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ASSESSING HEALTH CARE COSTS IN THE ELDERLY

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ABSTRACT

Accurate forecasts of future health care expenditures for cohorts of elderly individuals can be especially difficult. Current techniques use average per capita costs, based on local experience, adjusted for the cohort's age, sex, institutionalization, and welfare status distribution. This paper presents a method to adjust such per capita cost estimates to reflect more accurately the likely health status of a particular cohort. The adjustment uses the cause-of-mortality profile in the local population, which is a readily available tabulation known to be highly correlated with a major proportion of total medical care expenditures for people beyond age 65.

I. INTRODUCTION

A fundamental requirement in health economics and actuarial planning is the accurate forecast of health care expenditures for a group or cohort of individuals. For example, actuaries must set premiums, dividends, and premium refunds for group health insurance according to past experience and to future expected expenditures. Public health planners must assess future reimbursements and needs in order to set priorities in planning health care delivery systems.

Recently, the risk option of the 1976 Amendment to the Social Security Act added new importance to the need for accurate procedures to predict future health care costs. Under the risk option, a health provider, such as a qualified health maintenance organization (HMO), may choose to enroll a group of elderly people, who qualify for Medicare, into a total health care delivery plan. Although some of the cost of the plan is paid by the enrollees as premium and/or as coinsurance, the majority of the costs are paid directly by Medicare on a prospective basis.

Operationally, the basis of the risk option is the ability to estimate accurately the per capita medical care costs for the enrolled cohort during the coming year. This estimate is derived from an actuarial formula designed to

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adjust for differential health care requirements that result from differences in the demographic composition of the enrolled cohort. Based upon a percentage of this cost, the Health Care Finance Administration (HCFA) prepays the health provider. The health provider contracts to provide all required health care for this cohort at no additional cost to the Medicare program.

The rationale of the risk option is to control health care costs by providing the HMO an implicit financial incentive for good management. This is done by allowing the health provider to retain half of the money saved (up to a prespecified limit, now 20 percent of the projected cost) compared to the estimated yearly cost to Medicare to provide health care for the particular enrolled cohort of elderly individuals. The latter estimate is adjusted downward by 5 percent to represent cost savings expected in an HMO.

A number of factors make estimation of the expected future health care expenditures for an enrolled cohort of elderly individuals difficult. First, although the cohort is a sample from a local or regional population, it is not necessarily random.[1] Therefore, the regional per capita expenses are not necessarily a good measure of the expenses to be incurred by the enrolled cohort. Second, the previous health care cost experience of the cohort must be examined carefully. Past local experience is sensitive to a number of health and nonhealth status factors. For example, the projections may be sensitive to minor changes in the cost recovery methods employed by the health provider. Furthermore, cost projections may be affected by "one time only" health care requirements (like appendectomies). Third, the health care expenses incurred are a function of many factors, including geographic region and the ethnic, age and sex composition of the cohort as well as the types of health services required.

The current method of estimating costs is to figure a per capita cost based upon the local experience and apply this to the enrolled population. Although this method of forecasting expenditures for the enrolled population adjusts for regional and age effects, there is no adjustment for differential health care requirements resulting from local area differentials in health status. In this paper, we present a method of adjusting the per capita local cost estimates to reflect more accurately the health status of the enrolled cohort. We use the mortality profile (the probability of dying of a specific cause during the current year) in the local population to adjust our estimate of the age-specific local per capita cost estimates in order to reflect differences in health

[1]There are many possible causes of nonrandom sampling. The lack of randomness in sampling can be due to the method of recruiting or to a required medical examination. Alternatively, a lack of randomness in sampling could be due to a community perception of the pros and cons of membership. (See [6].)

status between local populations. We adjust for health status differentials in this way for two reasons. First, there is considerable evidence to indicate that (1) a large proportion of the total medical expenditure for people beyond age 65 is for medical care in the final year of life, (2) there are significant differences in medical expenditures among persons with different causes of death and (3) the medical conditions listed on the death certificate of the elderly often are a good indicator of the morbid processes leading to death. Second, the cause-specific mortality data used for the adjustment are regularly tabulated for all deaths in the United States and for local areas down to the county level. Thus, the data required for the tabulations are readily available and have known measurement characteristics.

II. PER CAPITA ADJUSTMENT

The current method of estimating the expected costs of care for a cohort is the adjusted average per capita cost (AAPCC). The AAPCC is calculated as follows (see [4]):

1. Each individual, both in the county population and in the enrolled cohort, is classified into one of thirty demographic groups. These groups represent age and sex categories, institutional status, and welfare status. Denote by $E_{i\,HMO}$ and $E_{i\,CO}$ the number of persons enrolled and in the county, respectively, (including potentially future enrolled) classified as members of demographic category i.
2. A set of underwriting cost factors are determined for each demographic group. These are given in Tables 1 and 2 of [4] and represent the ratio of the average health care cost for an individual in the demographic group to the U.S. average per capita cost (across all groups).
3. The average per capita cost of the individuals in the enrolled cohort is determined by adjusting the U.S. average per capita cost (USPCC) by the ratio of the demographic distribution of underwriting cost factors for the enrolled cohort to the county population. Explicitly:

$$A = USPCC \cdot \frac{\sum_{i=1}^{30} u_i E_{iHMO} \cdot \sum_{i=1}^{30} E_{iCO}}{\sum_{i=1}^{30} u_i E_{iCO} \cdot \sum_{i=1}^{30} E_{iHMO}}. \tag{1}$$

4. Multiply A in equation (1) by the ratio of the (5-year) average per capita cost in the county, ($APCC_{CO}$), to the (5-year) average per capita cost in the U.S., ($APCC_{US}$). In symbols, this adjusted average per capita cost

($AAPCC$) is given as:

$$AAPCC = \frac{APCC_{CO}}{APCC_{US}} \cdot A \ . \tag{2}$$

5. When the enrolled cohort is drawn from several counties, the above steps are repeated for each county and then used to form a weighted average according to the distribution of enrollees.

