concurrent model by using 1994 data to categorize 1994 spending. We examined predictive performance with the R^2 statistic and calculated predictive ratios by dividing predicted expenditures by actual expenditures for selected subgroups of the population. In calculating R^2, we adjusted predicted payment for persons who died in the prediction year using the adjustment described by Ellis and Ash.[4] First, we inflated payments to yield an annualized cost and then weighted each individual by the fraction of the year they were alive for the R^2 calculation.

CRG Development Process

The core research staff, which included 4 physicians, developed the overall CRG architecture with the premise that the resulting risk classification categories would depend on the nature and extent of an individual's underlying chronic illnesses and any combinations of chronic conditions involving multiple organ systems and would be further refined with an explicit specification of severity of illness within each category. The process began with the assignment of diag-

noses to risk groups based on their expected impact on an individual's future need for medical care, as well as their contribution to the likelihood of debility and death. The major determinant of the risk group assignment therefore was the burden of chronic illness, rather than acute illness. Acute illness may have important effects on current year spending but is much less likely to affect future spending or future health status. Research staff consulted frequently with subspecialists on a variety of disease conditions in determining risk group assignments. After creating an initial set of hypothesized risk groups, the research staff calculated mean expenditures for each risk group, beginning a highly iterative process in which the hypothesized risk groups and their interactions with other chronic and acute conditions were tested, modified, and tested again through multiple cycles. Whenever there was a conflict between statistical results and a plausible clinical rationale, the final decision always favored the clinical rationale.

Overview of CRG Clinical Logic

The resulting CRG logic is exhaustive, encompassing all diagnosis codes generated from inpatient and outpatient care, and assigns each individual to a single risk group. Determining the CRG assignment for an individual involves several steps that are detailed below.

Step 1: Creating a Profile

In the first step, each individual's computerized claims record of all diagnosis codes is used to create a disease profile and history of past medical interventions. CRGs assigns each diagnosis code to 1 of 37 major diagnostic categories (MDCs), which are based either on a single organ system or on a major clinical category such as infectious diseases, diagnoses in newborns, or diagnoses in pregnancy. The MDC list contains a number of additions to the MDCs used by Medicare for hospital reimbursement with diagnosis-related groups (available from the authors on request). Within each MDC, CRGs further assigns each diagnosis code to 1 of 534 base groups of similar codes called episode diagnostic categories, or EDCs; these groups serve as the building blocks of the CRG system. There are 3 types of EDCs: chronic, acute, and manifestations of chronic disease. Chronic disease EDCs are further subdivided into 3 categories (dominant, moderate, and minor chronic), and acute EDCs are subdivided into 2 categories (significant acute and minor acute). The various categories of chronic and acute EDCs are defined in Table 1.

A diagnosis is assigned to a chronic EDC (1) if its duration is lifelong, even if controlled by medication (eg, diabetes, hypertension); or (2) if it has a prolonged duration, even if a cure is possible under certain circumstances (eg, malignancy). The 164 chronic EDCs serve as the major determinants of the ultimate risk-group assignment. A diagnosis is assigned to an acute EDC if the duration of the disease is short and the disease could naturally resolve (eg, viral gastroenteritis) or a treatment exists that cures the disease (eg, pneumonia, fractured leg). Signs, symptoms, and findings (eg, chest pain) are also considered acute. Manifestation of chronic disease EDCs represents acute (diabetic ketoacidosis) or chronic (diabetic peripheral neuropathy) consequences of an underlying chronic illness. There are 264 acute EDCs and 106 manifestation of chronic disease EDCs. Both of these types of EDCs can be used to modify severity levels within risk groups that are created by chronic disease EDCs.

Within each MDC, the chronic EDCs are ranked hierarchically based on their relative contribution to an individual's debility, risk of death, and need for medical care. Chronic diseases that result in progressive deterioration of an individual's health are ranked highest in the chronic disease hierarchy. (Acute EDCs and manifestation of chronic disease EDCs are not ranked hierarchically.) Table 2 contains an example of the hierarchical ranking for chronic EDCs in the cardiac diseases MDC.

