Explanatory Ability of the ACG System Regarding the Utilization and Expenditure of the National Health Insurance Population in Taiwan—A 5-year Analysis

Wui-Chiang Lee[1,2]*, Tong-Po Huang[1,2]

[1]*Department of Medical Affairs and Planning, Taipei Veterans General Hospital, and*
[2]*National Yang-Ming University School of Medicine, Taipei, Taiwan, R.O.C.*

Background: The adjusted clinical group (ACG) is a diagnosis-based case-mix adjustment system, which has been widely evaluated in several countries other than Taiwan. The aim of this study was to assess the performance of the ACG system on the National Health Insurance (NHI) population in Taiwan.

Methods: We conducted longitudinal data analysis using the claims data of 1% of randomly sampled NHI enrollees from 2000 to 2004. The ACG software was used to assign each individual to 1 ACG category based on age, gender and aggregating diagnoses in each year from 2000 to 2004, respectively. The ACG distribution patterns and their relationships to expenditure were examined. Explanatory ability as measured by adjusted R^2 of the ACG system for same-year and next-year ambulatory and inpatient expenditure were examined by multivariate regression models for each year.

Results: The quality of NHI claim data was satisfactory in that 98.1% of the population could be assigned to ACG categories. The population's ACG patterns were substantially consistent but unequally distributed across the 5 years. Eighty percent of NHI expenditure were spent on people assigned to 21 ACGs. The explanatory abilities of individual's ACG and its components with respect to the variance of same-year and next-year 99% truncated visits, ambulatory expenditure, inpatient expenditure, and total NHI expenditure were quite consistent across years and were superior to age and gender. The explanatory performance was better for ambulatory than inpatient expenditure and was comparable to the statistics demonstrated in other countries.

Conclusion: The ACG system worked well for Taiwanese ambulatory visits and expenditure across years. Health care authorities can introduce the ACG system to quantify the population's morbidity burdens and medical needs. [*J Chin Med Assoc* 2008;71(4):191–199]

Key Words: adjusted clinical groups, adjusted diagnostic groups, case-mix adjustment, morbidity, National Health Insurance

Introduction

Taiwan launched its National Health Insurance (NHI) program in 1995. Although the NHI has decreased people's financial barriers to accessing health care, escalating medical expenditure have exceeded revenue from premiums since 1998.[1] In light of increasing medical needs and financial shortage, reform has been initiated with the goal of establishing an equitable, efficient and high-quality health care system.[2]

The introduction of valid risk adjustment mechanisms is widely believed to be crucial to maintaining equity while pursuing efficiency. In the 1990s, the Johns Hopkins *adjusted clinical groups* (ACGs) case-mix adjustment system was developed using medical diagnosis codes from administrative data to directly

*Correspondence to: Dr Wui-Chiang Lee, Department of Medical Affairs and Planning, Taipei Veterans General Hospital, 201, Section 2, Shih-Pai Road, Taipei 112, Taiwan, R.O.C.
E-mail: wclee@vghtpe.gov.tw • Received: August 23, 2007 • Accepted: March 6, 2008

quantify the overall requirement for resources based on diagnoses for individuals.[3,4] The ACG system takes into account a person's mix of diseases that stretches across visits, facilities and providers over a defined time period, typically 1 year. Each ACG category is used as an estimate for a group of patients with the same constellation of morbidities, thereby indicating the need for care of each category of patient. The validity and reliability of the ACG system has been widely evaluated in the United States,[3–5] Canada,[6,7] and several European countries.[8–13] Previous studies conducted in these countries found that the ACG system had satisfactory explanatory ability regarding the variance of same-year and next-year ambulatory and inpatient services.[4,7,14] Therefore, the ACG system has been applied to capitation rate adjustment,[15,16] performance profiling,[17–20] prediction of resource utilization,[21,22] and health services research.[23–25] Recently, the explanatory ability of the ACG system has been further enhanced by adding sophisticated statistical components such as ACG-predictive modeling (ACG-PM).[26]

Theoretically, Taiwan's NHI should be the ideal setting for adoption of the ACG system because all required input data are readily available. However, there have only been 2 studies conducted for the Taiwanese population, both covering very limited time frames.[27,28] Although these studies revealed that the ACG system worked well for veterans and sampled NHI populations in a given year, it remains unclear as to whether or not the explanatory ability is robust across years. Therefore, the aim of this study was to assess the performance of the ACG system on the NHI population from a longitudinal perspective.

Methods

Setting and data sources

We conducted longitudinal data analysis using the claims data of 1% of randomly sampled NHI enrollees in Taiwan from 2000 to 2004. This data set was issued by the National Health Research Institutes, Taiwan, for research purposes. The database provides comprehensive individual-level age, gender, ICD-9-CM codes, and expenditure for each ambulatory and hospital claim. Encrypted claims data of the sampled cohort population who were enrolled in the NHI program in 2000 were retrieved and followed-up for 5 years until December 31, 2004. An individual-specific analytic file was constructed by retrieving and aggregating each individual's age, gender, all diagnosis codes, ambulatory visits, ambulatory expenditure, inpatient expenditure, and total medical expenditure reimbursed by the NHI over each 12-month period from 2000 to 2004, respectively.