The $APCC_{CO}$ is a county wide average cost figure ostensibly estimated independently of the particular HMO enrolled cohort. Similarly USPCC and $APCC_{US}$ are nation wide cost figures estimated independently of the enrolled cohort. However, the ratio of the distribution of the enrolled to county demographic underwriting factors is intended to adjust for any selection or differential sampling of the population produced by the enrollment strategy. Therefore, this ratio is cohort dependent and should be sensitive to differences in expected health care requirements of the enrolled cohort relative to the general county cohort. To the extent that the demographic factors employed in the AAPCC (i.e., age and sex) do not represent differences in health care requirements between the enrolled and county populations, the AAPCC will not give satisfactory estimates of expected costs for the enrolled.

III. COSTS OF MORTALITY

Whether considering the local (county) population, or the particular enrolled cohort, any group of people in the same demographic category can be divided conceptually into two subgroups, namely, those people who will die during the coming year and those people who will not. In projecting health care costs, this division is very important. For example, recent research at HCFA has shown that approximately 6 percent of the Medicare population die annually. These people account for over 31 percent of Medicare's reimbursements (see [5]). The high health care cost for those who die during a year has been verified by an actuarial study of the Medicare experience of 1977 (see [2]). In that study the average charge for persons not dying in the year who were covered by part A and B was $712 for males aged 65-69. The average charge for those dying during the year was $4,996 for males aged 65-69, over seven times greater.

The marked difference in cost holds for both males and females and a few different age groups. The difference attenuates somewhat for the extreme old age groups. This is because, at very advanced ages, many of those not dying in a year are in the process of dying. A great percentage of the younger elderly, in contrast, are not in the mortality process but are "well." Thus, their need for health care is essentially dictated by general health maintenance requirements or by accidents.

To see the potential effect that these mortality costs can have on the AAPCC methodology consider the population of nonpoor, noninstitutionalized males in a county. Assume that this population is grouped into three age categories, 65-69, 70-74, and 75-79. Suppose also that, for each individual, the reimbursement required for the year is exactly the average of the 1977 Medicare experience, depending upon whether he survived the year or died. Table 1 gives average reimbursement values. For this example, we will assume that the proportion of individuals from each age group is the same in both the enrolled and the county cohorts, e.g., 0.5, 0.3, 0.2. We will assume that the annual mortality rates for the three age groups for the county are, respectively, 0.04, 0.05, 0.07. (The current mortality rates for U.S. males in these categories is about 0.031, 0.045, 0.066.)

Since the county and enrolled demographic distributions are exactly the same[2], the expected costs for the enrolled population using AAPCC will be the same as the county costs. The Medicare charges would be $987 per person. If, however, the HMO was unfortunate enough to sample a subgroup that has a mortality rate for the three age groups of the enrolled cohort of, respectively, 0.05, 0.07, 0.09, then the actual incurred reimbursable cost is $1,046. This is about 6 percent higher than the reimbursement to the HMO. This higher cost is due to the fact that the subgroup being sampled has a greater percentage of individuals who are in the process of dying and will require the more intensive health care associated with the last year of life. Thus, presumably, this subgroup may be considered collectively to be farther along in the death process. On the other hand, a fortuitous enrollment strategy which samples from a subgroup with male mortality rates of 0.03, 0.04,

TABLE 1

AVERAGE PART A AND B CHARGES FOR MALES FROM 1977 MEDICARE EXPERIENCE*

DEATH STATUS	AGE		
	65-69	70-74	75-79
Survivors	$ 712	$ 819	$ 952
Nonsurvivors	$4,996	$4,879	$4,376

* See [2].

[2]The relevant underwriting factor groupings here are limited to age groups since we are not considering institutional or welfare persons in either cohort.

0.05, for the three age categories would result in actual incurred reimbursable costs of $949 per capita, almost 5 percent below what the AAPCC projected. In this case, the subsample is more healthy in that there are fewer individuals within the final year of life.

In general, no matter how the population is distributed over the demograhic variables, the AAPCC will provide underestimates of the actual costs if the mortality rates of the enrolled cohort exceed those of the county. The AAPCC will provide overestimates of the actual costs if the mortality rates of the enrolled are less than those of the county.

Though the mortality rate differentials determine whether AAPCC will over or under estimate health costs, demographic factors are very important in determining the magnitude of the differences. Because of the large differences in costs of health care between the survivors and nonsurvivors at the younger ages (i.e. 65-69), differences in mortality rates for these age groups makes a larger contribution to the bias than similar differences in mortality rates in older age groups. This differential bias is further exaggerated by the fact that usually there are more people in the younger age groups than in the older age groups.

IV. COSTS OF CAUSES OF DEATH

In the previous section, we illustrated how a small difference between the total mortality rates of the enrolled cohort and the general county population resulted in a 6 percent difference between estimated and expected Medicare charges. In this section, we will show that the distribution of causes of death is also an important factor in health care costs.

For example, suppose we consider the five causes of death listed in table 2 with the average Medicare charge for the final year of life. These costs are approximated from the results given in [5]. Suppose also that we have

TABLE 2

FIVE GENERAL CAUSES OF DEATH AND THE AVERAGE CHARGE TO MEDICARE IN THE YEAR OF DEATH*

Cause	Medicare Charge
Ischemic Heart Disease (IHD)	$4,400
Cerebrovascular Disease (CVD)	4,400
Cancer	6,600
Accident	5,100
Other	5,300

* See [5].

a sample of males age 70 from the county. The rate of death during the year for the county and the enrolled are given in table 3.[3]
Note that the total mortality rates for persons aged 70 is constructed to be identical, that is 0.062. Since we are considering only one demographic group with the same mortality experience, using AAPCC, the reimbursable health costs of the county and enrolled populations will be estimated to be the same. However, applying the costs of table 2 to the rates in table 3, we see that the cost per capita (all 70-year olds) incurred by death is $309 for the county and $298 for the enrolled cohort (these are mortality costs only). Thus, the charge incurred by those who die in the enrolled population will be about 3.5 percent below the estimated charge.