The CRG system also uses procedure codes to assign patients to chronic EDCs in selected instances. For example, the procedure code for liver transplant assigns an individual to a chronic EDC for liver transplantation status. An individual with a procedure code for total parenteral nutrition will be assigned to a very high-cost EDC of the same name.

In addition, the CRG system uses dates of service in a number of instances, most importantly to identify recent acute events thought to indicate a more severe form of a chronic illness. For example, an individual with cancer who had undergone chemotherapy in the most recent 6 months would likely require more care and generate higher costs in the coming year than an individual without recent active treatment.

Step 2: Identifying the Primary Chronic Disease (PCD) in Each MDC, and Establishing Severity Levels Within Each PCD

For individuals with at least 1 chronic disease diagnosis, the second step identifies the most significant chronic disease within each MDC, called the PCD, and then assigns it a severity of illness level. In this step, if there are chronic diseases from more than 1 EDC within an MDC, the disease from the most highly ranked EDC is selected as the PCD. For an individual with angina pectoris who also had atrial fibrillation, 2 conditions from separate EDCs in the cardiac disease MDC, angina pectoris would be selected as the PCD, since it belongs to the higher-ranking EDC. Although only 1 PCD per MDC is allowed, an individual may have a PCD for 2 or more different MDCs. For example, a person with heart failure, emphysema, diabetes, and arthritis would have 4 PCDs, from EDCs in each of the MDCs for cardiac diseases, pulmonary diseases, diabetes, and musculoskeletal diseases.

TABLE 1. Categories of EDCs

Category	Number of EDCs	Examples
Dominant chronic disease		
Serious chronic conditions that often result in the progressive deterioration of an individual's health and often lead to death or significantly contribute to debility and future need for medical care	59	Congestive heart failure, cirrhosis,diabetes
Moderate chronic disease		
Serious chronic conditions that usually do not result in the progressive deterioration of an individual's health but can significantly contribute to an individual's debility, death, and future need for medical care	65	Hypertension, asthma, epilepsy
Minor chronic disease		
Chronic conditions that can usually be managed effectively throughout an individual's life, with typically few complications and limited effect on debility, death, and future need for medical care; they may, however, be serious in their advanced stages or may be a precursor to more serious diseases	40	Hyperlipidemia, hearing loss, migraine
Manifestation of chronic disease		
A chronic manifestation or acute exacerbation of an underlying chronic disease	106	Diabetic ketoacidosis, sickle cell crisis, diabetic neuropathy
Significant acute disease		
Significant acute diseases are expected to have only a transient impact on resource use and patient functional status, although they may precede or connote an increased risk for the development of chronic disease or can potentially result in significant sequelae; an acute illness is only classified as a significant acute illness if it occurred in the most recent 6-month period	156	Pneumonia, chest pain, head injury with coma
Minor acute disease		
Minor acute diseases may be mild or more serious but are self-limiting, are not a precursor to chronic disease, do not place the individual at risk for the development of chronic disease, and do not have significant long-term consequences.	108	Appendicitis, pharyngitis, fractured arm

Once a PCD has been identified, it is stratified into severity levels that reflect the extent and progression of the disease. The assignment of the severity level is specific to each EDC and takes into account factors associated with more severe or advanced forms of the disease. These factors include comorbid chronic and acute diseases from another EDC in the same organ system (atrial fibrillation in an individual with congestive heart failure); a more severe form of the disease as identified through a chronic manifestation of the disease (neuropathy in a diabetic); age if it relates to a specific disease progression (age over 65 for history of hip fracture); chronic diseases from other body systems when they are caused by the underlying disease (nephritis in an individual with systemic lupus); acute diseases from other organ systems when they are specifically related or are a reliable indicator of general health status (acute infections, neurologic and gastrointestinal diseases). Once a diagnosis has been selected as a severity of illness modifier for a PCD, it is not allowed to affect the severity level of a PCD from any other MDCs. For example, in an individual with both chronic pulmonary disease and congestive heart failure, the presence of a pleural effusion, which can increase the severity level of both conditions, would only be used once to modify congestive heart failure, the condition from the higher-ranking EDC.

