Comparing Underlying and Multiple Causes of Death in Analyzing Mortality among the Elderly: United States, 1986-1997

Isaac W. Eberstein, Charles B. Nam & Kathleen M. Heyman

Center for Demography and Population Health
&
Department of Sociology

Florida State University
Tallahassee, FL 32306-2240 USA

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Contact Information:
Isaac W. Eberstein, Center for Demography and Population Health, Florida State University, Tallahassee, FL 32306-2240 USA. 850-644-7108 (voice), 850-644-8818 (fax), eberstein@fsu.edu.

Charles B. Nam, Center for Demography and Population Health, Florida State University, Tallahassee, FL 32306-2240 USA. 850-644-7107 (voice), 850-644-8818 (fax), charlesnam2@earthlink.net.

Kathleen M. Heyman, Center for Demography and Population Health, Florida State University, Tallahassee, FL 32306-2240 USA. 850-644-3311 (voice), 850-644-8818 (fax), kmh3956@fsu.edu.

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Abstract

This paper compares unadjusted and age-adjusted mortality rates by underlying and multiple causes of death for adults ages 55 and over in the USA, according to age, sex, and race/ ethnicity. Data include 44,433 death records corresponding to a population of 203,924, taken from a linked file combining the US National Health Interview Survey (NHIS) (1986-1994) and the Multiple Cause of Death (MCD) file of the National Death Index (NDI) (1986-1997). Eight causes of death are specifically considered: heart disease, malignant neoplasms, cerebrovascular diseases, chronic obstructive pulmonary diseases, diabetes mellitus, pneumonia and influenza, and hypertension, along with a category of all other deaths. Both total mentions and cause combinations are examined. Findings suggest, first, that the total numbers of deaths associated with particular causes are substantially greater than is indicated by underlying cause. Second, the large number of combinations of causes evident in the data is not consistent with the homogeneity that is implied by the concept of a single underlying cause. Third, known mortality differentials by age, sex, and race/ ethnicity as indicated by the multiple cause data are generally consistent with prior research, but there is substantial variability in these patterns that is worthy of more detailed inspection. Although data limitations remain important constraints on this and other analyses of multiple cause data, the findings support the general conclusion that multiple cause data are preferable to analyses based solely on the concept of underlying cause of death. Multiple cause data may play an increasingly important role in helping to integrate research from diverse intellectual traditions that deals with questions of health disparities among the elderly in high income countries.

Mortality among elderly populations of high income countries is a topic of substantial and increasing interest, particularly as the concern with overall mortality rates evolves into work emphasizing more the levels and trends of specific causes of death. Questions about particular medical conditions such as hypertension or heart disease can inform our understandings of the patterns of death at the oldest ages by linking demographic research to ongoing work in epidemiology and public health. However, one barrier to the full realization of the potential of this type of research is the typical reliance on the concept of "underlying cause" as a single indicator of the medical conditions present at the time of death. Underlying cause refers to the "disease or injury that initiated the train of morbid events leading directly to death, or the circumstances of the accident or violence which produced the fatal injury" (NCHS, 2005a). However, conceptual considerations as well as some prior research suggest that failing to consider co-morbidity dramatically understates the true magnitude and causal structure of mortality linked to particular diseases or conditions (Manton and Stallard, 1984; Nam, 1990; Stallard, 2002; Ruzicka, Choi and Sadkowsky, 2004). Nonetheless, there has been only relatively limited research using multiple cause information to characterize mortality patterns. The purpose of the present study is to compare and contrast mortality rates by underlying and multiple causes of death.

Specifically, we use mortality data from the linkage of the US National Health Interview Survey (NHIS) (1986-1994) with the National Death Index (NDI) (1986-1997) for persons ages 55 and over (NCHS, 2005d). We examine seven leading medical causes of death in the USA, plus a residual category that includes all other causes, and look in particular at comparing combinations of these conditions with and without specification of an underlying cause of death. We also examine the total mortality burden of these conditions as measured by death rates where each is mentioned as either the underlying or as an associated cause. We describe cause-specific mortality by age, sex, and race/ ethnic status (unadjusted and age-adjusted). The theme of the analysis is to consider the "value added" by information on multiple causes of death.

Prior Research

There is substantial demographic research on mortality differentials by cause of death (e.g., Rogers, Hummer and Nam, 2000), but surprisingly little goes beyond the conventional approach emphasizing a single, underlying cause. Although one reason for this has likely been a public health strategy of targeting prevention/ intervention efforts, other disciplinary needs are emerging that call for a more comprehensive approach. Research on questions of population health increasingly combines work from the diverse traditions of health/ medical demography and epidemiology by emphasizing a common concern with how the full range of social and medical risks are translated into differential rates of death that are observed across important demographic groups (e.g., Massey, 2004; Kuh and Ben-Shlomo, 2004; Marmot, 2004; Seeman, 2004; Crimmins and Seeman, 2005; Steptoe and Marmot, 2005; Vaupel, 2005). A more comprehensive approach to the concept "cause of death," one which enables the identification of the contributions of multiple medical conditions, may be particularly important in this regard.