V. COSTS FOR MORTALITY AS A PROCESS

In the two previous sections we have used the annual mortality rate as an index of the aggregate health status of a cohort. We have seen that differential mortality patterns between the county and enrolled cohorts can cause a marked difference in per capita charges due to the additional expenses incurred by those in the terminal year of life. However, the morbidity that ultimately causes mortality is usually not an acute event. Some of the people dying of a heart attack in a given year, for example, have had previous heart attacks. In fact, approximately 68 percent of the males 65 or older at time of first myocardial infarct will survive over one year (based on the Framingham study, see [3]). Similarly, stroke and cancer victims often will need health care associated with the death process two or more years before their actual demise.

Thus, the use of mortality patterns as an index of health should account for more of the health care costs than just those costs incurred in the last year of life. For example, for each heart attack victim who dies, there are

TABLE 3

MORTALITY RATES BY CAUSE FOR A HYPOTHETICAL COUNTY AND AN ENROLLED SUBGROUP

Group	Cause of Death				
	IHD	CVD	Cancer	Accident	Other
County	.0300	.0080	.0120	.0010	.0110
Enrolled	.0420	.0020	.0070	.0005	.0105

[3]These county mortality rates are approximately those of Benton County, Washington and the enrolled rates those of Davis County, Utah.

many who receive considerable health care because of a coronary event who will die of a heart attack from, say, one to six years in the future.

In order to account for the medical care costs arising from the clinical management of a lethal chronic disease during its natural history, (from its initial clinical manifestation to death), we use a generalization of the logic of "bioactuarial" models of chronic disease prevalence. These models, using clinical and epidemiological data on the natural history of the chronic disease process, "project" backward chronologically from the age at death caused by a specific disease to the specific morbid events caused by the disease before death. These model's have been successful in estimating lung cancer prevalence patterns for health policy (see [8]), for national estimates of costs for treating lung cancer ([12]), and for forecasting disease prevalence patterns over time and space ([7]). In our modifications of the AAPCC, we restrict the range of this backward projection to just that portion of the natural history of the disease process that is clinically manifest, and requires treatment. Thus, our estimation of the morbid events prior to death is based on empirical observations (see [10] and [3]) of the pattern of treatment associated with the disease's natural history. This pattern of prior medical experience leading up to death from a particular cause is expressed in a probability table of recurrence relations, in other words, the likelihood of specific clinical courses (and associated costs) leading to the same death outcome. It is generalized, however, in the sense that (1) we can project morbid events, treatment costs and clinical complications for a wide range of diseases, and (2) we can deal with the fact that multiple, interdependent diseases interact during the natural history of the disease process to cause death ([11]). The ability to deal with the fact that death may be caused for multiple reasons ([8]) is critically important in describing the medical conditions and costs associated with mortality at advanced ages.

The possibility that the health care costs, associated with the medical conditions that eventually cause death, can extend back several years raises two issues:

1. How much should each death of a particular cause be weighted in modeling the expected health care costs for a specific local area population?
2. How much of the Medicare charges not accounted for by deaths in the year can be attributed to individuals in the death process who will die in subsequent years?

In the rest of this paper, we will focus on these two questions. In order to modify the AAPCC to deal with these problems, we will first need to define the following quantities:

i = index for the medical condition that becomes the underlying cause of death (for example, ischemic heart disease (IHD), cerebrovascular disease (CVD), cancer (CA)). Onset of this condition will be referred to as initiation of the mortality process.

$q_x(i)$ = probability that a person alive at the beginning of age x will die during the age interval $(x, x+1)$ of cause i.

$r_t(i)$ = probability that a person with condition i will die between years t and $t+1$ after onset of that condition.

$R_t(i)$ = probability of surviving t or more years after onset of condition i.

$$= \sum_{\tau=t}^{\infty} r_\tau(i)$$

l_x = number of individuals alive at age x.

$s_x(i)$ = proportion of people alive at beginning of age x who will have a cause i event year during $(x,x+1)$. (This could be an initiating event or an event subsequent to the initiating event.)

$b_i(x)$ = cost of an event year at age $(x,x+1)$ for condition i.

a_i = cost of death due to event i.

ϕ_i = annual recurrence rate of an event year for cause i.

In these definitions the term "event year" is used flexibly. For persons suffering from a stroke or myocardial infarction (MI), an event year is a year in which one or more attacks result in major health care requirements. For persons with cancer, each year that the person is still alive after the diagnosis of a tumor is an event year. Since the mortality classification of "accident" and "other causes" include a broad spectrum of causes of death, many of which are either acute, or for which the process is not clinically well defined, the first event year will be assumed to be fatal.

From the above definition, the annual cost due to mortality processes of condition i is given by:

$$\text{Cost}_i = \Sigma_x l_x\{q_x(i)\, a_i + b_i(x)\, s_x(i)\}. \tag{1}$$

Put in words, the cost for condition i is the sum, over all age groups, of the costs for the first event year plus the cost for the second event year, and so forth, up to the year of death plus any additional cost due to death. If we can assume that the individual will die as the result of one of the events, with no additional cost, then we set a_i to zero. It is possible that the person may have a series of events, such as multiple heart attacks and actually die of cancer or an accident with no mention made of the IHD condition. This situation can be modeled with a generalization of equation (1). This case, however, is not considered, explicitly, in this paper.

To determine costs using equation (1), we must first estimate the event year onset rates $s'_x(i)$. For the "accident" and "other" classifications, we assume that the first event is the terminal year, i.e., $s'_x(i) = q_x(i)$, where i = "accident" or i = "other." In general, however, the event year onset rate is related to the mortality rate for condition i by the equation

$$q_i(x) = \sum_{t=0}^{\infty} r_t(i)\, s'_{x-t}(i). \tag{2}$$

In words, this equation says that the number who die at age x with condition i is simply the sum of all individuals who had the condition onset at an age prior to x who survived to age x and then died in the age interval $(x, x+1)$.