Selected therapies or procedures can be used to increase the severity level of a PCD if they are indicative of advanced disease, such as amputation in patients with diabetes or peripheral vascular disease. The number of severity levels within a PCD ranges from 4 levels for dominant and moderate chronic illnesses to 2 levels for minor chronic illnesses and nondominant and nonmetastatic malignancies.

Step 3: Assigning Core Health Status Ranks and Combining PCDs Into Base CRGs

Once the PCD and severity level have been determined for each MDC for which there is a chronic disease present, the individual is assigned to 1 of 9 core health status ranks, arranged hierarchically from "Catastrophic" to "Healthy" according to an individual's debility and expected need for medical care. The core health status ranks are summarized in Table 3. Within core health status ranks, individuals are assigned to a "Base CRG," which is then stratified into

TABLE 2. Hierarchical ranking for chronic EDCs in the cardiac disease MDC*

Rank	EDC	Type
1	Major congenital heart disease	Dominant chronic
2	Moderate congenital heart disease	Dominant chronic
3	Congestive heart failure	Dominant chronic
4	Major chronic cardiac diseases	Dominant chronic
5	Cardiac valve disease	Dominant chronic
6	History of acute myocardial infarction	Dominant chronic
7	Angina and ischemic heart disease	Dominant chronic
8	Atrial fibrillation	Moderate chronic
9	Cardiac dysrhythmia and conduction disorders	Moderate chronic
10	History of coronary artery bypass grafting	Moderate chronic
11	History of coronary angioplasty	Moderate chronic
12	Cardiac device status	Moderate chronic
13	Coronary atherosclerosis	Moderate chronic
14	Hypertension	Moderate chronic
15	Ventricular and atrial septal defects	Minor chronic
16	Minor chronic cardiac diseases	Minor chronic

*The cardiac disease MDC also contains 8 chronic manifestation EDCs and 22 acute EDCs, which are not ranked hierarchically.

severity levels. The severity level assigned within the Base CRG becomes the individual's final CRG.

Individuals without a chronic disease diagnosis, who therefore have no PCDs, are assigned to Core Health Status 1 ("Healthy") if they have not had a significant acute diagnosis (defined in Table 1) in the past 6 months. Those with a significant acute diagnosis in the past 6 months are assigned to status 2. The remaining 7 Core Health Status ranks are for individuals who have at least 1 chronic disease. Those with only a single minor chronic PCD are assigned to status 3, and those with 2 or more minor chronic PCDs are assigned to status 4. Persons with a single moderate or dominant chronic PCD are assigned to status 5. Those with dominant or moderate chronic PCDs from 2 or more MDCs are assigned to a single base CRG in either status 6 or 7. For example, an individual with diabetes and congestive heart failure would be assigned to status 6 (Significant Chronic Disease in Multiple Organ Systems), while someone with diabetes, congestive heart failure, and chronic lung disease would be assigned to status 7 (Dominant Chronic Disease in Three or More Organ Systems). Status 8 contains individuals with dominant or metastatic malignancies, and status 9 contains those requiring long-term resource-intensive medical care such as ventilator-dependent or dialysis-dependent persons.

In status 6 and 7, which contain individuals with multiple chronic conditions, the base CRG may combine explicitly identified PCDs (eg, Diabetes and Congestive Heart Failure), or may contain combinations of dominant and moderate chronic conditions that are not explicitly identified (eg, Diabetes and 1 Other Dominant Chronic Disease). Only the most common chronic conditions are explicitly identified, since creating combinations of all possible PCDs would create very large numbers of CRGs, many with small numbers of patients.