There have been several discussions of the relative conceptual and empirical merits of identifying multiple causes as opposed to only the underlying cause of death, going back more than eighty years and continuing to the present (e.g., Dublin and Van Buren, 1923;

Israel, Rosenberg and Curtin, 1986). No real benefit is gained by reviewing these here (see Nam, 1990 for a detailed review of key issues). However, it is more than a little ironic that there is still a felt need to justify research which departs from the conventional single-cause strategy. Apart from the general strength of the idea that there are multiple causes of death as identified in prior discussions of the concept, it is most fundamentally through recognition of multiple conditions that disease-specific studies of high income populations (e.g., studies of hypertension or diabetes) can be linked to demographic mortality research (e.g., of heart disease or stroke). This much seems to be a point of consensus.

Nonetheless, there also seems to be some contention regarding the assessment of the relative benefits, in terms of substantive insights to be gleaned or new knowledge to be gained, from using multiple cause of death data. One basis for this disagreement concerns questions of accuracy, completeness/ comprehensiveness, and reliability in cause of death reports (Kircher, Nelson and Burdo, 1985; Sirken, Rosenberg, Chevarley and Curtin, 1987; Lloyd-Jones, Martin, Larson and Levy, 1998), which are presumably much more pressing for analyses emphasizing co-morbidity. This limitation is well-known in regard to some diseases, such as diabetes, where substantial under-reporting has been documented on death certificates for some time (Bild and Stevenson, 1992; Ochi et al., 1985). A second is the additional and substantial complexities in analyzing multiple cause data (Stallard, 2002; Manton and Stallard, 1984). Although some studies suggest underlying cause data are acceptable for some causes of death (e.g., lung cancer [Mannino, Ford, Giovino and Thun, 1998), no researcher to our knowledge has explicitly claimed that analyzing underlying cause data is preferable. Still, the relative surfeit of work based on underlying cause, in comparison with a lack of multiple cause studies, clearly demonstrates that this is the practice of researchers in the field. We share with other researchers the theoretical conviction that multiple cause data are preferable to relying solely on underlying cause of death, and we are committed to empirically examining these points of contention. Our immediate objective is to contribute to the cumulating body of empirical work in this area. The long term goal of this research is to facilitate analytical innovations and improvements in data systems such that multiple cause information becomes the standard for demographic research on differential mortality and a bridge to link these studies with the work of other researchers around the concept of population health.

Data & Methods

Data. The data come from the linked file of the National Health Interview Survey, 1986-1994 (NCHS 2005d), with the National Death Index, 1986-1997 (NCHS, 2005c).[1] Matches of NHIS survey respondents to the NDI are based on a program designed by NCHS that uses a probabilistic scoring algorithm to best determine which individuals interviewed in the NHIS subsequently died during the follow-up period (NCHS, 2005e).[2] The combination of the NHIS and NDI generates in effect a cohort data set containing prospective social, economic, and health information and later mortality follow-up that is very useful for national mortality analyses, although even such a large sample is tested by the demands of creating combinations of detailed cause of death categories. Although the

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[1] A more current version of the data set has been made available by NCHS, although restrictions to on-site use effectively preclude analysis by researchers without active grants (NCHS, 2005e).

[2] The approach assigns weights to 12 criteria—including social security number, first and last name, middle initial, father's surname, birth month and year, age, sex, race, state of birth, and state of residence—and sums the weights to determine the quality of the potential matches. After summing, the potential matches are classified into one of five classes based on the strength of the match. We use the cut point for identifying decedents that NCHS recommends, which is estimated to correctly classify over 97 percent of individuals (NCHS, 2005e).

general US vital statistics file might be preferable because of a larger number of cases (e.g., Stallard, 2002), we are engaged in other on-going work using these data to study social and economic differentials in multiple causes of death, and it is here that the NHIS-NDI data file is superior to alternatives because of the breadth of information it provides.

The NHIS-NDI data set has well known strengths and relatively limited weaknesses for purposes such as ours (cf. Rogers, Hummer & Nam, 2000). Among the strengths are having individuals or household members as sources for information on an extensive range of social, demographic, economic, and health variables, gathered prospectively. One particular benefit of this strategy is to improve consistency in characteristics such as race/ ethnicity which might be used in analysis, in contrast to studies combining vital and census records. In addition, the NHIS samples are large and national in scope.

The most important limitation of the data set is likely that the sample frame for the baseline NHIS includes only the civilian non-institutionalized population, thereby excluding the least healthy people, most notably persons residing in nursing homes and prisons. One consequence of this exclusion is that death rates estimated from these data are generally lower than from US vital statistics data (Hummer et al. 1999). This is particularly the case at the oldest ages, where the percentage in nursing homes is highest (US Bureau of the Census, 2003). Similarly, specific causes of death likely more characteristic of the institutionalized population (e.g., Alzheimer's disease and other forms of dementia) will be underrepresented until the NHIS samples age sufficiently so that the proportion institutionalized at the time of death more closely approximates the national percentage.