ADG, ACG and PRI assignment

The ACG software (version 7.0)[26] was used without modification of the developers' grouping algorithm. This algorithm enables each diagnosis to be classified into 1 of 32 clinically cogent morbidity clusters, named *aggregated diagnosis groups* (ADGs), according to the likely persistence of the condition, grade of severity, etiology, diagnostic certainty, and need for specialty care. The individual's total number of unique ADGs, together with his/her age and gender, are used to group each case into mutually exclusive morbidity clusters, named ACGs. Each individual was assigned 1 or more ADGs but only 1 of the total 89 ACGs in a given year.

ACG-PM is a process that applies existing patients' risk factor variables to prospectively identify persons with high medical needs who are at risk for above-average future medical service utilization. The risk factor variables used in ACG-PM include: age groups, sex, ACGs, hospital dominant markers (50% or higher probability of future admission), dichotomous medically frail markers, and specific disease markers indicating either common high-cost chronic illnesses or uncommon conditions that have high impact on both cost and health. The ACG-PM software produces 2 types of predictive risk factors: first, the probability score representing the likelihood that a member will be among those persons using extraordinary health care resources in the coming year and, second, a *predictive resource index* (PRI) that expresses anticipated resource use as a relative value.[26] The PRI is applied to calculate expected resource use in the next year. We calculated the PRI for each individual based on his/her prior-year number of visits (PRI-v), ambulatory expenditure (PRI-a), inpatient expenditure (PRI-i), and total NHI expenditure (PRI-t), respectively.

Data analysis

All data were analyzed using STATA version 8 (Stata Corp., College Park, TX, USA); p values were 2-sided, with the significance level set at 0.05. The application of the data sets was reviewed and approved by the Institutional Review Board of the National Health Research Institutes. All the personal identifiers were encrypted and modified to protect patient privacy and confidentiality before the data were released.

ACGs and utilization distributions

Distributions of the cohort population according to their assigned ACGs in each year were plotted and compared using Pearson's correlation method from

2000 to 2004. The reasons for ungrouped diagnoses were examined. We compared the mean number of visits, and ambulatory, inpatient and total (ambulatory plus inpatient) expenditure per person per year between 2000 and 2004. Furthermore, we calculated the total expenditure for each ACG category using 2004 data to examine the relationship between the population's expenditure and their ACG distributions.

Concurrent analysis

The explanatory abilities of ACGs and their ADG components regarding same-year variance of visits, and ambulatory, inpatient and total expenditure were examined. In accordance with the methodologies used in previous validation studies,[3,11] a series of multivariate linear regression models were constructed to compare the abilities of alternative case-mix models to explain the variance of 99%-truncated (i.e. excluding the top 1% of extremely-high users) visits and expenditure of each year. Four regression models were used: Model 1a consisted of each individual's age and gender; Model 2a consisted of each individual's age, gender and total number of unique ADGs in a given year; Model 3a consisted of age, gender and 32 ADG dummy variables; and Model 4a consisted of ACG dummy variables. The explanatory ability of each model regarding the variance in visits and expenditure was measured by adjusted R^2.

Prospective analysis

The explanatory abilities of each individual's ADGs, ACGs and PRI regarding his/her next-year variance of 99%-truncated utilization and expenditure were examined by 6 regression models. Model 1b consisted of each individual's age and gender; Model 2b consisted of each individual's age, gender and total number of unique ADGs in a given year; Model 3b consisted of age, gender and 32 ADG dummy variables; Model 4b consisted of ACG dummy variables; and Model 5b consisted of different kinds of PRI (PRI-v, PRI-a, PRI-i, PRI-t) as continuous independent variables. We used prior-year visits, and ambulatory, inpatient and total expenditure as independent variables in Model 6b to examine the explanatory ability of prior-year utilization.

Results

ACG assignment

Claims data retrieved from a total of 184,275 sampled cases were used; mean age in 2000 was 33 years. An average of 98.1% of the total population could be assigned to 1 of the 89 ACG categories. The grouping rate was highest in 2003 (99.2%) and lowest in 2002 (97.8%). The reasons for unmatched grouping were miscoding of age (45%), gender of newborns (21%), incomplete information on immigrants and laborers from other countries (14%), and ICD-9 codes (8%).

Table 1 lists the mean number of unique ADGs per person per year from 2000 to 2004. Some people were missed, possibly due to moving or studying overseas, withdrawal from insurance, or death. People were assigned to an average of 4.62 unique ADGs in 2000, and this figure increased continuously to 5.21 in 2004. The distribution patterns among ACGs were highly consistent across the 5 years (Figure 1). Pearson's correlation coefficient ranged from 0.975 to 0.999 between each year. In 2004, about 9.0% of the total population was assigned to ACG 0300, followed by ACG 4910, ACG 2400, ACG 3400, and ACG 1800. People were unequally distributed among ACGs. The most assigned 5 ACGs included 34.1% of the total population and the top 25 most assigned ACGs included 80.2% of the total population. The details of ACG assignment in each year are listed in the Appendix.