Individuals with a single PCD, who are assigned to Base CRGs in Core Health Status ranks 3 and 5, have the same severity level they were assigned in the previous step. For those with multiple PCDs, the assignment of severity level is more complicated. We created severity level assignments for Base CRGs in Core Health Status 6, formed by the combination of 2 or more PCDs by means of an empirical iterative process using "conjunctive consolidation"[10] to yield 6 or fewer severity levels. An example of this process appears in Table 4 for the base CRG that combines the PCDs for congestive heart failure (CHF) and diabetes. Cross-tabulating the severity levels for these PCDs yields 16 cells, with expenditures increasing monotonically as the severity level combinations increase from left to right and from top to bottom. We consolidated these cells into 6 severity levels based on the data and clinical judgment. The most desirable pattern of consolidating 16 cells into 6 levels of severity varies somewhat among the pairs of PCDs that constitute this status, depending on the relative significance of the 2 diseases in the base CRG.

For base CRGs at core health status 7, with 3 or more Dominant Chronic PCDs, use of a conjunctive consolidation process would have been prohibitively complicated, since the combination of 3 PCDs each with 4 severity levels would yield 64 cells. We therefore created an empirical categoriza-

TABLE 3. CRG core health status ranks

Core health status	Examples
1. Healthy	
No chronic diseases and no significant acute illness in the past 6 months	
2. History of significant acute disease	
No PCD but at least 1 significant acute disease occurred in most recent 6 months	Pneumonia, pancreatitis, pelvic inflammatory disease
3. Single minor chronic disease	
Only 1 minor PCD	Migraine, chronic stomach ulcer
4. Minor chronic disease in multiple organ systems	
2 Or more minor PCDs	Chronic bronchitis and benign prostatic hypertrophy, migraine and hyperlipidemia
5. Single dominant or moderate chronic disease	
Only 1 dominant or moderate chronic PCD	CHF, diabetes, cerebrovascular disease, asthma
6. Significant chronic disease in multiple organ systems	
Identified by the presence of 2 or more PCDs of which at least 1 is a dominant or moderate chronic disease (but no more than 2 dominant chronic PCDs); minor PCDs that are at severity level 2 or higher are considered significant chronic diseases, but PCDs that are a severity level 1 minor chronic disease are not used in this status level	CHF and cerebrovascular diseases Diabetes and 1 other dominant chronic disease
7. Dominant chronic disease in 3 or more organ systems	
Dominant chronic PCDs in 3 or more organ systems	CHF and diabetes and COPD CHF and 2 or more other dominant chronic diseases
8. Dominant and metastatic malignancies	
Include primary malignancies that dominate the medical care required, or a nondominant malignancy that is metastatic (nondominant or nonmetastatic malignancies are treated as moderate chronic diseases)	Lung cancer, stomach cancer, metastatic prostate cancer
9. Catastrophic conditions	
Includes long-term dependency on a medical technology (eg, dialysis, respirator, total parenteral nutrition) and life-defining chronic diseases or conditions that dominate the medical care required	Dependence on dialysis, ventilator dependence, persistent vegetative state

COPD, chronic obstructive pulmonary disease.

tion of 6 severity levels for all status 7 CRGs (details of this process can be obtained from the authors).

The final structure of CRGs consists of 9 CRG Core Health Status ranks, which are subdivided into a total of 269 Base CRGs. As shown in Table 5, the Base CRGs are subdivided into severity levels, resulting in 1075 total CRGs.

Calculating Payment Rates

CRG payment weights are established based on the average future cost per enrollee in a health plan. For example, with the average expenditure set to 1.00, a relative payment weight of 2.00 for a CRG means that enrollees in that CRG on average will be twice as costly in the subsequent year as the average enrollee. Using CRGs for prospective risk adjustment requires at least 1 year of historical claims data to assign individuals to risk groups but requires 2 years of claims data if the payer also wishes to compute its own CRG payment weights—1 year to assign CRGs and the second to determine the payment weights. Alternatively, a payer who chose to use payment weights derived from a different population would only need 1 year of claims data. For example, a health plan that serves senior citizens could use the relative payment weights derived from the entire Medicare population. Although expenditures may vary across regions due to differences in labor and capital costs, the relative resource use among risk groups should remain constant absent major breakthroughs in care or changes in practice patterns.