The relationship between $s_x(i)$, $s'_x(i)$, $R_x(t)$, and ϕ_i is given in the equation

$$s_x(i) = s'_x(i) + \sum_{t=1}^{\infty} s'_{x-t}(i)\, R_{x-t}(i)\, \phi_i. \tag{3}$$

The total number of individuals with an event year at age x is equal to the number who initiate condition i at age x, plus all those who had initial events before x, and survived to age x with a recurring event year at age x, to $x+1$. Thus, to estimate costs, we need estimates of the recurrence rates, ϕ_i, the survival probabilities after first event, $R_t(i)$, and the incidence rate $s'_x(i)$. Both the recurrence rates and the survival rates after onset can be calculated from past experience. However, the rate of onset of condition i is dependent on the health of the particular cohort receiving care. Thus, the past experience used to estimate $s'_x(i)$ must be restricted to the experience of the sampled subgroup for which we are assessing costs. Since this is usually unavailable or, if available, often unreliable, we will estimate the onset rates $s'_x(i)$ using the mortality experience of the sampled cohort and equation (2). We then apply the estimates of $s'_x(i)$ in equations (1) and (3) to determine costs.

In summary, the formulas (1), (2) and (3) determine how much deaths by cause i in the sampled cohort contribute to health costs. For example, if a death by IHD is the result of an average of three heart attacks during three different years, then each death by IHD incurs a cost, in the year of death, and in two prior years. Thus, an IHD death would have to be counted as having three event years. On the other hand, death from lung cancer which has an average survival time of about five months from diagnosis to death, would be counted as incurring health care costs in only the terminal year. Of course, the cost for a cancer event year will not be the same as the IHD year.

VI. IMPLEMENTING THE MORTALITY PROCESS MODEL

As an example of how to implement the model, we will consider the five causes of death given in table 3. For the causes "Cancer," "Accidents," and "Other," we assume that the first event year is fatal. This means that $r_0(i) = 1$ for all of these causes. We note that this assumption does not mean, for example, that a person will not incur costs due to accidents except in the year he dies of an accident. Instead, the assumption means that the individual incurs no health care costs due to the accident mortality process prior to the year he dies due to an accident. The mortality process costs we are modeling here are intended to account for the extreme costs due to mortality.

In addition to the costs of the mortality process, individuals in the cohort will require health care for general health maintenance and for the treatment of injuries due to accidents. These costs are probably not well predicted from mortality data. Note also that general health maintenance care costs do not include health care required as a result of a mortality process even though death may be a couple of years off. The costs for this care are included in mortality costs.

One may feel that the "Cancer" category should have a cost accrual in two or more years prior to death. For some cancers this is true. For other cancers, such as lung and pancreatic, the time of death is often less than a year after diagnosis. Since treatment costs for diagnosis to death make up the major reimbursed charges, individuals dying of these fast growing or late diagnosed cancers will incur costs primarily in the year of death. For the purpose of our example, though, we have used a cancer diagnostic category that includes both fast and slow growing cancers, we have not specialized the procedure to allow for health care costs for slow growing tumors in more than a single event year. Certainly the procedures illustrated below can be adapted for those cancer types that progress relatively slowly. In our example, the assumption that cancer costs accrue in a single year will generate a small bias in the cancer costs accrual since the health costs for slowly progressing tumors will be absorbed under the general health maintenance costs.

For both IHD and CVD causes, we will model incurred costs in years prior to the year of death as given in section V. For the survival and mortality probabilities of stroke, we consider only data relating to infarctive stroke. Approximately 85 percent of completed strokes are infarctive (see [3]). Hemorrhagic stroke, making up most of the rest, has a poorer prognosis, higher mortality rates and, consequently, are less expensive to treat. Thus, the estimate of costs produced by assuming that all strokes are infarctive will tend to overestimate stroke costs slightly. Table 4 gives the survival probabilities for infarctive stroke (see [3]). We will assume that anyone dying of IHD will die of sudden death (SD) or of myocardial infarct (MI) or coronary insufficiency (CI) within thirty days of either of the latter two. These can be either acute or chronic ischemic heart disease patients. We will not consider angina pectoris (AP) as an event since usually this is treated on an outpatient basis. Since the MI and CI mortality rate (thirty days after the event) are the same, we assume that we can group these.

In the U.S., most deaths for males are due to MI not CI. Table 5 gives the survival probabilities for males with MI by age and time since event (see [3]). The survival probability for SD is zero, of course. Thus, we determine $r_0(IHD)$ as,

$$r_0(IHD) = \text{prob}(SD/\text{event}) + \text{prob}(MI \text{ or } CI \text{ Death/event}) \tag{4}$$

where

$$\text{prob}(SD/\text{event}) = \frac{\text{Incidence rate } SD}{\text{Incidence rate } SD + MI + CI}. \tag{5}$$

Table 6 gives the $r_0(IHD)$ estimates for males by age group. This table also gives the probability of a given SD coronary event; coronary event means SD, MI, or CI. Calculation of the conditional probability in equation

TABLE 4

SURVIVAL FOLLOWING FIRST COMPLETED STROKE, UNITED STATES, 1975*

AGE AT STROKE	SURVIVAL TIME					
	1 Month	1 Year	2 Years	3 Years	4 Years	5 Years
55-64	0.835	0.729	0.678	0.630	0.586	0.545
65-75 Males	0.795	0.619	0.534	0.460	0.397	0.342
Females	0.795	0.633	0.558	0.491	0.433	0.381
75-84 Males	0.699	0.459	0.373	0.304	0.247	0.201
Females	0.699	0.477	0.403	0.340	0.288	0.243
85+ Males	0.542	0.280	0.195	0.136	0.096	0.066
Females	0.542	0.293	0.214	0.156	0.114	0.083

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TABLE 5

SURVIVAL DATA AND LIFE TABLE FOR MALES
BASED ON THE FRAMINGHAM HEART STUDY DATA FOR MYOCARDIAL INFARCTION PATIENTS*

Age at Diagnosis	Survival Time	Cummulative Survival Probability (CP)
55-64	0-30 days	0.881
	30 days-1 year	0.851
	1-2 years	0.822
	2-3 years	0.772
	3-4 years	0.732
	4-5 years	0.669
	5-6 years	0.635
	6-7 years	0.600
	7-8 years	0.586
	8-9 years	0.559
	9-10 years	0.529
	10-11 years	0.476
	11-12 years	0.456
	12-13 years	0.411
65+	0-30 days	0.733
	30 days-1 year	0.683
	1-2 years	0.629
	2-3 years	0.568
	3-4 years	0.471
	4-5 years	0.454
	5-6 years	0.436

* See footnote for table 4.