Table 1. Average utilization and expenditure per person per year for the sampled National Health Insurance (NHI) population in Taiwan from 2000 to 2004*

	Year				
	2000	2001	2002	2003	2004
NHI population (*n*)	184,275	182,791	178,613	178,698	178,258
Utilization per person per year					
Unique ADGs (*n*)	4.62 ± 0.02	4.68 ± 0.01	4.83 ± 0.01	5.00 ± 0.01	5.21 ± 0.01
Visits (*n*)	14.3 ± 0.01	14.3 ± 0.03	13.8 ± 0.05	14.2 ± 0.03	14.9 ± 0.04
Ambulatory expenditure	9,996 ± 68	10,486 ± 73	10,798 ± 71	11,655 ± 148	12,662 ± 98
Inpatient expenditure	4,547 ± 91	4,890 ± 104	5,097 ± 102	5,356 ± 112	6,009 ± 123
Total NHI expenditure	14,815 ± 122	15,379 ± 135	15,764 ± 130	16,771 ± 148	18,672 ± 171

**Data presented as mean ± standard error of the mean. ADGs = aggregated diagnosis groups.*

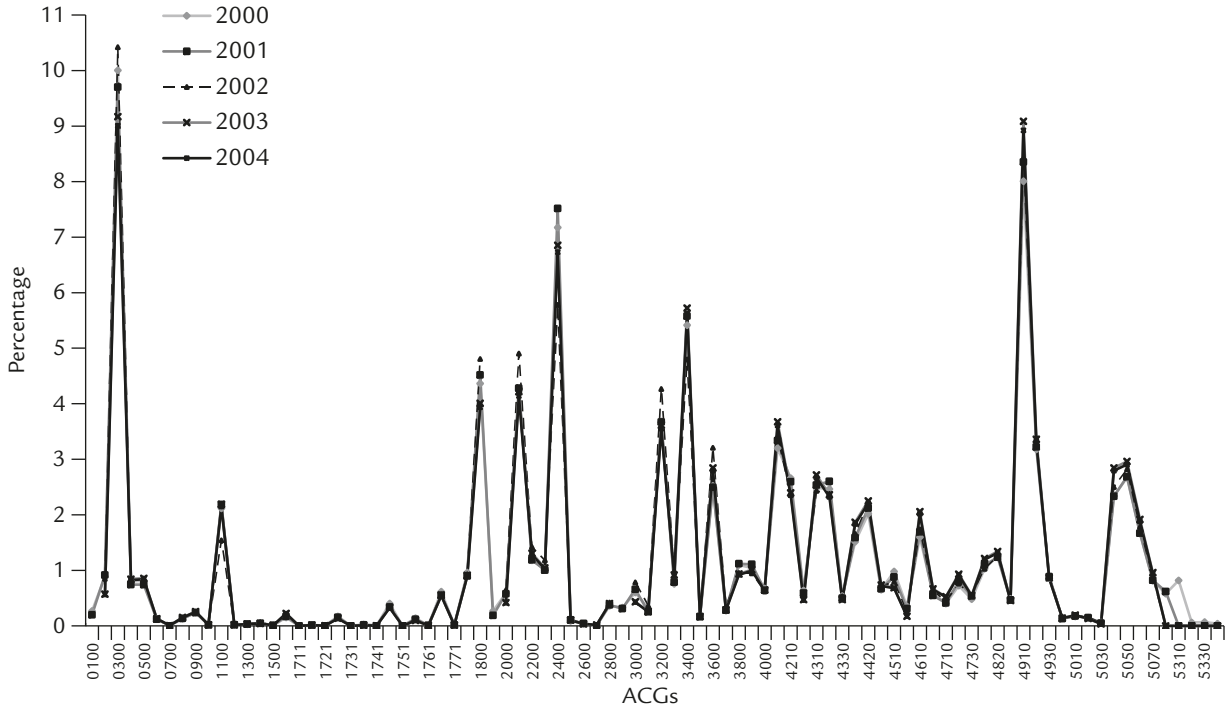

Figure 1. National Health Insurance population showed consistent distributions among the adjusted clinical group (ACG) categories (except ACG 5200) from 2000 to 2004.

Correlations between ACGs and expenditure

Ambulatory and inpatient expenditure increased from 2000 to 2004 (Table 1). Comparing 2004 expenditure to that in 2000, there was a 26.7% increase in ambulatory expenditure and 32.1% increase in inpatient expenditure. Moreover, expenditure was disproportionately concentrated in a few ACGs. In 2004, only 8.9% of the total population was assigned to ACG 4910, but these people spent 13.0% of the total expenditure. About 24.4% of the total population were grouped into 6 ACGs (5050, 4920, 5060, 5040, 5070, 4100), but they spent 50.4% of the total expenditure. Furthermore, 80% of total NHI expenditure was used by people assigned to 21 out of 89 (23.6%) ACGs.

Concurrent analyses

The explanatory abilities of each regression model to the variance of same-year visits and expenditure are listed in Tables 2 and 3. For ambulatory visits, Model 1a explained only 3.8–6.6% of the variance. The power increased to 57.3% in 2004 after adding the number of unique ADGs (Model 2a), and to 58.4% after adding the 32 ADG dummy variables (Model 3a). ACGs alone (Model 4a) explained 43.0–52.8% of the variance, a little lower than the ADG-based models. There was a trend of increasing explanatory ability regarding same-year visits from 2000 to 2004.

For ambulatory expenditure, Model 1a explained 11.5–13.7% of the variance, and the explanatory ability increased to 41.4–46.0% in Model 2a and to 46.0–52.4% in Model 3a. Model 4a explained 41.5–46.6% of the variance in same-year ambulatory expenditure. The explanatory ability of all models was quite consistent across years. For inpatient expenditure, Model 1a explained only 1.0–1.3% of the variance, and the explanatory power increased to 2.1–2.8% for Model 2a, and to 8.1–9.9% for Model 3a. Model 4a explained 7.8–9.8% of the variance. The explanatory ability to inpatient expenditure was lower than that to ambulatory visits and expenditure.

