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A CHRONIC DISEASE SCORE FROM AUTOMATED PHARMACY DATA

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Abstract—Using population-based automated pharmacy data, patterns of use of selected prescription medications during a 1 year time period identified by a concensus judgement process were used to construct a measure of chronic disease status (Chronic Disease Score). This score was evaluated in terms of its stability over time and its association with other health status measures. In a pilot test sample of high utilizers of ambulatory health care well known to their physicians ($n = 219$), Chronic Disease Score (CDS) was correlated with physician ratings of physical disease severity ($r = 0.57$). In a second random sample of patients ($n = 722$), its correlation with physician-rated disease severity was 0.46. In a total population analysis ($n = 122{,}911$), it was found to predict hospitalization and mortality in the following year after controlling for age, gender and health care visits. In a population sample ($n = 790$), CDS showed high year to year stability ($r = 0.74$). Based on health survey data, CDS showed a moderate association with self rated health status and self reported disability. Unlike self-rated health status and health care utilization, CDS was not associated with depression or anxiety. We conclude that scoring automated pharmacy data can provide a stable measure of chronic disease status that, after controlling for health care utilization, is associated with physician-rated disease severity, patient-rated health status, and predicts subsequent mortality and hospitalization rates. Specific methods of scoring automated pharmacy data to measure global chronic disease status may require adaptation to local prescribing practices. Scoring might be improved by empirical estimation of weighting factors to optimize prediction of mortality and other health status measures.

Health status measurement Utilization Health services insurance claims data Outcomes

INTRODUCTION

This paper reports a series of analyses evaluating the stability and validity of a measure of chronic disease status derived from the population-based automated pharmacy data of a large health maintenance organization. This research extends the work of Mossey and Roos who evaluated the use of insurance claims data to measure health status [1]. They developed a scale measuring illness severity as a function of claims data aggregated over 1 year time periods. Illness severity was measured by assigning points based on patterns of ambulatory and inpatient utilization and associated diagnoses. They showed that the resulting Illness Scale score increased with age; was higher for persons with interval disease events than for controls; was associated with probability of dying in the following year; and was associated with self report health status measures including self rated health, number of chronic conditions,

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activities of daily living, and days in bed in the prior year. They concluded that

> "at a time when collecting primary data to estimate an individual's overall health status (particularly over long periods of time) is becoming almost prohibitively expensive, these analyses have shown that reliable and valid measures of health status can be developed from claims information."

The use of routine health care data to measure health status is subject to potential biases introduced by differentials in the level of utilization among persons with comparable illness severity and by provider variation in diagnosis and treatment of similar illness states. Wennberg [2], in commenting on the work of Mossey and Roos, observed that

> "the information in claims data bases is, by definition, based on utilization. For this reason, this new application must contend with a serious bias: it is now well understood that physicians differ among themselves on the definition of need, the diagnosis of illness, and the value of treatments and that clinical decisions are subject to a variety of non-health related influences including the supply of hospital beds and the supply of physicians. Thus, morbidity levels reflecting utilization represent an assessment of need based on average clinical experience... not an assessment based on patients' self evaluation of his or her own level of illness or an assessment derived from standardized clinical examinations."

Given the potential utility of a measure of health status based on automated health care data, further research on the use of routine health care data may be warranted, despite the potential limitations and sources of bias. In particular, given the increasing availability of automated pharmacy databases for large population groups and the relevance of prescription medicine use to chronic disease status, the use of automated pharmacy data to measure chronic disease status may deserve special attention. Examples of potential uses of a measure of chronic disease status derived from automated pharmacy data include: comparison of global morbidity levels in different population groups; comparison of morbidity levels of respondents and non-respondents in survey research and case–control studies; efficient two-stage sampling of frail elderly subjects; evaluation of the extent to which physical comorbidity explains the relationship between psychological illness and disability; evaluation of whether participants and non-participants in a breast cancer screening program differ in their overall health status; adjustment for differences in disease comorbidity when comparing the costs of health care of persons with a specific chronic condition to controls; and determining the extent to which the work load of physicians may differ due to patient morbidity differences beyond those attributable to age and sex differences. These examples of the use of a chronic disease score derived from automated pharmacy data have either been carried out or are planned by researchers studying enrollees of Group Health Cooperative of Puget Sound.

This paper describes the development and evaluation of a measure of chronic disease status derived from population-based automated pharmacy data. These analyses evaluate the usefulness of a measure of chronic disease status in terms of its stability over time and its association with other health status measures after controlling for age, gender and level of utilization of health care.