Finally, the NHIS linkage to the NDI is not exact, and this may affect the accuracy of the indicated mortality rates (cf., NCHS, 2005e). Some of the records in the NHIS do not have sufficient information to match to the NDI, resulting in some 2% of cases being lost to follow-up. The problems of incomplete information and erroneous matches are likely more severe for Hispanics than others, due to different naming practices, possibly lower/ less accurate use of social security numbers, and to possible emigration from the US after participating in the NHIS (e.g., the so-called "salmon bias" [Palloni and Arias, 2004; Palloni and Morenoff, 2001]). The extent of the resulting bias, while unknown, is probably not large, although it may affect the validity of specific comparisons involving Hispanics (Patel, Eschback, Ray and Markides, 2004a; 2004b).

Measures. The analysis is based on a scheme of eight causes of death, identified though ICD-9: heart disease excluding hypertension [Heart] (390-398, 402, 404, 410-429), malignant neoplasms [Cancer] (140-165, 170-175, 179-208), cerebrovascular diseases [Stroke] (430-438), chronic obstructive pulmonary diseases [Respiratory] (490-496), diabetes mellitus [Diabetes] (250), pneumonia and influenza [Flu] (480-487), hypertension [Blood pressure] (401, 403), and all other causes, including external causes [Other]. Although additional conditions are identified in the data set, the analysis is limited to these leading causes to insure there are sufficient cases for examination according to demographic characteristics of interest. Nonetheless, it is still the case that we are constrained by inadequate sample size for Hispanics and Other race/ ethnic groups except for the leading causes of death. Hypertension is separated from other conditions commonly grouped within the category of heart disease because of its importance as a unique risk factor, alone and in combination with other conditions. Although deaths from external conditions may not typically be considered when attention is focused on multiple causes, recent evidence demonstrates that combinations of conditions may be important even for these causes of death (Ruzicka et al., 2004).

There are two approaches to identifying and analyzing multiple cause of death data, total mentions and cause combination (Nam, 1990; Wrigley and Nam, 1987). Both are based on death certificate reports (NCHS, 2005b). Multiple cause approaches go beyond the information on underlying cause by incorporating additional information on medical conditions that contributed to death, either as part of the chain of events subsequent to the underlying cause (Part I) or as a significant contributing condition that was distinct from the underlying cause (Part II). We use both total mentions and cause combinations approaches here.

Total mentions mortality rates are computed by allocating each death to every cause that appears in any of these fields anywhere in the death record. Each death can be counted multiple times, reflecting all of the identified medical conditions associated with it. Thus, the sum of the mortality rates across the various total mentions cause categories does not equal the actual overall death rate. Total mentions rates are superior to underlying cause rates as a way to identify the total burden of deaths associated with particular medical conditions. Rather than dying “from” one or another underlying cause, total mentions rates reflect the relative level of deaths “with” each of these conditions. This is an important distinction for several reasons, including the interdependence of various medical conditions (Stallard, 2002), the probability of a multiplier effect of having multiple medical conditions on the odds of death, and the likelihood that attribution of causal priority to one or another of these multiple medical conditions is imprecise within the bounds of current diagnostic practice and etiologic convention (Sirken et al., 1987). For present purposes, the total mentions rates provide an “upper bound” of mortality associated with each medical condition.

In contrast, a cause combinations approach counts each death only once and examines particular combinations of conditions. This approach maximizes the detailed description of the unique combination of medical conditions, and it provides a useful contrast to the assumed homogeneity of one disease as “the” cause of death which is implicit in both the underlying cause and the total mentions approaches. There are two particular strategies of cause combination, one within the categories of underlying cause and the second across these categories. We follow both strategies in this study. Additional description of these approaches will be delayed until data are presented.

Methods. The analysis is a straightforward application of demographic methods of direct standardization and comparison of rates. There are 203,924 persons ages 55 or older who were included in the NHIS between 1986 and 1994, and 44,433 of them appear to have died as of December 31, 1997, based on the NDI match procedures (21.8%). Because this figure characterizes the aggregate mortality experience of various populations over periods ranging from as short as 4 years (1994-1997) to as long as 12 years (1986-1997), depending on the date of the original NHIS survey, it is appropriate to express rates in terms of person years of exposure from the time of the NHIS survey through 1997. Such a computation generates an overall mortality rate of 3,118 deaths per 100,000 person years (shown below in Table 1).