For total expenditure, Model 1a explained only 3.2–3.9% of the variance, and the explanatory power increased to 9.0–10.8% for Model 2a and to 16.2–19.2% for Model 3a. Model 4a explained 15.8–18.2% of the variance in same-year total NHI expenditure.

Prospective analyses

The explanatory abilities of each model regarding the variance of next-year visits and expenditure are listed in Tables 2 and 3. For ambulatory visits, Model 1b explained 4.6–6.7% of the next-year variance. Adjusted R^2 increased to 29.5–33.5% for Model 2b, 31.6–35.4% for Model 3b, and 28.6–32.3% for Model

Table 2. Explanatory ability of regression models (in adjusted R^2 value) regarding the variance of same-year (concurrent) and next-year (prospective) ambulatory visits and ambulatory expenditure of each year from 2000 to 2004

	Ambulatory visits					Ambulatory expenditure				
	2000	2001	2002	2003	2004	2000	2001	2002	2003	2004
Concurrent analysis										
Model 1a: age, gender	0.038	0.045	0.057	0.061	0.066	0.115	0.118	0.137	0.132	0.128
Model 2a: age, gender, no. of ADGs	0.441	0.530	0.546	0.554	0.573	0.411	0.460	0.460	0.458	0.459
Model 3a: age, gender, ADG dummies	0.457	0.544	0.559	0.566	0.584	0.460	0.521	0.522	0.524	0.524
Model 4a: ACGs alone	0.430	0.505	0.516	0.513	0.528	0.415	0.466	0.459	0.458	0.456
Prospective analysis										
Model 1b: age, gender		0.046	0.054	0.063	0.067		0.079	0.081	0.089	0.090
Model 2b: age, gender, no. of ADGs		0.309	0.309	0.295	0.335		0.183	0.177	0.180	0.181
Model 3b: age, gender, ADG dummies		0.333	0.334	0.316	0.354		0.221	0.215	0.213	0.214
Model 4b: ACGs alone		0.323	0.313	0.286	0.319		0.189	0.188	0.193	0.194
Model 5b: PRI by ACG-PM		0.187	0.193	0.179	0.197		0.233	0.236	0.234	0.234
Model 6b: prior-year utilization		0.538	0.555	0.533	0.566		0.298	0.308	0.309	0.301

ADGs = aggregated diagnosis groups; ACGs = adjusted clinical groups; PRI = predictive resource index; ACG-PM = ACG-predictive modeling.

Table 3. Explanatory ability of regression models (in adjusted R^2 value) regarding the variance of same-year (concurrent) and next-year (prospective) inpatient expenditure and total medical expenditure of each year from 2000 to 2004

	Inpatient expenditure					Total medical expenditure				
	2000	2001	2002	2003	2004	2000	2001	2002	2003	2004
Concurrent analysis										
Model 1a: age, gender	0.010	0.011	0.012	0.013	0.013	0.033	0.032	0.035	0.039	0.038
Model 2a: age, gender, no. of ADGs	0.021	0.023	0.023	0.025	0.028	0.098	0.090	0.092	0.108	0.106
Model 3a: age, gender, ADG dummies	0.081	0.087	0.088	0.095	0.099	0.171	0.162	0.170	0.192	0.190
Model 4a: ACGs alone	0.078	0.089	0.090	0.094	0.098	0.158	0.158	0.163	0.182	0.179
Prospective analysis										
Model 1b: age, gender		0.010	0.014	0.013	0.014		0.030	0.042	0.040	0.034
Model 2b: age, gender, no. of ADGs		0.014	0.019	0.018	0.018		0.055	0.068	0.064	0.058
Model 3b: age, gender, ADG dummies		0.034	0.033	0.035	0.034		0.085	0.090	0.088	0.080
Model 4b: ACGs alone		0.024	0.024	0.027	0.026		0.066	0.070	0.069	0.065
Model 5b: PRI by ACG-PM		0.039	0.048	0.045	0.043		0.104	0.101	0.093	0.083
Model 6b: prior-year utilization		0.110	0.093	0.088	0.086		0.093	0.094	0.088	0.082

ADGs = aggregated diagnosis groups; ACGs = adjusted clinical groups; PRI = predictive resource index; ACG-PM = ACG-predictive modeling.

4b. PRI-v (Model 5b) explained 17.9–19.7% of the variance, and prior-year number of visits (Model 6b) explained 53.3–56.6% of the next-year variance. For ambulatory expenditure, Model 1b explained 7.9–9.0% of the next-year variance. This figure increased to 17.7–18.3% for Model 2b, 21.3–22.1% for Model 3b, 18.8–19.4% for Model 4b, and to as high as 23.3–23.4% for Model 5b (PRI-a). Prior-year ambulatory expenditure explained 29.8–30.9% of the next-year variance in ambulatory expenditure.

For inpatient expenditure, Model 1b explained only 1.0–1.4% of the next-year variance. The explanatory

ability increased to 1.4–1.9% for Model 2b, 3.3–3.5% for Model 3b, and 2.4–2.7% for Model 4b. PRI-i explained 3.9–4.8% of the next-year variance. Prior-year inpatient expenditure explained 8.6–11.0% of the next-year variance. For total expenditure, Model 1b explained only 3.0–4.2% of the next-year variance. It increased to 5.5–6.8% for Model 2b, 8.0–9.0% for Model 3b, and 6.5–7.0% for Model 4b. PRI-t explained 8.3–10.4% of the next-year variance, which was compatible with the explanatory ability by prior-year total medical expenditure (8.2–9.4%).