Example of the Effect of Coexisting Diseases

Table 6 shows an example of the effect of the full CRG model for 7 Base CRGs that result from the interaction of 3 chronic illnesses, diabetes mellitus (DM), CHF, and chronic obstructive pulmonary disease. In this analysis, we calculated actual 1994 Medicare payments for CRGs assigned using 1993 data. There are 3 status 5 Base CRGs for individuals with only 1 of these chronic diseases, 3 status 6 Base CRGs that result from pairing these 3 PCDs, and the single status 7 Base CRG that combines all 3. As expected, payment in-

TABLE 4. Consolidating 16 combinations of severity levels into 6 overall severity levels*

	Severity Level	Diabetes			
		1	**2**	**3**	**4**
	1	6.3	7.4	9.6	9.7
		1	**2**	**3**	**3**
CHF	2	8.9	9.6	10.4	11.2
		2	**3**	**3**	**4**
	3	9.6	10.9	11.7	14.2
		3	**3**	**4**	**5**
	4	12.1	13.0	13.4	16.4
		4	**4**	**5**	**6**

*Top numbers in each cell represent yearly cost (in thousands of dollars), and bottom numbers in bold indicate the consolidated severity level.

creased with increasing numbers of coexisting diseases and with increasing severity of illness within each Base CRG. The differences in actual payments illustrate the substantial impact that specific combinations of multiple chronic diseases can have on future healthcare spending.

Predictive Performance

The most common statistical measure used to compare risk adjustment systems is reduction of variance (R^2), which measures the proportion of variation in the dependent variable that is explained by a risk adjustment system. In the analyses that follow, we expressed R^2 as the percentage of variation in future expenditures explained by CRGs. Thus, an R^2 of 10.5 would mean that 10.5% of the variation in future expenditures is explained by the risk-adjustment system.

For purposes of validating the CRG model, we reserved the Medicare payment data from 1994 and the diagnostic information from 1993 and did not use them in the CRG development process. In Table 7, we present prospective and retrospective, or concurrent, R^2 analyses of Medicare payments for 1994, with CRG assignment based on 1 or 2 years of claims data. The table also presents R^2 values calculated with and without the adjustment for individuals who died in the prediction year for the prospective analyses. For the prospective analyses, we used data from 1993 to assign CRGs and used the 1993 payment weights (generated by the CRG assignment for 1992 data) to predict 1994 expenditures. The R^2 for CRGs assigned using 1 year of data to predict 1994 expenditures was 10.88; using 2 years of data to assign CRGs actually reduced R^2 somewhat. The retrospective analysis shows the results of using CRGs to categorize current-year spending and do not include a death adjustment. In this analysis, the data used to assign CRGs come from the year for which the expenditures are being predicted. As expected, the R^2 is much higher.

We also examined how closely CRG payment predictions approximated actual payments using predictive ratios, calculated by dividing predicted payments by actual payments, for several risk subgroups. Table 8 displays these results for 1994 Core Health Status ranks, predicted expenditure quintiles, and for several categories of age and gender. In the quintile analysis, CRGs tended to underestimate payments in the lower quintiles and to slightly overestimate payments for individuals in the top quintile. In the age and

TABLE 5. Number of CRGs by Core Health Status rank*

CRG core health status	Number of Base CRGs	Severity levels per Base CRG	Total CRGs
1. Healthy	1	None	1
2. Significant acute	6	1	6
3. Single minor chronic	40	2	80
4. Multiple minor chronic	1	4	4
5. Single dominant or moderate chronic	106	4 or 2†	394
6. Multiple significant chronic	61	6, 4, or 2*	328
7. Three or more dominant chronic	21	6	126
8. Dominant or metastatic malignancy	22	4	88
9. Catastrophic	11	4	44
Total	269		1075