TABLE 6

PROBABILITY OF DEATH IN FIRST YEAR OF EVENT

Age	Males	
	Prob (*SD*/Event)	$r_0(IHD)$
55-64	.2469	.3591
65-74	.1078	.3906
75+	.1078	.3906

(5) was done using the 1975 U.S. white male incidence rates. The values of $r_t(IHD)$ for each time and age are determined from the data presented in table 5. Table 7 contains recurrence rates specific to the age at first "attack." Although this includes AP we will use it for the more severe IHD.

The first step in applying the model is to estimate the onset rates, $s'_x\ (i)$, for each condition or mortality process, i, in the population. To make these estimates, we will use equation (2). However, equation (2) is overparameterized (underspecified) meaning that the number of equations in the system

TABLE 7

ANNUAL RECURRENCE RATE FOR IHD BY AGE AT FIRST OCCURRENCE*

Age at First Attack	Male	Female
55-64	.0867	.1412
65+	.1145	.2308

* See footnote for table 4.

is less than the number of unknowns. Note that the system of equations is generated by varying the ages x and resembles the system of equations generated by the quadrature solution of a Fredholm integral equation of the first kind (see [9]). Solutions to such equations are often calculated by imposing a stabilizing constraint such as a constant first difference of $s'_x\ (i)$ over short intervals of the values of x. In our case, imposing such a condition in solving $s'_x\ (i)$ is the same as requiring the change in the onset rate $s'_x\ (i)$ to be linear over short age intervals. This assumption does not appear too restrictive and will be used to solve for $s'_x\ (i)$ using equation (2). This assumption allows us to use the recurrence and survival data in combination with the mortality experience of the HMO cohort, and the nonenrolled county cohort, to estimate $s'_x\ (i)$.

VII. EXAMPLE

To illustrate the methodology, we examined the mortality experience of white males in two counties: Davis County, Utah and Benton County, Washington. These counties are both arid and are made up of a predominantly middle-class urban population. We will assume that the Davis County experience is the enrolled HMO and the Benton County experience that of the county residents.

Using the mortality experience for these counties for 1976-77, we estimate $s'_x\ (i)$ using equation (2). These estimates are not tabulated here. Initially, we assume $b_i\ (x) = \$1$ and $a_i = 0$. Subsequently, we determine the "actual" mortality costs by multiplying resulting estimates by the entire costs in table 2. Under this assumption, we combine equations (3) and (1) to get estimates of costs for each age group and condition. The calculation of this cost is based on the assumption that, for each death from a specific cause, say IHD, we include an estimated number of events occuring at the specific ages which are not fatal but incur a health care cost attributable to the mortality process, that is, an IHD event year that is not fatal. Expenses due to a previous event year are assumed to have been paid during year of event.

TABLE 8

ANNUAL PER CAPITA COSTS, BY AGE, FOR WHITE MALES FOR TREATMENT OF IHD AND CVD CONDITIONS ASSUMING $1 PER EVENT YEAR TREATMENT COSTS

Age	IHD		CVD	
	Benton County	Davis County	Benton County	Davis County
70.......	$.03772	$.04485	$.00808	$.00136
71.......	.04184	.04842	.01247	.00334
72.......	.04584	.05035	.01825	.00737
73.......	.04962	.05095	.02384	.01164
74.......	.05307	.05122	.02726	.01509
75.......	.05610	.05068	.02815	.01725
76.......	.05850	.04993	.02440	.01816
77.......	.06029	.04949	.01747	.01838
78.......	.06107	.05006	.01075	.01856
79.......	.06077	.05230	.00687	.01898

TABLE 9

ANNUAL PER CAPITA COSTS, BY AGE, FOR WHITE MALES FOR TREATMENT OF ACUTE CONDITIONS DURING LAST YEAR OF LIFE TERMINAL YEAR COSTS ARE ASSUMED TO BE $1

AGE	CANCER		ACCIDENT		OTHER	
	Benton	Davis	Benton	Davis	Benton	Davis
70.......	$.01152	$.00784	$.000816	$.000482	$.01135	$.01232
71.......	.01286	.00812	.000972	.000677	.01292	.01184
72.......	.01455	.00817	.001282	.000948	.01491	.01049
73.......	.01615	.00829	.001637	.001246	.01703	.00901
74.......	.01725	.00876	.001956	.001521	.01901	.00815
75.......	.01742	.00987	.002148	.001725	.02057	.00863
76.......	.01605	.01216	.001974	.001639	.02147	.01104
77.......	.01342	.01545	.001492	.001297	.02189	.01488
78.......	.01045	.01891	.001064	.001025	.02220	.01928
79.......	.00809	.02171	.001051	.001149	.02275	.02339

Tables 8 and 9 give the per capita costs based upon $1 of health care provided during each event year for each cause.

To determine the age-specific costs for the five mortality processes considered, we multiply the entries in table 8 and 9 by the costs listed in table 2 and sum. We are assuming implicitly here that the cost of an event year is independent of age, $b_i(x) = b_i$, or mortality outcomes, $a_i = 0$. To adjust for mortality costs, recall that we can set a_i in equation (1) to a non-zero value. The results are given in table 10. Table 10 summarizes the differences between the estimated health care costs due to mortality and the costs ex-

TABLE 10

ANNUAL PER CAPITA COSTS DUE TO THE MORTALITY PROCESS ASSUMING COSTS GIVEN IN TABLE 2.