Discussion

The ACG system worked well across years

Our study shows that the majority of the NHI population can be appropriately assigned to ACG categories. There are several advantages to adopting the ACG system in Taiwan. First, the administrative barriers are low for providers because they have used the ICD-9-CM coding system and uploaded the data to the Bureau of NHI (BNHI) on a regular basis since 2000. As a single-payer system, the BNHI possesses all required inputs on a national basis for operating the ACG system. Second, although the accuracy of diagnosis coding has not been verified, the coding quality is acceptable for the purpose of running the ACG system given that the percentage of non-grouped diagnosis codes was considerably lower than the 5% recommended by the developers.[26] Third, the reliability of the system is also recognized given the finding that the distributions of ACGs were highly consistent for the cohort population across 5 years.

Satisfactory explanatory ability

This study found that the explanatory ability of the ACG system was quite stable across years and compatible with previous studies conducted in other countries.[3,7,11,12] Regarding the variance of same-year ambulatory expenditure, the explanatory power of the ADG-based model to the Taiwanese population was quite similar to that of people in the United States (42–49%)[3] and Canada (Manitoba, 50.1%).[7] The explanatory power of the ACG-based model was nearly the same between Taiwan (41–46%) and Manitoba, Canada,[7] and was a little higher than that in the United States (34–39%)[3] and Sweden (38%).[11] The explanatory ability for next-year ambulatory expenditure of the NHI population (20–22%) was also similar to that of the United States (18–21%)[3] and Canada (21–26%).[7] This international comparability is noteworthy given the differences in the health care delivery and reimbursement systems and people's behaviors between Taiwan and those countries.

However, some limitations to the generalizability of our results should be mentioned. First, the accuracy of these diagnoses has not been systematically estimated and, thus, the validity of the ACG system is still potentially threatened by the degree of coding accuracy. However, compared to other encounter-based systems, the ACG system is relatively robust because the exact diagnostic code is not of prime importance to the system. The crucial point is that the code belongs to the right cluster of diagnoses in terms of ADGs, resulting in the expression of each patient's health status as a combination of different types of morbidity.[10] Second, clinicians might assign provisional diagnoses in the first few encounters. The inclusion of provisional diagnoses may cause an increase in the ability of case-mix to explain ambulatory expenditure. Third, the explanatory ability of the ACG system regarding ambulatory visits and expenditure was significantly better than inpatient and total expenditure. The ACG system was originally designed for ambulatory use, and inpatient expenditure might be too diverse to fit the limited number of ACG categories. Fourth, because claims data are highly protected, they could not be linked to other databases, and so we examined only how well ACGs explained what levels of services were actually provided rather than those that were really needed.

Policy implications

Recent studies have found that an individual's health care needs and costs are correlated with his/her total morbidity burdens instead of the particular disease he/she may have.[29,30] Therefore, accurate methods are needed for estimating an individual's and a population's morbidity burdens, otherwise, the payment scheme would be misaligned with health care needs.[7] Traditionally, age and gender data were widely used for risk adjustment because they are easy to get and hard to manipulate. This study, as well as other studies conducted in Sweden (11.4%),[11] Canada (Manitoba, 8.1%),[7] and the United States (3–6%),[3] highlights the limitations of age and gender in risk adjustment. On the other hand, prior utilization and expenditure had the highest predictive ability, but their disadvantage is to encourage utilization rather than efficiency. For many countries and insurers, population morbidity burdens have replaced or added to the original demographic data and prior utilization in the equation of resource allocation. For instance, the *Risk Adjustment Reform Act* of Germany mandates the move from a demographics-based (age, sex, disability status) to

a morbidity-based case-mix adjustment mechanism to allocate resources among sicknesses.[31]

We suggest that the ACG system can be applied to measure morbidity burdens on a population basis in Taiwan. The Department of Health or the BNHI can use the ACG system to obtain information on people's morbidity burdens rather than just on disease patterns. The same method can also be applied to certain groups of people, such as servicemen, veterans, farmers, and aborigines, for the purpose of comparing their morbidity patterns to those of the general population. Furthermore, the annual total budget of the NHI program is capped for cost containment. Budget allocation is mainly based on residents' mean age, gender, standardized mortality rate, and prior-year expenditure of a given NHI administrative branch. Residents' morbidity burdens have not yet been considered as predictors of next-year expenditure. More studies are needed to assess the feasibility of adding ACG-based morbidity burden variables in budget allocation equations, especially for ambulatory care budget.

In conclusion, our study found substantial feasibility and reliability in the ACG system to measure morbidity burdens and to explain the variance of ambulatory visits and expenditure of the Taiwanese population. Although the quality of diagnosis coding needs to be continuously improved, appropriate use of the ACG system can aid health care authorities in their efforts toward an equitable and efficient NHI.

Acknowledgments

This study was supported by the Veterans General Hospitals University System of the Taiwan Joint Research Program and Tsou's Foundation (VGHUST93-P1-07, VGHUST94-P1-06). The authors wish to thank them for their generous support. The authors also thank the Johns Hopkins ACG Group for technical support.