*Includes the following combinations:
1. 2 dominant chronic PCDs, 1 dominant chronic PCD plus 1 or more moderate chronic PCDs, or 2 or more moderate chronic PCDs, all of which have 6 severity levels
2. 1 dominant or moderate chronic PCD plus 1 or more minor chronic PCD of severity level 2 or greater (4 severity levels)
3. a nondominant, nonmetastatic malignancy PCD plus a minor chronic PCD of severity level 2 or greater (2 severity levels)
†Dominant or moderate chronic PCDs have 4 severity levels, but nondominant, nonmetastatic malignancy PCDs have 2 severity levels.

TABLE 6. Medicare 1994 actual payments ($) sorted by Base CRG and severity level for individuals with DM, CHF, and COPD and for combinations of these diseases*

Base CRG	Core Health Status	Severity Level 1	2	3	4	5	6
DM	5	3352	4367	5295	7682		
COPD	5	4193	5017	6774	7843		
CHF	5	4905	6435	6749	8926		
COPD & DM	6	5676	7695	7827	8910	11,164	14,404
COPD & CHF	6	4983	7405	9176	10,440	12,303	14,181
DM & CHF	6	6598	9302	9724	11,105	14,203	16,004
DM & COPD & CHF	7	8895	12,681	14,772	15,966	19,807	21,444

*Each severity level within a Base CRG constitutes a final CRG.
DM, diabetes mellitus; COPD, chronic obstructive pulmonary disease.

gender analysis, CRGs overestimated payments for younger age groups and underestimated payments for older groups. This latter pattern suggests that payment estimation could be improved with adjustments for age and gender, both of which can be readily incorporated into the CRG method.

DISCUSSION

The algorithm for assigning CRGs is complex, since it creates groups for combinations of chronic illnesses and makes provision for differences in severity of illness within diagnostic groups. CRGs also use procedure codes and dates of service in several instances to assign or modify risk groups. In an unpublished analysis on Medicare data, we determined that removing procedure codes and dates of service and using only diagnosis codes reduced R^2 by approximately 16%.

Although R^2 values for the prospective CRG model appear low, they represent a substantial improvement over a previous model used for determining payment for Medicare HMOs. That model included independent variables of age, gender, disability status, and Medicaid eligibility but no diagnosis code data and yielded R^2 values of less than 2%.[11] Because most spending in a given year results from circumstances that are difficult to predict, such as major acute illnesses or acute deterioration of underlying chronic conditions, substantially higher R^2 values for any predictive model are unlikely. In fact, the maximum R^2 for a prospective risk-adjustment system has been estimated at 20–25%.[12] The best previously reported R^2 for a prospective system for a similar group of Medicare enrollees was 9%.[3] The model used for capitation-based payment for Medicare beginning in 2000, which uses only demographic data and the most important inpatient diagnosis in the preceding year, yielded an R^2 of 6.2%.[2] The Federal Center for Medicare and Medicaid Services has subsequently proposed to upgrade its capitation payment methodology for Medicare + Choice plans by using a limited number of diagnoses from outpatient encounters in addition to inpatient data beginning in 2004.[13]

The analysis of Medicare data presented in this report did not include adjustments for age, gender, disability, and Medicaid or "dual eligibility" status, which have been shown to increase predictive performance when used in evaluations of other systems. A previous analysis with CRGs showed that adjustments for age and gender increased R^2 by less than 1%

TABLE 7. R^2 for CRGs prediction of 1994 expenditures for the Medicare population*

	Years of data used to assign CRGs	R^2
With death adjustment		
Prospective analysis, 2 years of data	1992, 1993	10.66
Prospective analysis, 1 year of data	1993	10.88
Without death adjustment		
Prospective analysis	1993	11.88
Retrospective/concurrent analysis, 1 year of data	1994	42.75

*Payment weights used for the prospective analyses are based on 1993 spending for CRGs assigned using data from 1992 only.