METHODS

In 1977, Group Health Cooperative of Puget Sound (GHC) established a population-based computerized information system for delivery and control of prescription medications [3]. This information system has been used extensively in pharmacoepidemiologic and health services research. As part of a broader program of health services and epidemiologic research in the Center for Health Studies of Group Health Cooperative (GHC), a series of analyses were carried out to evaluate the feasibility of using the pharmacy database to measure the chronic disease status of all HMO enrollees.

The following methods were used to define a Chronic Disease Score (CDS) from the pharmacy database. A multidisciplinary group including GHC physicians, pharmacists, epidemiologists and health services researchers defined consensus scoring rules in accord with the following principles:

(1) The score should increase with the number of different chronic diseases under treatment, but not with the number of times a particular class of medication was used.
(2) The score should increase with the complexity of the regimen used to treat a given chronic disease.
(3) Potentially life-threatening or progressive diseases should receive a higher score than stable and benign diseases.
(4) Medication regimens contributing to the score should target diseases, not symptoms.

Specifically, medications frequently used in the management of symptomatic conditions (e.g. analgesics, anti-inflammatory medications, anti-depressant medications, sedative-hypnotic medications) should not be counted.

Using these principles, the group reviewed the pharmaceutical formulary of Group Health Cooperative, identified chronic conditions and medications that should contribute to the Chronic Disease Score, and reached agreement on a weight that should be assigned for a given pattern of medication use. Medications used for treatment of diseases of children were not considered, so the resulting score was evaluated only for persons aged 18 years or older. The scoring rules are summarized in Table 1. In most cases, the weight was assigned based on the occurrence of any use of a medication, not the number of times a prescription was filled, so that persons who adhered to use of the medication regimen or who were given prescriptions that needed to be filled at shorter intervals would not receive a higher score than persons receiving the same prescription who did not adhere to the medication regimen. Except as noted in Table 1, if more than one medication in a class had been used, it was counted as use of a single medication. Because of the large number of medications on the formulary, the need to take local prescribing practices into account, and the potential complexity of the scoring rules, it was decided to base the scoring rules on expert judgement rather than develop an empirically derived scoring algorithm.

GHC's pharmacy database records prescriptions filled by enrollees through its pharmacies. Virtually all GHC enrollees have insurance coverage for prescription medicines when the prescription is filled through a GHC pharmacy, with either no or a modest co-payment. Methodologic studies indicate that over 90% of prescriptions are filled through GHC pharma-

Table 1

Chronic disease	Medication class(es)	Scoring rules
Heart disease	(1) Anti-coagulants, hemostatics (2) Cardiac agents, ACE inhibitors (3) Diuretic loop	One class = 3 Two classes = 4 Three classes = 5
Respiratory illness	(1) Isoproterenol (2) Beta-adrenergic, misc. (3) Xanthine products (4) Respiratory products including bronchodilators and mucolytics but excluding cromolyn (5) Epinephrine	One class = 2 Two or more classes = 3
Asthma, rheumatism	Glucocorticoids	Score = 3
Rheumatoid arthritis	Gold salts	Score = 3
Cancer	Antineoplastics	Score = 3
Parkinson's	L-Dopa	Score = 3
Hypertension	(1) Antihypertensives (except ACE inhibitors) or calcium channel blockers (2) Beta blockers, Diuretics	If class (1) = 2 If class (2) & not (1) = 1
Diabetes	Insulin Oral hypoglycemics	Score = 2
Epilepsy	Anticonvulsants	Score = 2
Asthma, rhinitis	Cromolyn	Score = 2
Acne	(1) Antiacne tretinoin (2) Topical macrolides	Either class with 2 + prescriptions filled = 1
Ulcers	Cimetidine	Score = 1
Glaucoma	Ophthalmic miotics	Score = 1
Gout, hyperuricemia	Uric acid agents	Score = 1
High cholesterol	Antilipemics	Score = 1
Migraines	Ergot derivatives	Score = 1
Tuberculosis	Antitubercular agents	Score = 1

cies. A SAS [4] program was written by one of the coauthors (KS) to apply the scoring rules to GHC's historical pharmacy data files for 1 year periods. CDS was calculated by summing each of the individual scores assigned for use of specific classes of medications.