Finally, because our interest is in comparing various ways of taking co-morbidity into account and whether/ how this may affect comparisons among sub-populations, we are not especially concerned with making comparisons to national population figures. Thus, to simplify the analysis we use unweighted data from the NHIS-NDI. One consequence of this decision is that we do not present significance tests for demographic differences (e.g., by sex or race/ ethnicity), because the computation of these tests requires adjustment for the complex sampling frame of the original survey. Rather, we simply highlight cells based on fewer than 25 deaths in order to provide some guidance in regard to the stability of the estimated rate. We limit analysis of unique combinations of the eight cause categories to those with a minimum of 100 deaths.

Findings

Table 1 presents unadjusted and age-adjusted death rates for each underlying cause, overall and separately by age (unadjusted only), sex, and race/ ethnicity. Cause-specific mortality rates are listed in decreasing order of magnitude, with the residual category of "all other" causes at the end. This table affirms the well known picture of the leading underlying causes of death, with heart disease the first cause, followed by cancer, stroke, respiratory conditions, flu, diabetes and hypertension. Some variability is evident by age, with cancer mortality higher than heart disease among persons 55-64 years of age, and, indeed, while death rates from heart disease increase substantially by age (the rate for 85+ is more than three times for 55-64), cancer death rates are basically flat and even decline somewhat across these age groups (cf. Arbeev et al, 2005). Mortality from stroke, influenza, and hypertension tend to follow the same pattern as heart disease, while death rates from diabetes are more like the pattern for cancer. Deaths from respiratory conditions increase to ages 75-84, and then decline at the oldest ages.

Table 1

The data in Table 1 also affirm the well known sex mortality differential, with death rates for males higher than for females, overall and age-adjusted, for all underlying causes except hypertension. Death rates from hypertension as the underlying cause are essentially the same for males and females. In addition, there is some variability by sex in the ranking of these causes of death, with diabetes moving ahead of influenza among women.

Finally, race/ethnic mortality patterns are also as expected, with rates for Blacks generally higher than for Whites, and those for Hispanics and Other Races generally lower. One exception involves deaths from respiratory conditions as the underlying cause, where mortality is higher among Whites than Blacks in the age-adjusted rates. Diabetes is strikingly more important as an underlying cause of death among Blacks and Hispanics than among Whites. Although overall rates are not as high when considered as an underlying cause, deaths from hypertension are similarly about twice as common among Blacks than among either Whites or Hispanics. Even with these few categories of medical conditions, the numbers of deaths for Other Races are quite small for some of these causes, so only limited comparisons are made for this group, here and throughout the analysis.

The data in Table 1 on underlying causes of death provide the basis for comparison of the remaining tables in the paper. Table 2 contains total mentions mortality rates for the same medical conditions. As mentioned above, total mentions rates include each death multiple times, once for every medical condition associated with it. Thus, it is appropriate to consider total mentions rates as providing an upper bound of the mortality burden of each condition.

Table 2

Most striking in Table 2 is the substantially higher rates of mortality associated with particular causes, with most medical conditions contributing to 2-3 times more deaths than are reflected in the underlying cause of death statistics in Table 1. This is especially the case for hypertension, where the total mentions age adjusted mortality rate (AAMR) of 222 per 100,000 is almost 14 times higher than the rate of 16 when it is the underlying cause of death. Diabetes has a similar though not so extreme pattern, where this condition contributes to some 3.4 times more deaths than would be indicated by its role as underlying cause (AAMR of 275 versus 81). Clearly, hypertension and diabetes contribute many deaths where they are not considered the underlying causes and, thus, where their impacts are not apparent from conventional mortality statistics.

At the opposite extreme from hypertension and diabetes is cancer, where the total mentions AAMR of 932 is about 13% higher than the underlying cause death rate of 823. This suggests that where cancer is present at the time of death, diagnostic practice and etiologic convention typically lead to its being considered the underlying cause. Therefore, underlying cause mortality rates for cancer reflect more closely its reported prevalence at the time of death than for other medical conditions.

Intermediate between hypertension and cancer are the other medical conditions. Heart disease, like cancer, is typically considered the underlying cause of death when present, although it is noteworthy that heart disease is reported to contribute to almost two thirds more deaths than are identified by underlying cause statistics (AAMRs of 1659 [Table 2] and 1022 [Table 1]). Total mentions rates indicate that the other medical conditions in the table (flu, respiratory conditions, and stroke) contribute to from 2 to 3 times more deaths than are apparent than when they are listed as underlying causes.

Although the mortality rates in Table 2 certainly suggest that many medical conditions contribute to far more deaths than would be evident from the statistics on underlying cause, the general conclusions with regard to demographic differences are generally consistent with inferences from Table 1. The leading causes based on total mentions are the same overall and by age, except that the pattern of higher mortality from cancer than from heart disease at the youngest ages (55-64), evident in the data on underlying cause, is reversed such that heart disease is the leading cause of death at all ages. The same age pattern of mortality by cause is evident whether using total mentions or underlying cause of death. Similarly, the pattern of leading causes and differentials is the same by sex and by race/ethnicity for underlying cause and for total mentions.