References

1. Cheng TM. Taiwan's new national health insurance program: genesis and experience so far. *Health Aff (Millwood)* 2003; 22:61–76.
2. Task Force on Reforming the National Health Insurance System. *Final Report to Department of Health.* Taipei, Taiwan: Department of Health, Executive Yuan, Republic of China, 2004. [In Chinese]
3. Starfield B, Weiner J, Mumford L, Steinwachs D. Ambulatory care groups: a categorization of diagnoses for research and management. *Health Serv Res* 1991;26:53–74.
4. Weiner JP, Starfield BH, Steinwachs DM, Mumford LM. Development and application of a population-oriented measure of ambulatory care case-mix. *Med Care* 1991;29:452–72.
5. Rosen AK, Loveland S, Anderson JJ, Rothendler JA, Hankin CS, Rakovski CC, Moskowitz MA, et al. Evaluating diagnosis-based case-mix measures: how well do they apply to the VA population? *Med Care* 2001;39:692–704.
6. Reid RJ, Roos NP, MacWilliam L, Frohlich N, Black C. Assessing population health care need using a claims-based ACG morbidity measure: a validation analysis in the Province of Manitoba. *Health Serv Res* 2002;37:1345–64.
7. Reid RJ, MacWilliam L, Verhulst L, Roos N, Atkinson M. Performance of the ACG case-mix system in two Canadian provinces. *Med Care* 2001;39:86–99.
8. Juncosa S, Bolibar B. A patient classification system for our primary care: the ambulatory care groups (ACGs). *Gac Sanit* 1997;11:83–94.
9. Carlsson L, Borjesson U, Edgren L. Patient based 'burden-of-illness' in Swedish primary health care: applying the Johns Hopkins ACG case-mix system in a retrospective study of electronic patient records. *Int J Health Plann Manage* 2002;17: 269–82.
10. Carlsson L, Strender LE, Fridh G, Nilsson G. Types of morbidity and categories of patients in a Swedish county: applying the Johns Hopkins Adjusted Clinical Groups System to encounter data in primary health care. *Scand J Prim Health Care* 2004;22:174–9.
11. Engstrom SG, Carlsson L, Ostgren CJ, Nilsson GH, Borgquist LA. The importance of comorbidity in analysing patient costs in Swedish primary care. *BMC Public Health* 2006;6:36.
12. Orueta JF, Lopez-De-Munain J, Baez K, Aiarzaguena JM, Aranguren JI, Pedrero E. Application of the ambulatory care groups in the primary care of a European national health care system: does it work? *Med Care* 1999;37:238–48.
13. Orueta JF, Urraca J, Berraondo I, Darpon J, Aurrekoetxea JJ. Adjusted Clinical Groups (ACGs) explain the utilization of primary care in Spain based on information registered in the medical records: a cross-sectional study. *Health Policy* 2006;76:38–48.
14. Weiner JP, Dobson A, Maxwell SL, Coleman K, Starfield B, Anderson GF. Risk-adjusted Medicare capitation rates using ambulatory and inpatient diagnoses. *Health Care Financ Rev* 1996;17:77–99.
15. Fowles JB, Weiner JP, Knutson D, Fowler E, Tucker AM, Ireland M. Taking health status into account when setting capitation rates: a comparison of risk-adjustment methods. *JAMA* 1996;276:1316–21.
16. Weiner JP, Tucker AM, Collins AM, Fakhraei H, Lieberman R, Abrams C, Trapnell GR, et al. The development of a risk-adjusted capitation payment system: the Maryland Medicaid model. *J Ambul Care Manage* 1998;21:29–52.
17. Tucker AM, Weiner JP, Honigfeld S, Parton RA. Profiling primary care physician resource use: examining the application of case mix adjustment. *J Ambul Care Manage* 1996;19:60–80.
18. Greene BR, Barlow J, Newman C. Ambulatory care groups and the profiling of primary care physician resource use: examining the application of case-mix adjustments. *J Ambul Care Manage* 1996;19:86–9.
19. Powe NR, Weiner JP, Starfield B, Stuart M, Baker A, Steinwachs DM. System-wide provider performance in a Medicaid program: profiling the care of patients with chronic illnesses. *Med Care* 1996;34:798–810.
20. Weiner JP, Starfield BH, Powe NR, Stuart ME, Steinwachs DM. Ambulatory care practice variation within a Medicaid program. *Health Serv Res* 1996;30:751–70.
21. Meenan RT, Goodman MJ, Fishman PA, Hornbrook MC, O'Keeffe-Rosetti MC, Bachman DJ. Using risk-adjustment models to identify high-cost risks. *Med Care* 2003;41:1301–12.

22. Wahls TL, Barnett MJ, Rosenthal GE. Predicting resource utilization in a Veterans Health Administration primary care population: comparison of methods based on diagnoses and medications. *Med Care* 2004;42:123–8.
23. Briggs LW, Rohrer JE, Ludke RL, Hilsenrath PE, Phillips KT. Geographic variation in primary care visits in Iowa. *Health Serv Res* 1995;30:657–71.
24. Forrest CB, Reid RJ. Prevalence of health problems and primary care physicians' specialty referral decisions. *J Fam Pract* 2001;50:427–32.
25. Starfield B, Powe NR, Weiner JR, Stuart M, Steinwachs D, Scholle SH, Gerstenberger A. Costs vs quality in different types of primary care settings. *JAMA* 1994;272:1903–8.
26. *The Johns Hopkins ACG Case-Mix System, Version 7.0. Release Notes. May, 2005.* Baltimore: Johns Hopkins Bloomberg School of Public Health, 2005.
27. Chang RE, Lin W, Hsieh CJ, Chiang TL. Healthcare utilization patterns and risk adjustment under Taiwan's National Health Insurance system. *J Formos Med Assoc* 2002;101:52–9.
28. Lee WC, Yang JS, Hung SH, Huang TP. Applying the Adjusted Clinical Groups system to quantify veterans' morbidity burdens and adjusted their medical utilizations. *JHM* 2007; 8:64–87. [In Chinese]
29. Starfield B, Lemke KW, Herbert R, Pavlovich WD, Anderson G. Comorbidity and the use of primary care and specialist care in the elderly. *Ann Fam Med* 2005;3:215–22.
30. Wolff JL, Starfield B, Anderson G. Prevalence, expenditures, and complications of multiple chronic conditions in the elderly. *Arch Intern Med* 2002;162:2269–76.
31. Busse R. Disease management programs in Germany's statutory health insurance system. *Health Aff (Millwood)* 2004;23: 56–67.