Using a variety of data sources available through studies carried out at the Center for Health Studies, a series of analyses were carried out to assess the stability and validity of CDS, after controlling for age, gender and ambulatory utilization. The samples and study variables are summarized in Table 2. In brief, an initial pilot study with a sample of high utilizers well known to their primary care physicians was carried out to estimate the correlation of CDS with physician ratings of physical disease severity. CDS was also compared to physician ratings of disease severity in a second random sample of enrollees on the panel of one GHC physician [5]. In a probability sample interviewed in a chronic pain survey [6, 7], the association of CDS with self-rated health status, measures of psychological impairment and chronic pain status was assessed. A probability sample of enrollees aged 65 or older interviewed in an evaluation of a senior health promotion program [8] was used to evaluate the association of CDS with functional disability. The distribution of CDS by age and gender, its correlation with age, gender and total ambulatory visits, and its ability to predict hospitalization and mortality was evaluated among all Central and East region (Seattle and surrounding communities) enrollees aged 18 or older. Hospitalizations to GHC facilities were identified through GHC's inpatient information system. Deaths were identified by linking the Washington State Death register to GHC's enrollment file.

Statistical analyses were carried out using SAS [4]. Multivariate analyses included the estimation of first order and partial correlations using PROC CORR and logistic regression analyses using PROC LOGIST.

RESULTS

Among all Central and East region adult enrollees in 1985 ($n = 122{,}911$), CDS showed a moderate correlation with total ambulatory visits ($r = 0.42$) and with age ($r = 0.37$), but was uncorrelated with gender ($r = 0.007$). In contrast, total ambulatory visits showed a lower correlation with age ($r = 0.28$ for males and $r = 0.11$ for females) and a higher correlation with gender ($r = 0.12$).

Table 3 shows the age–sex distribution of CDS for Central and East region GHC enrollees. The percent with a CDS of 4+ increased with age, but males and females showed similar percentages with an elevated CDS. We also examined the distribution of total ambulatory visits by age and gender (data not shown). Among persons between the ages of 18 and 44, there was a large gender differential in the percent with 11 or more ambulatory visits (11.0% for females vs 3.0% for males).

A problem in measuring health status using health care data is that some persons with

Table 2. Samples and study variables used to evaluate CDS.

Sample	Variables	Sample size
Pilot sample of persons in the top 10% of users of ambulatory visits for their age–sex group	Physician rating of physical disease severity (well, mild, moderate, severe)	219
Random sample of persons in the panel of one physician	Physician rating of physical disease severity (well, minimal, moderate, severe, terminal) [5]	722
A probability sample of adult GHC enrollees aged 18–74 interviewed for a chronic pain survey	Self rated health status [9] SCL-90-R depression [10] SCL-90-R anxiety [10] SCL-90-R somatization [10] Graded chronic pain status [7]	1016
A probability sample of GHC enrollees 65+ interviewed for a senior health promotion study	Medical Outcomes Shortform functional disability scale [8, 11]	2247
All Central and East region enrollees, 1985	Age, gender, ambulatory visits 1986 hospitalizations 1986 deaths	122,911

Table 3. Percent with CDS of 1–3 or 4+ in 1985 among adult GHC enrollees residing in the Seattle area by age and gender ($n = 122,911$)

	Males		Females	
	1–3	4+	1–3	4+
18–44	12.8%	2.7%	16.7%	3.7%
45–64	27.0%	12.6%	30.5%	12.0%
65–74	31.5%	28.5%	36.9%	23.1%
75+	30.1%	39.4%	34.5%	38.7%
All ages	20.2%	10.7%	24.2%	10.8%

significant levels of illness may not make contact with a health care provider during the time period used in the assessment. We examined the percent with a CDS of 4+ by age among all Central and East region enrollees making no ambulatory visits in 1985. The percent with a CDS of 4 or greater increased with age in this group: 18–44 years of age, 0.4%; 45–64, 1.8%; 65–74, 4.3%; and 75 years or older, 11.8%. A significant percentage of older persons received an elevated CDS (4 or greater) in the absence of contact with a health care provider. This is possible because medications are often refilled without visiting a health care provider, reducing the extent to which CDS depends on doctor visits in any given one year time period. Of course, the proportion with an elevated CDS did increase with increasing numbers of health care visits in all age groups.

We compared CDS to primary care physician ratings of the severity of physical disease (well, mild, moderate, severe) in a pilot sample of high utilizers (the top 10% of total ambulatory visits for the patient's age–sex group). The Pearson correlation of CDS with the physicians' ratings was $r = 0.57$. The percent with a CDS of 4 or greater was 6.1% among those rated well by the physician, 23.0% among persons rated as having mild physical disease; 55.4% among persons rated as having moderate physical disease; and 71.7% among persons rated as having severe physical disease. In a second random sample of 722 patients, the correlation of CDS with physician ratings of disease severity was found to be 0.46. In this sample, the percent with a CDS of 4 or greater was 3.4% among those rated as well, 7.8% among those rated as having minimal disease severity, 25.4% among those with moderate disease, and 58% among those rated as having severe physical disease.