Age	Benton County	Davis County	Ratio Benton/Davis
70	$342	$323	1.06
71	397	348	1.14
72	463	368	1.26
73	528	384	1.38
74	578	400	1.45
75	606	418	1.45
76	595	447	1.33
77	554	493	1.12
78	508	534	0.95
79	477	587	0.81

pected to be incurred by the HMO due to the mortality experience of the enrolled. The differences are based upon difference in :

1. Overall age-specific mortality rates.
2. Distribution of causes of death.
3. Numbers of individuals requiring costly health care due to the mortality process but not dying during the year.

From table 10 it is clear that an HMO enrolling a cohort of elderly individuals from Benton County, which fortuitously have the same mortality experience as Davis County, will be overreimbursed an average of 27 percent (assuming a uniform age distribution) under the current methodology for mortality related health care costs for each male 70-77 years old. Reversing the situation, an HMO in Davis County with the mortality experience of Benton County, will be underreimbursed an average of 27 percent for health care costs associated with mortality.

After age 78, the projected health care costs for Davis County exceed those of Benton County. This is a result of the later age at death in Davis County. In general, populations with good mortality conditions (higher than average life expectancies) will have greater health care costs associated with mortality at later ages. Depending upon the particular demographic structure of the elderly population, the impact of these expected costs for the individual could be greatly multiplied.

For example, the World War II baby boom will reach age 65 between 2010 and 2015. Thus, in those years, the cost differentials of the type projected here could have an extremely adverse effect on the fiscal stability of

HMO's nationally. For example, many bankruptcies of HMO's could occur nationally, due to this influx of an extremely large cohort of 65-year-olds in those enrolled cohorts with an adverse mortality structure (like Benton County). This will occur precisely at the time when the health care needs of the elderly population will be increasing rapidly. On the other hand, certain HMO's (e.g., those with a mortality structure like Davis County) could experience extremely large profits during the same period. Unfortunately, these HMO's, who would be advantaged in the period 2010 to 2015, would themselves experience severe financial difficulties about ten years later when these large elderly cohorts experience the higher mortality costs found at advanced ages in the mortality-advantaged counties (after age 77 in Davis County).

VIII. MORTALITY COSTS INCURRED PRIOR TO TERMINAL YEAR

In section VI, we attributed an extra health care cost to each IHD death and each CVD death based upon the probable number of years preceding death that each individual would have had a major, but not lethal, IHD or CVD event requiring health care. In this section, we will use this method of accounting to estimate how much of the health care costs not attributed to individuals in their final year of life may be attributed to individuals having a potentially lethal event but who survive the year. Assuming no such retrospective accounting, the entries in table 8 would be replaced by the associated age and cause specific mortality rates. The difference between these mortality rates and the entries in table 8 represents the additional cost per dollar of health care delivered, associated with the mortality process, but not incurred in the last year of life. Multiplying these differences by the costs listed in table 2 gives the mortality costs listed in table 10 which are not incurred in the year of death. Table 11 gives these additional costs for IHD and CVD events combined.

From table 11, we see that around 30 percent of the costs in table 10 are incurred prior to the last year of life. Recall the estimate that about 31 percent of the Medicare charges are incurred by individuals in their last year of life ([9]). Assuming all charges in the last year of life are due to the mortality process, we estimate that an additional 9.3 percent (30 percent × .31) of the Medicare costs in a year are due to the mortality processes of individuals not dying in a year. This makes a total of about 40 percent of the Medicare charges attributable to mortality processes. Including cancer as a chronic state, incurring costs for more than the terminal year of life, will increase this percentage another few points.

TABLE 11

AMOUNT AND PERCENT OF TOTAL MORTALITY COST IN TABLE 10 WHICH IS NOT INCURRED IN THE LAST YEAR OF LIFE BUT WHICH IS REQUIRED DUE TO THE CHRONIC CONDITION OR MORTALITY PROCESS OF THE INDIVIDUAL

Age	Benton County		Davis County	
	Additional Costs	Percent of Total	Additional Costs	Percent of Total
70	$109	32	$107	33
71	129	32	120	34
72	152	33	134	36
73	173	33	145	38
74	187	32	151	38
75	194	32	151	36
76	188	32	148	33
77	173	31	147	30
78	158	31	151	28
79	149	31	162	28

IX. ADJUSTING FOR MORTALITY

From the above examples, we see that local area health status differences, correlated with mortality rates and causes of death profiles in the HMO enrolled cohort, can cause the calculated AAPCC to be seriously biased. To improve the cost forecast, we conclude that the risk factors $[u_i]$ must be adjusted for local mortality experience. One method for effecting such an adjustment is as follows:

Define the following for Parts A and B individually:

APC = average annual per capita cost of health care in the Medicare program;

a_{ij} = average annual per capita cost for individual in demographic factor group i dying of cause j, $j = 1, \ldots, J$;

a_{i0} = average per capita maintenance costs;

$m_{ij}^{(k)}$ = annual rate of death by cause j for individuals in demographic factor group i in cohort k. Here k signifies county or HMO cohort;

$$U_{ij} = \frac{a_{ij}}{\text{APC}} \quad \begin{matrix} i = 1,2,\ldots \\ j = 0,1,2,\ldots,J. \end{matrix}$$

Then the mortality-adjusted AAPCC is given as

$$AAPCC^* = USPCC \cdot \frac{APCC_{CO}}{APCC_{US}} \cdot \frac{\sum_i (\sum_{j=1}^{J} U_{ij} m_{ij}^{(HMO)} + U_{i0}) E_{iHMO} \cdot \sum_i E_{iCO}}{\sum_i (\sum_{j=1}^{J} U_{ij} m_{ij}^{(CO)} + U_{i0}) E_{iCO} \cdot \sum_i E_{iHMO}}. \quad (6)$$

In this adjustment formula, note that the maintenance cost factor a_{i0}, includes maintenance costs for those who die in the year. In the previous examples, we assumed that all costs incurred in the last year of life were associated with the mortality process. In addition, the cost factors a_{ij} for a protracted chronic condition, say j, must be accrued for more than the last year of life. In the previous examples, we accrued costs for IHD events and CVD events by using the probable number of previous events prior to death. This cost accrual was modeled here with a bioactuarial model. Note also that in the examples above, we did not consider any maintenance costs but only mortality costs.