Appendix. Distributions of the cohort population among adjusted clinical groups (ACGs) in Taiwan from 2000 to 2004

ACG description	Frequency (%)				
	2000	2001	2002	2003	2004
0100 Acute minor, age 1	0.270	0.200	–	–	–
0200 Acute minor, age 2–5	0.888	0.918	0.846	0.574	0.565
0300 Acute minor, age ≥ 6	10.004	9.701	10.420	9.170	9.005
0400 Acute: major	0.801	0.742	0.853	0.840	0.825
0500 Likely to recur, without allergies	0.813	0.743	0.857	0.855	0.840
0600 Likely to recur, with allergies	0.131	0.120	0.128	0.131	0.129
0700 Asthma	0.006	0.007	0.007	0.008	0.008
0800 Chronic medical, unstable	0.128	0.133	0.132	0.151	0.148
0900 Chronic medical, stable	0.241	0.238	0.258	0.258	0.253
1000 Chronic specialty	0.023	0.017	0.023	0.021	0.021
1100 Ophthalmologic/dental	2.116	2.186	1.540	2.190	2.151
1200 Chronic specialty, unstable	0.014	0.021	0.016	0.019	0.019
1300 Psychosocial, without psychosocial unstable	0.028	0.032	0.036	0.033	0.032
1400 Psychosocial, with unstable, without stable	0.053	0.047	0.066	0.044	0.044
1500 Psychosocial, with unstable and stable	0.012	0.011	0.009	0.013	0.012
1600 Preventive/administrative	0.152	0.169	0.188	0.224	0.220
1711 Pregnancy, 0–1 ADG, delivered	0.001	0.000	0.001	0.001	0.001
1712 Pregnancy, 0–1 ADG, not delivered	0.016	0.014	0.011	0.016	0.015
1721 Pregnancy, 2–3 ADGs, no major ADG, delivered	0.004	0.003	0.002	0.003	0.003
1722 Pregnancy, 2–3 ADGs, no major ADG, not delivered	0.169	0.154	0.139	0.137	0.134
1731 Pregnancy, 2–3 ADGs, ≥ 1 major ADG, delivered	0.000	0.001	0.001	0.002	0.002
1732 Pregnancy, 2–3 ADGs, ≥ 1 major ADG, not delivered	0.024	0.018	0.019	0.010	0.010
1741 Pregnancy, 4–5 ADGs, no major ADG, delivered	0.006	0.006	0.003	0.004	0.004
1742 Pregnancy, 4–5 ADGs, no major ADG, not delivered	0.401	0.339	0.351	0.331	0.325
1751 Pregnancy, 4–5 ADGs, ≥ 1 major ADG, delivered	0.002	0.003	0.005	0.002	0.002
1752 Pregnancy, 4–5 ADGs, ≥ 1 major ADG, not delivered	0.136	0.118	0.115	0.099	0.098
1761 Pregnancy, ≥ 6 ADGs, no major ADG, delivered	0.009	0.009	0.007	0.008	0.008
1762 Pregnancy, ≥ 6 ADGs, no major ADG, not delivered	0.616	0.552	0.564	0.553	0.543
1771 Pregnancy, ≥ 6 ADGs, ≥ 1 major ADG, delivered	0.018	0.017	0.017	0.014	0.014
1772 Pregnancy, ≥ 6 ADGs, ≥ 1 major ADG, not delivered	0.962	0.900	0.932	0.911	0.895
1800 Acute minor and acute major	4.365	4.519	4.808	4.009	3.937
1900 Acute minor and likely to recur, age 1	0.270	0.190	–	–	–
2000 Acute minor and likely to recur, age 2–5	0.590	0.581	0.644	0.422	0.415
2100 Acute minor and likely to recur, age > 5, without allergy	4.284	4.280	4.904	4.219	4.143
2200 Acute minor and likely to recur, age > 5, with allergy	1.182	1.188	1.420	1.307	1.283
2300 Acute minor and chronic medical: stable	1.023	1.005	1.180	1.044	1.026

(*Continued*)

Appendix (*Continued*)