In a probability sample of HMO enrollees, we examined the correlation of CDS and visits with: self-rated health status (excellent, good, fair poor), graded chronic pain status, and SCL-90-R scale scores for depression, anxiety and somatization (Table 4). In this sample, visits showed moderate to high stability from the year before interview to the year after interview ($r = 0.59$). CDS showed much higher stability from the baseline year to the follow-up year ($r = 0.74$), and this stability was not substantially reduced by partialling out the effects of age, sex and baseline visits. The correlation of CDS with self-rated health status ($r = 0.23$) was only slightly higher than the correlation of visits with self-rated health ($r = 0.19$). However, controlling for age, gender and visits had no effect on the relationship between CDS and self-rated health status.

Graded chronic pain status is an ordinal variable with the following levels: non-recurrent pain; recurrent pain; severe-persistent pain with no disability days; severe-persistent pain with 1–6 disability days; and severe-persistent pain with 7+ disability days [7]. CDS showed slightly lower correlation ($r = 0.10$) with graded chronic pain status than did visits ($r = 0.15$). CDS was uncorrelated with SCL-90-R depression and anxiety scores, while visits showed modest but statistically significant correlations with depression and anxiety. Both visits and CDS showed statistically significant correlations with SCL-90-R somatization, a measure of the severity of diffuse physical symptomatology. The correlation of CDS and somatization was not reduced by partialling out the effects of age, gender and visits.

It is of interest that self rated health status, a widely used measure of illness severity, was uncorrelated with age ($r = 0.02$) in this sample. Self rated health status also showed stronger

Table 4. Correlation of total health care visits and CDS with selected health status variables ($n = 790$).

	Total health care visits	CDS	
	First order*	First order*	Partial†
Age	0.09	0.34	NA
Gender	0.13	−0.03	NA
Health care visits			
Same year	1.00	0.38	NA
Following year	0.59	0.41	0.21
CDS			
Following year	0.38	0.74	0.63
Self-rated health	0.19	0.23	0.23
Chronic pain status	0.15	0.10	0.08
SCL depression	0.10	−0.01	0.05
SCL anxiety	0.09	0.00	0.08
SCL somatization	0.16	0.20	0.20

*First order correlations of 0.07 or greater are statistically significant at $p < 0.05$.

†Partial correlations with CDS are adjusted for age, gender and total health care visits in the same year.

correlation with chronic pain status ($r = 0.21$), SCL-90-R depression ($r = 0.28$), anxiety ($r = 0.28$) and somatization ($r = 0.35$) than did CDS. A positive correlation of self rated health status and measures of psychological distress has been reported previously [9].

CDS was found to be associated with functional disability in a sample of 2247 persons aged 65 or older ($\chi^2 = 180.9$, $df = 12$, $p < 0.001$). The percent with a CDS of 4 or greater increased from 16.7% among persons with no limitations, to 26.0% among persons with limitations in vigorous activities, and to 42.9% among persons with limitations in activities of daily living. The percentage with high levels of ambulatory utilization also increased with level of functional disability ($\chi^2 = 160.5$, $df = 12$, $p < 0.001$). Visits showed a somewhat stronger correlation with functional disability ($r = 0.42$) than did CDS ($r = 0.26$). After adjustment for age, gender and visits, the partial correlation of CDS and functional disability was somewhat reduced ($r = 0.19$), but remained highly statistically significant ($p < 0.0001$).

Analysis of 1986 mortality and hospitalization rates as a function of 1985 CDS, stratified by age, showed that CDS was strongly associated with subsequent probability of death and probability of being hospitalized (Table 5). Age-specific differences in mortality between persons with a CDS of 1–3 vs 0 were negligible or modest, while differences in mortality between persons with a CDS of 4 or greater vs 1–3 were typically large.

Logistic regression analyses were carried out to estimate the relative odds of hospitalization and of death as a function of CDS after adjusting for age and gender (Table 6). In these analyses, CDS was modeled as an ordered set of indicator variables (0, 1, 2, . . . , 7+). Relative to persons with a CDS of 0, a CDS of 7 or greater was associated with a 5-fold increase in risk of hospitalization and a 10-fold increase in risk of dying. Parallel analyses were carried out to assess how well ambulatory visit rates predicted death and hospitalization. Persons with 18 or more visits, relative to persons with 0–4 visits, had a 4.9-fold increase in risk of dying and a 5.6-fold increase in risk of hospitalization.