Table 3 presents mortality rates from the combination of associated medical conditions within the categories of underlying cause as identified in Table 1, with the constraint we imposed of at least 100 total deaths for a particular combination to be separately identified. Within each underlying cause, subtotals present the same data as shown in Table 1. Beyond this, the rows identify the mortality rates associated with each particular combination of conditions. These data give weight to the diagnostic insight that is reflected when a particular medical condition is designated as the underlying cause of death. For example, in this table the combination of, say, “heart disease as underlying cause and diabetes as associated cause” in the top panel is considered separately from the combination of “diabetes as underlying cause and heart disease as associated cause” further down in the table. Interestingly, mortality rates are higher with heart disease as the underlying cause, but the pattern of demographic differentials is the same for these two combinations.

Table 3

Perhaps most striking in Table 3 is the wide variety of conditions associated with each underlying cause of death, and the varying levels of the consequent mortality rates. There are fifteen combinations of associated conditions with heart disease as the underlying cause (plus a residual category), nine for cancer, and fourteen for the residual category of “all other” underlying causes. In contrast, hypertension as an underlying cause does not have any combinations of sufficient size, and the other conditions have from four to six. For both cancer and heart disease, the combinations with the highest mortality rates are those deaths with no associated causes (e.g., “heart disease alone” or “cancer alone”). This is not the case for the other causes, where death rates for some of the combinations are higher than for the underlying cause alone. The sheer complexity of the patterns is an important finding.

One important question concerns the extent to which the pattern of demographic differentials for underlying causes of death varies across combinations of associated causes. To a large extent, overall patterns are reproduced. But, the magnitudes of the differentials vary substantially, and there are some reversals. For instance, gender patterns vary widely across the specific combinations of underlying causes and associated conditions. Similarly, differentials vary in both size and direction across race/ ethnicity, and the particular age pattern is not as consistent as would be assumed from the inspection of underlying causes of death. Although there is a tendency for general patterns to be replicated across the combinations, there is nonetheless substantial variability.

Table 4 also follows the general rubric of “cause combination,” but in this case the medical conditions are combined without regard to what is the underlying cause of death. That is, “diabetes and heart disease” are combined into a single category whether diabetes or heart disease is underlying. The only criterion we set is that each combination have a minimum of 100 deaths; thus, the patterns identified are contingent only on the range of medical conditions being considered and the extent of their association, both medically and in terms of the completion of death certificates. Varying judgment as to which among several medical conditions is underlying will not affect this kind of analysis, so long as all medical conditions present at the time of death are identified and recorded.

Table 4

Just as Table 3 emphasized the complexity of the range of associated conditions characterizing persons with the same underlying cause of death, the data in Table 4 highlight the complexity of combinations that appear when attention is not limited to which is underlying. Indeed, there are 25 combinations involving heart disease and twelve for cancer. Similarly, even the conditions less typically judged to be the underlying cause of death are well represented in a range of combinations. For instance, there are eleven different combinations involving flu, and ten for hypertension (including several four-way combinations such as heart disease, stroke, hypertension, and “other”). Certainly this approach to the data is well suited to illustrating the joint occurrence of these conditions. This is another important finding.

The general pattern of demographic differentials observed based on the earlier tables is also evident in the cause combinations in Table 4. However, there is more variability in the extent of age, gender, or race/ ethnic differentials across these combinations, along with more exceptions.

One useful way to interpret the cause combinations in Table 4 is as a decomposition of the total mentions mortality rates for each medical condition (from Table 2) without regard to underlying cause of death. So, for example, the overall AAMR for diabetes is 275 per 100,000 (Table 2), which is substantially higher than the death rate of 81 per 100,000 with diabetes as the underlying cause (Table 1). Inspecting the combinations for diabetes in Table 4, it is evident that most deaths involving diabetes occur jointly with heart disease, either alone (AAMR of 55) or with other conditions (six unique combinations with an aggregate AAMR of 103). Interestingly, aggregating these combinations in Table 4 suggests a greater mortality impact of heart disease and diabetes (AAMR of 158) than is evident from considering either to be the underlying cause of death, as in Table 3. That is, when heart disease is judged to be the underlying cause of death, the aggregate AAMR for this condition and diabetes jointly is 69 per 100,000. When diabetes is underlying, there are 35 deaths per 100,000 jointly with heart disease. The difference of 54 deaths per 100,000 related to the combination of diabetes and heart disease in comparison to the aggregated combinations in Table 4 is not inconsequential. Clearly, it is important to examine cause-specific mortality from a variety of perspectives in order to get a more comprehensive view of the extent of deaths associated with particular medical conditions, alone and in combination with others.