ACG description	Frequency (%)				
	2000	2001	2002	2003	2004
2400 Acute minor and eye/dental	7.171	7.516	5.780	6.853	6.730
2500 Acute minor, psychosocial, without unstable	0.090	0.109	0.103	0.105	0.103
2600 Acute minor, psychosocial, unstable without stable	0.038	0.044	0.044	0.038	0.037
2700 Acute minor, psychosocial, with unstable and stable	0.009	0.009	0.017	0.019	0.018
2800 Acute major and likely to recur	0.364	0.378	0.419	0.402	0.395
2900 Acute minor and major/likely to recur, age 1	0.330	0.310	–	–	–
3000 Acute minor and major/likely to recur, age 2–5	0.603	0.660	0.783	0.436	0.428
3100 Acute minor and major/likely to recur, age 6–11	0.312	0.254	0.363	0.258	0.254
3200 Acute minor and major/likely to recur, age ≥ 12, without allergy	3.681	3.672	4.265	3.615	3.550
3300 Acute minor and major/likely to recur, age ≥ 12, with allergy	0.757	0.787	0.989	0.916	0.898
3400 Acute minor/likely to recur/eye and dental	5.413	5.576	4.800	5.723	5.621
3500 Acute minor/likely to recur/psychosocial	0.181	0.162	0.207	0.169	0.166
3600 Acute minor/major/likely to recur/chronic medical: stable	2.523	2.497	3.206	2.847	2.796
3700 Acute minor and major/likely to recur/psychosocial	0.276	0.284	0.349	0.289	0.284
3800 2–3 other ADG combinations, age 1–17	1.097	1.119	0.953	0.937	0.920
3900 2–3 other ADG combinations, male, age 18–34	1.043	1.108	0.947	1.010	0.992
4000 2–3 other ADG combinations, female, age 18–34	0.675	0.642	0.618	0.648	0.636
4100 2–3 other ADG combinations, age > 34	3.202	3.338	3.409	3.674	3.608
4210 4–5 other ADG combinations, age 1–17, no major ADG	2.661	2.595	2.360	2.394	2.352
4220 4–5 other ADG combinations, age 1–17, ≥ 1 major ADGs	0.639	0.590	0.581	0.474	0.466
4310 4–5 other ADG combinations, age 18–44, no major ADGs	2.487	2.536	2.431	2.718	2.668
4320 4–5 other ADG combinations, age 18–44, 1 major ADG	2.464	2.603	2.377	2.363	2.322
4330 4–5 other ADG combinations, age 18–44, ≥ 2 major ADGs	0.537	0.499	0.532	0.475	0.467
4410 4–5 other ADG combinations, age > 44, no major ADGs	1.515	1.590	1.657	1.868	1.834
4420 4–5 other ADG combinations, age > 44, 1 major ADG	2.018	2.119	2.204	2.251	2.210
4430 4–5 other ADG combinations, age > 44, ≥ 2 major ADGs	0.652	0.672	0.713	0.735	0.722
4510 6–9 other ADG combinations, age 1–5, no major ADGs	0.977	0.879	0.793	0.689	0.679
4520 6–9 other ADG combinations, age 1–5, ≥ 1 major ADGs	0.350	0.312	0.241	0.176	0.174
4610 6–9 other ADG combinations, age 6–17, no major ADGs	1.599	1.691	1.739	2.058	2.020
4620 6–9 other ADG combinations, age 6–17, ≥ 1 major ADGs	0.586	0.547	0.643	0.666	0.654
4710 6–9 other ADG combinations, male, age 18–34, no major ADGs	0.401	0.413	0.433	0.527	0.517
4720 6–9 other ADG combinations, male, age 18–34, 1 major ADG	0.726	0.801	0.762	0.930	0.913
4730 6–9 other ADG combinations, male, age 18–34, ≥ 2 major ADGs	0.481	0.542	0.543	0.549	0.540
4810 6–9 other ADG combinations, female, age 18–34, no major ADGs	1.029	1.096	1.029	1.216	1.194
4820 6–9 other ADG combinations, female, age 18–34, 1 major ADG	1.260	1.238	1.261	1.342	1.317
4830 6–9 other ADG combinations, female, age 18–34, ≥ 2 major ADGs	0.486	0.468	0.479	0.457	0.449
4910 6–9 other ADG combinations, age > 34, 0–1 major ADG	8.005	8.355	8.423	9.086	8.923
4920 6–9 other ADG combinations, age > 34, 2 major ADGs	3.177	3.221	3.384	3.358	3.298
4930 6–9 other ADG combinations, age > 34, 3 major ADGs	0.861	0.889	0.895	0.866	0.850
4940 6–9 other ADG combinations, age > 34, ≥ 4 major ADGs	0.136	0.131	0.163	0.142	0.139
5010 ≥ 10 other ADG combinations, age 1–17, no major ADGs	0.172	0.177	0.192	0.195	0.191
5020 ≥ 10 other ADG combinations, age 1–17, 1 major ADG	0.147	0.147	0.156	0.135	0.132
5030 ≥ 10 other ADG combinations, age 1–17, ≥ 2 major ADGs	0.060	0.052	0.051	0.037	0.036
5040 ≥ 10 other ADG combinations, age ≥ 18, 0–1 major ADG	2.336	2.335	2.499	2.846	2.795
5050 ≥ 10 other ADG combinations, age ≥ 18, 2 major ADGs	2.669	2.685	2.818	2.961	2.908
5060 ≥ 10 other ADG combinations, age ≥ 18, 3 major ADGs	1.665	1.669	1.783	1.916	1.881
5070 ≥ 10 other ADG combinations, age ≥ 18, ≥ 4 major ADGs	0.813	0.822	0.886	0.959	0.942
5110 No diagnosis or only unclassified diagnosis	0.580	0.620	–	–	–
5310 Infants: 0–5 ADGs, no major ADGs	0.820	–	–	–	–
5320 Infants: 0–5 ADGs, 1 major ADG	0.060	–	–	–	–
5330 Infants: ≥ 6 ADGs, no major ADGs	0.070	–	–	–	–
5340 Infants: ≥ 6 ADGs, ≥ 1 major ADGs	0.040	–	–	–	–