Table 5. Hospitalizations and deaths in 1986 per 1000 population by age and CDS in 1985

	CDS		
	0	1–3	4+
	Hospitalizations		
18–44	45.5	80.2	162.2
45–64	45.5	80.2	162.2
65–74	75.0	113.6	217.2
75+	133.0	165.5	280.6
All ages	55.9	92.7	198.5
	Deaths		
18–44	0.7	0.7	7.1
45–64	2.4	4.7	23.2
65–74	8.8	14.1	51.7
75+	35.5	40.3	98.7
All ages	2.6	8.3	46.0

Table 6. Adjusted odds ratios of hospitalization and death in 1986 predicted from 1985 CDS, adjusted for age and gender

CDS	Hospitalization (8585 admissions)	Death (1053 deaths)
0	1.00	1.00
1	1.37***	1.20
2	1.66***	1.96***
3	1.61***	1.99***
4	2.28***	2.94***
5	2.82***	4.01***
6	3.09***	5.62***
7+	5.02***	9.84***
	$n = 106{,}733$	$n = 122{,}911$

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

A final set of logistic regressions estimated the extent to which CDS predicted death and hospitalization after controlling for ambulatory visits as well as age and gender. In these analyses, CDS remained a highly significant predictor of hospitalization at all levels, although the odds ratios were reduced by adjusting for visits (e.g. the adjusted odds ratio for hospitalization among persons with a CDS of 7 or greater was 2.57). Adjustment for visits had little impact on the strength of the association of CDS with mortality. Only among persons with a CDS of 7 or greater was the difference in odds ratios notable—the adjusted odds ratio in this group was reduced from 9.84 to 7.68 by adjusting for visits as well as age and gender.

DISCUSSION

Chronic Disease Score was highly correlated with itself from one year to the next ($r = 0.74$), showing greater stability than ambulatory visits. It was only moderately correlated with ambulatory utilization ($r = 0.42$). Since utilization is presumably correlated with chronic disease severity, the correlation of visits and CDS is not necessarily indicative of bias. CDS was associated with a variety of health status measures after controlling for age, gender and visits. Its association with self-rated health status and mortality was not substantially reduced by controlling for utilization. The association of CDS with risk of hospitalization was reduced by

controlling for visits, but this could reflect the importance of level of ambulatory utilization in determining risk of hospitalization independent of chronic disease status.

CDS showed a moderate correlation with age and was uncorrelated with depression and anxiety. In contrast, self-rated health status, a widely used global measure of health status, showed moderate correlation with depression and anxiety, but with uncorrelated with age in the study sample. Previous research has shown that self rated health status is associated with measures of psychological distress [9]. Since psychological distress measures were associated with utilization rates, the lack of association of psychological distress and CDS suggests that it may be less influenced by distress-related patterns of illness behavior.

Further methods research evaluating the strengths and limitations of health status measures derived from automated pharmacy data seem to be justified by results to date. Empirical studies which attempt to increase prediction of other health status variables (e.g. mortality) and reduce error variance and bias would be particularly useful. For a variety of reasons, we chose to develop initial scoring rules based on expert opinion rather than develop scoring rules empirically. The *a priori* scoring rules performed well in predicting mortality and hospitalization rates. But, the predictive power of the scoring rules might be improved through empirical estimation of weighting factors. While the results of this report support the measurement of global chronic disease severity using automated pharmacy data, the specific scoring rules we used may need to be changed for use in other settings.

Given that existing self report measures of global health are also subject to measurement biases, measures like the CDS and Mossey and Roos' Illness Score show sufficient stability and validity to be considered for selected research purposes. Such measures are most likely to be useful in situations where the organization of health care and access to services is reasonably uniform. Our data show that the association of CDS with other health status measures is not appreciably affected by controlling for utilization. Interpretation of a pharmacy-based measure of health status requires attention of utilization bias, provider variation in treatment patterns, and secular trends in prescribing patterns (just as interpretation of self report measures of health status requires attention to reporting biases). A significant advantage of a measure of chronic disease status based on automated pharmacy data is that it can be obtained for large population groups over time at minimal cost. Given the potential uses of such a measure in epidemiologic and health services research, further research on the use of automated pharmacy data to measure health status seems to be warranted.

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