Naturally the mortality rates $m_{ij}^{(k)}$ will not be known, prospectively. However, in the absence of a medical breakthrough or change in recruitment, mortality rates for major causes of death change slowly in both the county and HMO enrolled cohorts. Therefore, the recent past experience can be used to adjust future cost estimates.

We note that if the county and HMO enrolled cohorts have the same mortality experience for each demographic category and, in addition, have the same proportion of their population in these demographic categories, then the adjustment factor is unity. In other words, the county average per capita cost can be used as an estimate for the health care costs of the enrolled HMO cohort. If the mortality experience is different, however, then health care costs will differ even though the distribution of health care costs across demographic factor groups are the same for HMO enrolled and county cohorts. In addition, if the mortality experience of both the HMO enrolled cohort and the county are equal to that of the U.S. for each demographic group, then equation (2) and equation (6) will be equal, regardless of the values of E_{iCO} and E_{iHMO}.

X. CONCLUSION

In summary, the onset rates of the mortality processes in a cohort can have a considerable impact on the incurred health care costs. However, in assessing future health care costs for a cohort, one cannot determine *a priori* what the rate of onset of IHD or CVD is in the cohort. Only retrospectively can this be estimated using, for example, the methods illustrated here. In the absence of a medical breakthrough, changes in cohort recruitment, or some other major intervention, the chronic disease and mortality process onset rates change slowly in a cohort. Therefore, retrospective estimates of the morbid events associated with death can be used in forming prospective cost estimates by using recent mortality experience. This would be done by estimating the functions s'_x (i) using recent data. Under a stable recruitment and health care delivery system, these values can be assumed for the current enrolled cohort. For situations where a trend is suspected, estimation of s'_x (i) for different years will indicate how estimates should be changed. We note here that the use of s'_x (i) from the recent past experience to estimate cost resembles the methods used for calculating claim reserves for private health policies (see [1]).

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DISCUSSION OF PRECEDING PAPER

CLIFTON MAZE:

This discussion outlines my concerns about some of the assumptions and methods used in this paper.

The authors state that the AAPCC is "adjusted downward by 5 percent to represent cost savings expected in an HMO." However, many HMOs have developed efficient mechanisms for delivering medical care and are able to achieve savings of much more than 5 percent, while other HMOs may achieve no savings at all.

The authors cite recent research at HCFA that showed approximately 6 percent of the Medicare population die annually, accounting for over 31 percent of Medicare's reimbursements. My review of the given reference indicated the reimbursement for decedents was 28 percent rather than 31 percent. Furthermore, other studies of the Medicare population showed substantially lower reimbursement percentages. One study (Piro and Lutins, 1973) found that enrollees who died during 1967 accounted for 22 percent of program expenditures. A later study covering 1979 (Helbing, 1983) found that 21 percent of Medicare expenditures were for persons who died.

The cited study excluded enrollees sixty-five and sixty-six years of age. When the experience of the entire Medicare population sixty-five years and over is reflected, only 5 percent rather than 6 percent of the Medicare population die annually.

The authors reference and calculate values based on Medicare Part A and B charges. However, under Medicare, costs are not necessarily equal to charges. Since the terms have distinct definitions, the authors' interchangeable use of them probably affects some of the values calculated using table 1.

Understanding sections III and IV is more difficult because the authors do not illustrate how to calculate their resultant values. In section IV, the authors conclude that a "small difference between the total mortality rates . . . resulted in a 6 percent difference between the AAPCC estimate and expected Medicare charges." I compared the assumed county rates (0.04, 0.05, 0.07) with the sample enrolled rates (0.05, 0.07, 0.09). The enrolled rates are respectively 25, 40, and 29 percent higher than the county rates. Using the proportion of individuals from each age group (0.5, 0.3, 0.2) as weights, the overall enrolled mortality rates are 31 percent higher than the county rates.

I am not convinced that a 31 percent greater chance of dying is a relatively "small difference." But if the combined enrolled mortality rate were, say, 5 percent higher than the combined county rate, the resultant difference between the AAPCC estimate and expected Medicare charges would be less than 1 percent. Similar concerns arise with the authors' attempts to illustrate that the distribution of causes of death is an important factor in health care costs. Here, although the total mortality rate is identical for the county and the enrolled, the enrolled rates by cause are not reasonable deviations. The deviations range from −75 to +40 percent. The authors applied the costs of table 2 to these rates. Yet, it was not clear how the costs in table 2 could have been readily approximated from the results given in the paper's cited reference.

ROLAND E. KING:

The authors are to be congratulated on an interesting theoretical discussion of how mortality affects health care costs and how a mortality-adjusted model for health insurance premiums might be developed. However, most actuaries who have had practical experience with rate setting and who might contemplate using a mortality-adjusted model would want to weigh the enormous cost of developing such a rate setting mechanism against the resultant marginal improvement in precision. The authors demonstrate in section III that it would require an enormous differential in mortality experience (in excess of 30 percent) to result in a 6 percent change in the AAPCC.

The authors' use of the word "accurate" to describe the operational basis of the AAPCC is somewhat misguided. When Congress enacted Section 114 of the Tax Equity and Fiscal Responsibility Act of 1982, authorizing AAPCC reimbursement to HMOs and competitive medical plans (CMPs), it never intended that the AAPCC be in any sense an accurate estimate of the costs of the HMO or CMP to treat a cohort of enrollees. Indeed, the legislation specifically requires that the AAPCC be an estimate of what a group of enrollees would have cost had they not been enrolled in an HMO or CMP. The factor of 95 percent which is applied to the AAPCC to determine the HMO or CMP payment amount is a policy target, not an estimate of how much more efficient HMOs and CMPs are. Thus, the AAPCC is simply a device to pay HMOs and CMPs prospectively in a manner consistent with their business practices. Most efficient HMOs are operating at less than 95 percent of the AAPCC, and an HMO or CMP operating as high as 95 percent of the AAPCC would be ill advised to choose risk-based reimbursement.