TABLE 8. Predictive ratios: number of Medicare beneficiaries, average expenditure, predicted expenditure, and predictive ratio by Core health status rank, predicted expenditure quintile, and age and gender categories for 1994*

	Number of enrollees	Average payment ($) in 1994	Predicted payment for 1994	Predictive ratio
Core health status rank				
1. Healthy	341,521	2062	1984	0.962
2. History of significant acute disease	57,678	2819	2831	1.004
3. Single minor chronic disease	128,988	2643	2595	0.982
4. Minor chronic disease in multiple organ systems	34,586	3399	3348	0.985
5. Single dominant or moderate chronic disease	390,212	3913	3957	1.011
6. Significant chronic disease in multiple organ systems	269,245	7479	7510	1.004
7. Dominant chronic disease in 3 or more organ systems	31,886	13,708	13,639	0.995
8. Dominant or metastatic malignancies	23,927	11,284	11,108	0.984
9. Catastrophic conditions	8351	30,968	32,677	1.055
Quintile				
First	256,805	2042	1962	0.961
Second	256,805	2338	2262	0.968
Third	259,895	3182	3134	0.985
Fourth	258,640	4742	4701	0.992
Fifth	255,869	10,427	10,650	1.021
Age and gender groups				
Female				
Age <65	43,583	5248	5670	1.080
Age 65–69	90,151	3372	4019	1.192
Age 70–74	202,379	3487	4062	1.165
Age 75–79	165,790	4312	4475	1.038
Age 80–84	126,973	5003	4871	0.974
Age 85+	129,307	5694	5416	0.951
Male				
Age <65	65,939	4634	5234	1.129
Age 65–69	75,222	3811	4214	1.106
Age 70–74	152,145	4075	4328	1.062
Age 75–79	112,481	4953	4812	0.972
Age 80–84	72,335	5773	5305	0.919
Age 85+	50,269	6473	5760	0.890
Total all enrollees	1,286,57	4537	4537	1.00

*CRG assignments for individuals were based on 1993 data. CRG payment weights were calculated using 1993 payments for CRGs that were assigned using 1992 data.

for the Medicare database.[8] CRG predictive performance would likely improve somewhat with the addition of adjustments for disability and Medicaid eligibility.

Some previously described risk-adjustment methods that use computerized data from both inpatient and outpatient settings, such as Diagnostic Cost Groups and its refinement, Hierarchical Coexisting Conditions,[2–4,7] generate cost predictions by assigning regression-based scores to individuals based on their membership in up to several diagnostic categories and some procedure categories, as well as certain demographic characteristics (eg, age, gender, disability status). An individual's predicted expenditure is determined by the sum of those scores. CRGs, along with another previously described method, Ambulatory Cost Groups,[5,6] differ in that they assign individuals to single mutually exclusive risk groups based on *International Classification of Diseases, Ninth Revision, Clinical Modification* codes and demographic information. For CRGs, the combination of chronic conditions, as well as the severity levels of those conditions, is the primary determinant of risk-group assignment. The predicted expenditure is based on the historical spending for the individual's risk group. CRGs are able to take account not only of

the effect of specific interactions among chronic conditions, but also the interaction of higher and lower levels of severity among those conditions.

CRGs are limited by the issues common to systems based on administrative data, including inaccuracies and unreliability of the coding process, variation in coding practices, and lack of clinical precision inherent to diagnosis codes.[14,15] Clinical information with potentially powerful predictive value, such as laboratory measures of renal function, estimations of ventricular function in patients with heart disease, and performance measures of activities of daily living for individuals with dementia and cerebrovascular disease, is unavailable in claims-based data. These deficiencies are compensated by the widespread applicability and considerably lower cost of claims-based risk adjustment systems.