Discussion

Although the concept of underlying cause of death has proven useful in medical research and practice, the findings of this research indicate that focusing exclusively on single causes of death is an over-simplification that obscures both the total mortality burden of particular medical conditions as well as their joint effects. There are substantially more deaths associated with particular diseases than are reflected in underlying cause statistics. Further, the idea of underlying cause of death implies a homogeneity in health conditions that is not consistent with the large number of combinations evident in the data, even among decedents sharing the same underlying cause. When examined across underlying causes, an even larger number of combinations is apparent. Indeed, one inference suggested by the data concerns just how much the idea of underlying cause oversimplifies the description of the morbid status of elderly persons, particularly those in high income, low mortality countries, where most deaths occur from chronic disease. Although the idea of underlying cause is useful in targeting prevention/ intervention efforts, it is a barrier to synthesizing research from health/ medical demography and epidemiology that share a focus on how disease processes that involve the operation of multiple conditions may be reflected in mortality statistics.

Beyond the existence of combinations and the high level of mortality burden hidden by underlying cause of death statistics, the analysis also examined basic differentials across demographic categories of age, sex, and race/ ethnicity. Two important inferences from the findings are both that generalizations from prior research are reproduced in the multiple cause data (e.g., known differentials by age, sex, and race/ ethnicity appear consistent with prior research) and that there is substantial variability in these patterns that is worthy of more detailed inspection (e.g., two examples are the divergent age pattern of cancer mortality and the varying death rates associated with diabetes alone and in several combinations jointly with heart disease).

These are important findings, but it is also important to acknowledge limitations in the precision with which these assessments could be made because of the possibility of systematic data limitations – particularly the accuracy and completeness in the assessment of the full range of medical conditions present at the time of death and the completeness and reliability of the recording of these conditions on death certificates. Many problems are known to exist in death certificate reports of some of the conditions of particular interest here (e.g., diabetes [Bild and Stevenson, 1992; Ochi et al., 1985]). Further, how diagnostic practice and etiologic convention may impact the way in which death certificates are completed (and the extent to which multiple conditions are reported at all) is also particularly germane.

It is unfortunately typical that studies of multiple cause data end with calls for improvement in regard these critical issues, and it does seem as if these data are improving over time. Still, autopsy rates are low (Hoyert, 2001), so that morbid conditions and, particularly, the combination of conditions present at the end of life may not be fully known. Similarly, the completion of death certificates is reportedly often not a high priority for medical personnel, so that even if medical conditions are accurately observed at the time of death, whether these are fully and reliably recorded is not assured. It is important to continue to develop data systems that minimize these shortcomings.

These limitations aside, it is also important to acknowledge other constraints on the analysis reported above. First, although the NHIS-NDI data set is extensive and included over 44,000 deaths of persons ages 55 and older, there was nonetheless a problem in regard cell size in some cause combinations for all groups and particularly for Hispanics and Other race/ ethnic groups. National vital statistics data would have provided more cases for even the least common conditions (e.g., Stallard, 2002), but the present work is part of a larger effort focused on the analysis of social and economic differentials in multiple causes of death, where the NHIS-NDI data are particularly well-suited (e.g., Benjamins, Hummer, Eberstein and Nam, 2004).

Second, as mentioned above, the quality of the NHIS-NDI linkages may vary by race/ ethnicity such that there are a greater number of cases lost to follow-up among Hispanics. This might help to account for their observed generally lower adult mortality (cf. Palloni and Arias, 2004; Patel et al., 2004a; 2004b).

Overall, the analysis reported above contributes to the increasing body of literature supporting the principle that multiple cause of death reports are preferable to strategies emphasizing a single underlying cause of death. These efforts typically add value above and beyond underlying cause reports and can contribute to the integration of work from diverse points of view that will provide a more comprehensive synthesis of health and demographic perspectives on the morbidity and mortality of the elderly. Less clear is our contribution to an affirmative conclusion in regard to concerns over data quality and analytical complexity. Albeit methodologically straightforward, our analytical approach is certainly constrained by issues of data quality and the need for even larger sample size to enhance the reliability of the estimated mortality rates. This challenge provides an important task for the future.

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Table 1. Mortality Rates[a], Unadjusted and Age Adjusted, for Selected UNDERLYING CAUSES of Death through 1997 among NHIS respondents (1986- 1994) ages 55 and older, by Age, Sex, Race.

Cause of Death[b]	Unadjusted											Age Adjusted						
Underlying Cause	Total Population					Sex		Race/Ethnicity										
	Total	55-64	65-74	75-84	85+	Male	Female	White	Black	Hispanic	Other	Total	Male	Female	White	Black	Hispanic	Other
Heart (H)	1087	670	853	1594	2070	1308	926	1094	1233	729	697	1022	1292	821	1011	1226	752	693
Cancer (C)	803	907	776	812	583	1033	636	810	910	519	499	823	1045	658	830	942	528	517
Stroke (S)	209	101	160	330	438	207	211	210	226	181	142	192	200	183	188	220	188	138
Respiratory (R)	148	116	145	193	129	197	113	160	107	71	77	142	191	109	153	106	75	84
Influenza (F)	102	31	71	165	289	125	84	104	98	76	71	90	121	71	90	94	81	68
Diabetes (D)	80	85	77	82	68	84	76	68	144	126	83	81	84	77	67	149	133	89
Hypertension (B)	17	9	12	28	35	15	19	15	33	12	22	16	15	16	14	31	13	22
All Other (O)	672	467	530	940	1228	786	588	674	731	518	543	641	784	538	632	736	541	557
Total	3118	2388	2625	4144	4840	3757	2653	3136	3484	2231	2133	3008	3733	2473	2986	3504	2310	2171
N of deaths	*44433*	*8879*	*15357*	*14587*	*5610*	*22515*	*21918*	*36459*	*5954*	*1328*	*692*	-	-	-	-	-	-	-