It is interesting that the authors have advocated the use of the mortality-adjusted rate structure for the AAPCC and the elderly only, while having demonstrated that mortality differentials generally have a greater effect on health care costs at the younger ages. Perhaps this is tacit recognition that most health insurance companies would find the method impractical and cumbersome. If this is the case, why do the authors feel the Medicare program would not find the method impractical as well?

As the authors have demonstrated, the mortality-adjusted model is useful only when the mortality of the HMO or CMP population differs substantially from that of the general population in a particular geographic area. In the final analysis, the "accuracy" of the mortality-adjusted model is highly dependent upon the ability to estimate in advance the difference in the mortality experience of the HMO or CMP from that of the general population. Put another way, the improvement in the AAPCC estimate is only as good as the ability to predict mortality differentials. The authors dismiss this concern with the statement: "In the absence of a medical breakthrough, changes in cohort recruitment, or some other major intervention, the chronic disease and mortality process onset rates change slowly in a cohort." However, it is very likely that in a group the size of many HMOs, mortality experience would fluctuate unpredictably from year to year.

JEFFREY PETERTIL:

The authors' fine paper is a timely contribution to the growing body of actuarial commentary on health care costs and the elderly. In table 1, they have isolated a noteworthy set of statistics from the Gresch and Leong paper that appeared in *TSA*, XXXIV (1982). The relationship between health care costs for survivors and nonsurvivors and the way that relationship changes with age should be of interest to all actuaries working in this field. The authors' comments on the possible ramifications for equitable financing of group care if these relationships are ignored are quite pertinent.

In seeking a framework for annualization of costs related to morbidity, the authors have followed the lead provided by table 1 and have chosen to relate costs to the likely survivor/nonsurvivor proportions of a population. This leads to their thesis that examination of mortality rates by cause of death will provide the means to adjust cost estimates to more accurately reflect the health risk of a group.

My observation is that these adjustments would use mortality statistics to answer a morbidity question. The authors note that the recommended mortality statistics are readily available and that 40 percent or more of the medicare charges are attributable to what they call mortality processes. This does leave, however, over half of the costs unexplained by the recommended statistics. Much theoretic work remains; therefore, I would suggest we continue the analysis proposed by the authors but attempt to incorporate morbidity statistics. Such morbidity data are not as readily available as the recommended mortality statistics, but they are growing in volume and availability. One example is the data base currently being generated in conjunction with the Medicare, prospective-payment system which uses diagnosis-related groups. This paper's foray into this area serves the dual purpose of presenting a framework for current analysis or adjustment and providing an example of the type of analysis which will be useful in probing the growing and evolving body of morbidity data.

(AUTHORS' REVIEW OF DISCUSSION)

H. DENNIS TOLLEY AND KENNETH G. MANTON:

The comments on our paper clarify certain important issues and also correct some details. We appreciate the efforts of the discussants in making these points. Our specific responses to these should clarify the paper's thesis.

With respect to the 31 percent of Medicare reimbursement accounted for by those dying, we agree that Lubitz and Prihoda [5] quoted 28 percent. Our figure came from an earlier presentation of this paper. From the results of Gresch and Leong [2], the percent of Medicare reimbursements attributed to those dying are 24.9 percent for males and 19.1 percent for females. This estimate, however, is based on death during the calendar years 1975-77 and not based on the last year of life. Both figures would be adjusted upward to account for the costs during the last complete year of life.

The "small difference between total mortality rates" is correctly pointed out to result in a 31 percent higher overall mortality rate. The use of the word "small" is incorrect. The intent of the phrase was a note on obtainable mortality pattern. Mr. King points out mortality experience at the HMO level can fluctuate from year to year. Similarly, different groups of enrollees can experience widely different mortality rates even though the underwriting risk factors used in the AAPCC calculation would imply the groups are similar. This is illustrated by the Benton County-Davis County example. This potential for wild behavior in relative overall mortality rates from one group of enrollees to another supports the thesis that mortality experience of the cohort should be a parameter of the cost formula.

In the paper "costs" and "charges" are used interchangeably. The Medicare charges are the costs to the Medicare program although not the costs incurred by the HMO and not the costs charged to the patient. The cost figures used serve to illustrate the use of a mortality based index. The only constraint for this illustration to be applicable to overall costs is that the relative cause specific costs for death be the same as in table 2. Otherwise, the values given in tables 8 and 9 must be multiplied by different factors. The values in table 2 agree with those quoted by Hartunian, Smart, and Thompson [3].

The phrase "accurately estimate the per capita medical costs" refers to estimating the Medicare costs that would have been paid had the individuals not been enrolled in the HMO. Although the proposed method would be useful in structuring rates for an individual HMO, mortality costs specific to the HMO would be required. In the present paper improving the accuracy of estimated medicare costs (not HMO costs) requires using Medicare mortality costs. Any source of inaccuracy in the estimate of what Medicare costs would have been incurred will provide the basis for antiselection with regard to HMOs electing the risk option. HMOs, whose capitation costs are overestimated, will tend to make a greater profit while those with underestimated capitation rates will not select the option.

There are three points of concern in implementing the mortality adjustment in forming estimates. The first of these regards solving the Fredholm equation to back forecast costs associated with the death process. These costs are assigned at the time of death but may be incurred for several months or years prior to actual demise. Fortunately these estimates need to be made only once with occasional updates as patient care changes. These equations and back forecasts need not be made by each HMO. The second concern regards the advance estimation of mortality rates. However, bias in these estimates can be retrospectively corrected by additional payments or refunds according to the deviation of actual mortality experience from predicted. In this sense the mortality adjustment plays the role of a reinsurance index. Instead of paying for costs in excess of a fixed amount as in stop loss, the reinsurer (HCFA) would pay an additional amount for each death (or each death over a specified number). Unfortunately, this scenario brings up the third concern—the association of a reward to the HMO for each death. This problem was pointed out in a report by Cookson (1982). This undesirable characteristic would appear to limit the utility of the mortality index in the public reimbursement formula. However, the use of mortality in a cost index is useful from a budget and internal control perspective.