The analyses presented in this report are limited to Medicare data. CRGs performed comparably with Medicaid and private insurance data sets, as presented in the CRG final report.[8] CRGs also performed well in a separate analysis of children with chronic conditions in a population containing a mix of Medicaid and non-Medicaid enrollees.[9]

CONCLUSIONS

Clinical Risk Groups are capable of categorizing patients according to their risk of debility and expected future resource use, using only computerized diagnosis codes and a limited number of procedure codes. CRGs were developed in an intensively iterative process that relied on the creation of mutually exclusive risk groups. Payment weight calculations are based on simple within-group averages rather than on additive scores derived from regression coefficients. CRGs incorporate the effect of multiple coexisting and interacting chronic diseases and allow for adjustment for severity of illness; both of these features are necessary for evaluating the relatively small numbers of patients who consume a disproportionate share of resources. Although the CRGs algorithm is complex, the end result is a system of conceptually straightforward, clinically meaningful categories. The CRG system has predictive capability comparable to other prospective risk-adjustment systems. CRGs are therefore potentially useful not only as a basis for capitation-based payment systems but also as a tool for managing healthcare information.

REFERENCES

1. US Department of Health and Human Services, Health Care Financing Administration. Medicare and Medicaid statistical supplement 2000. *Health Health Care Financ Rev.* 2001;22:32.
2. Pope GC, Ellis RP, Ash AS, et al. Principal inpatient diagnostic cost group model for Medicare risk adjustment. *Health Care Financ Rev.* 2000;21:93–118.
3. Ellis RP, Pope GC, Iezzoni L, et al. Diagnosis-based risk adjustment for Medicare capitation payments. *Health Care Financ Rev.* 1996;17:101–128.
4. Ellis RP, Ash A. Refinements to the diagnostic cost group (DCG) model. *Inquiry.* 1995–1996;32:418–429.
5. Fowles JB, Weiner JP, Knutson D, et al. Taking health status into account when setting capitation rates: a comparison of risk-adjustment methods. *JAMA.* 1996;276:1316–1321.
6. Weiner JP, Dobson A, Maxwell SL, et al. Risk-adjusted Medicare capitation rates using ambulatory and inpatient diagnoses. *Health Care Financ Rev.* 1996;17:77–99.
7. Ash AS, Ellis RP, Pope GC, et al. Using diagnoses to describe populations and predict costs. *Health Care Financ Rev.* 2000;21:7–28.
8. Averill, RS, Goldfield N, Eisenhandler J, et al. *Development and Evaluation of Clinical Risk Groups (CRGs).* Wallingford, CT: 3M Health Information Systems; 1999.
9. Neff JM, Sharp VL, Muldoon J, et al. Identifying and classifying children with chronic conditions using administrative data with the clinical risk group classification system. *Ambul Pediatr.* 2002;2:71–79.
10. Feinstein AR. *Multivariable Analysis.* New Haven: Yale University Press; 1996:512–528.
11. Ash A, Porell F, Gruenberg L, et al. Adjusting Medicare capitation payments using prior hospitalization data. *Health Care Financ Rev.* 1989;10:17–29.
12. Newhouse JP, Manning WG, Keeler EB, et al. Adjusting capitation rates using objective health measures and prior utilization. *Health Care Financ Rev.* 1989;10:41–54.
13. Boulanger J. Letter to Medicare + Choice Organizations and Participants in Covered Demonstration Projects. Center for Medicare & Medicaid Services; March 29, 2002.
14. Iezzoni L. Data sources and implications: administrative databases. In: Iezzoni L, ed. *Risk Adjustment for Measuring Healthcare Outcomes.* 2nd ed. Chicago: Health Administration Press; 1997:169–242.
15. Hughes JS, Ash AS. Reliability of risk adjustment methods. In: Iezzoni LI, ed. *Risk Adjustment for Measuring Healthcare Outcomes.* 2nd ed. Chicago: Health Administration Press; 1997:365–390.