[a]Rates per 100,000 person years. Shaded cells indicate rates based on 25 or fewer deaths. Age adjustments reflect the US 2000 standard population.

[b]Causes of death based on ICD-9. Diseases of Heart [Heart] (390-398, 402, 404-429), Malignant Neoplasms [Cancer] (140-165, 170-175, 179-208), Cerebrovascular Diseases [Stroke] (430-438), Chronic Obstructive Pulmonary Diseases [Respiratory] (490-496), Diabetes Mellitus [Diabetes] (250), Pneumonia & Influenza [Flu] (480-487), Hypertension with or without renal disease [Blood Pressure] (401, 403), and All Other [Other].

Table 2. Mortality Rates[a], Unadjusted and Age Adjusted, From TOTAL MENTIONS of Selected Causes of Death by Age, Sex and Race (Ages 55+).

Cause of Death[b]	Unadjusted											Age Adjusted						
Total Mentions	Total Population					Sex		Race/Ethnicity										
	Total	55-64	65-74	75-84	85+	Male	Female	White	Black	Hispanic	Other	Total	Male	Female	White	Black	Hispanic	Other
Heart (H)	1751	1161	1422	2476	3105	2113	1487	1750	1994	1339	1205	1659	2087	1343	1631	1987	1387	1214
Cancer (C)	919	979	875	985	755	1204	712	929	1031	588	573	932	1210	729	940	1061	600	591
Stroke (S)	409	204	322	632	832	423	399	407	474	321	311	376	410	347	366	459	330	307
Respiratory (R)	372	282	367	485	343	520	264	400	273	197	216	355	502	252	380	269	202	217
Influenza (F)	293	134	227	449	663	381	229	300	280	234	213	267	368	200	269	266	245	215
Diabetes (D)	280	252	270	331	262	306	260	253	429	380	262	275	301	255	244	433	389	273
Hypertension (B)	232	168	197	321	349	232	232	213	374	222	191	222	230	212	199	373	229	194
All Other (O)	1693	1184	1382	2350	2906	2021	1454	1699	1877	1326	1175	1615	2001	1337	1596	1865	1374	1204
Total[b]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[a]See Table 1 for description of study population and ICD-9 codes. Rates per 100,000 person years. Shaded cells indicate rates based on 25 or fewer deaths. Age adjustments reflect the US 2000 standard population.

[b]The total mortality rates are not applicable since deaths are counted multiple times.

Table 3. Mortality Rates[a], Unadjusted and Age Adjusted, from Combinations of Associated Medical Conditions WITHIN Underlying Causes of Death by Age, Sex, and Race (Ages 55+).

Cause of Death	Unadjusted											Age Adjusted						
AC Combinations within UC	Total Population					Sex		Race/Ethnicity										
	Total	55-64	65-74	75-84	85+	Male	Female	White	Black	Hispanic	Other	Total	Male	Female	White	Black	Hispanic	Other
HEART (H)																		
Heart only	458	309	363	644	853	562	382	460	530	291	318	436	560	338	431	529	304	309
C	21	11	15	34	37	32	13	21	22	12	12	19	31	12	19	21	12	13
CO	13	5	10	22	26	17	10	13	15	7	3	11	17	8	11	15	6	3
S	31	14	21	47	87	30	32	31	35	17	31	28	30	27	28	33	16	30
SO	29	9	20	48	79	28	29	28	33	17	31	25	28	24	25	31	17	29
R	38	25	35	57	34	58	23	41	23	18	18	35	55	21	39	23	18	18
RO	27	18	23	41	42	39	19	30	18	12	22	26	38	18	28	19	11	20
F	13	2	6	24	46	14	12	13	12	12	9	11	14	10	11	11	13	9
FO	14	3	8	25	46	16	13	15	8	8	9	12	15	11	13	7	9	10
D	37	34	38	40	31	43	33	34	60	37	28	37	43	32	33	61	37	30
DB	8	7	8	11	4	8	9	7	16	22	9	8	8	8	6	16	22	9
DO	25	22	21	33	30	26	24	25	22	29	34	24	25	24	24	22	30	38
B	29	19	24	40	48	32	26	28	42	15	15	27	32	23	26	42	16	16
BO	21	12	14	33	46	21	21	20	33	15	3	20	20	18	18	34	16	2
O	254	142	181	390	564	296	223	258	277	170	120	237	294	195	236	277	176	123
Remainder	71	37	66	105	97	87	59	71	87	49	34	65	83	53	63	85	48	34
Subtotal	*1087*	*670*	*853*	*1594*	*2070*	*1308*	*926*	*1094*	*1233*	*729*	*697*	*1022*	*1292*	*821*	*1011*	*1226*	*752*	*693*
CANCER (C)																		
Cancer only	368	459	359	339	209	450	309	378	400	178	182	385	460	328	396	428	177	191
H	75	78	68	85	74	99	58	73	93	71	68	76	100	59	73	95	77	72
HR	8	8	7	10	5	12	5	9	4	5	12	8	12	5	8	5	6	12
HO	48	44	41	55	70	62	37	47	61	35	9	47	63	36	47	62	34	8
R	16	18	19	14	4	26	9	18	9	5	3	17	26	9	19	10	4	2
RO	16	18	16	16	8	23	11	17	13	7	6	16	22	12	17	14	8	6
F	12	12	13	12	12	19	8	13	11	5	18	12	19	8	13	10	5	20
FO	13	12	14	14	11	22	7	13	16	12	12	13	21	7	13	15	11	11
O	164	177	160	170	126	216	126	163	198	121	111	167	218	129	166	197	120	118
Remainder	83	80	80	97	64	106	66	80	105	81	77	82	104	66	79	106	84	77
Subtotal	*803*	*907*	*776*	*812*	*583*	*1033*	*636*	*810*	*910*	*519*	*499*	*823*	*1045*	*658*	*830*	*942*	*528*	*517*
STROKE (S)																		
Stroke only	50	25	38	79	105	45	54	52	49	20	22	46	44	47	47	49	19	20
H	17	8	13	26	44	16	18	18	13	13	12	16	16	16	17	13	14	10
HO	17	5	13	28	49	17	17	18	13	8	15	15	16	14	16	12	8	15
B	10	6	10	14	13	8	12	9	16	10	18	10	8	11	9	15	10	21
BO	9	7	6	14	18	9	9	8	16	13	9	9	9	8	8	15	14	9
O	46	15	31	80	112	47	45	48	40	35	18	41	44	38	42	39	35	18
Remainder	59	0	49	90	97	65	55	56	80	81	46	41	63	50	50	78	86	45
Subtotal	*209*	*101*	*160*	*330*	*438*	*207*	*211*	*210*	*226*	*181*	*142*	*192*	*200*	*183*	*188*	*220*	*188*	*138*

[a]Cause combinations with 100+ total deaths. Shaded cells indicate rates based on 25 or fewer deaths. See Table 1 for description of study population and method. Mortality rates are per 100,000 person years.

Table 3. Mortality Rates[a], Unadjusted and Age Adjusted, from Combinations of Associated Medical Conditions WITHIN Underlying Causes of Death by Age, Sex, and Race (Ages 55+), continued.

Cause of Death	Unadjusted											Age Adjusted						
AC Combinations within UC	Total Population					Sex		Race/Ethnicity										
	Total	55-64	65-74	75-84	85+	Male	Female	White	Black	Hispanic	Other	Total	Male	Female	White	Black	Hispanic	Other
RESPIRATORY (R)																		
Respiratory only	15	11	16	16	20	19	13	17	11	2	3	14	18	12	16	11	2	4
H	20	17	19	26	10	27	14	21	16	3	9	19	27	13	21	15	4	9
HO	25	18	25	34	19	32	20	27	15	18	18	24	30	19	25	15	19	19
FO	10	7	9	14	8	14	7	11	5	0	9	9	13	7	10	5	0	11
O	38	34	36	48	30	49	30	41	29	22	22	37	49	29	40	29	24	25
Remainder	41	30	38	55	41	56	29	44	30	25	15	39	55	28	41	31	26	16
Subtotal	*148*	*116*	*145*	*193*	*129*	*197*	*113*	*160*	*107*	*71*	*77*	*142*	*191*	*109*	*153*	*106*	*75*	*84*
INFLUENZA (F)																		
Flu only	16	3	8	31	51	18	14	17	11	7	6	14	18	12	15	10	8	7
H	10	2	4	14	44	12	8	10	9	15	0	9	12	6	8	9	17	0
HO	16	4	11	26	44	18	14	16	17	7	12	14	17	11	14	16	7	13
O	29	8	22	45	84	37	24	30	28	27	12	26	35	20	26	27	28	11
Remainder	32	14	26	49	66	41	25	32	33	20	40	29	39	22	28	32	20	38
Subtotal	*102*	*31*	*71*	*165*	*289*	*125*	*84*	*104*	*98*	*76*	*71*	*90*	*121*	*71*	*90*	*94*	*81*	*68*
DIABETES (D)																		
Diabetes only	2	2	1	2	2	2	2	2	3	2	0	2	2	2	2	3	2	0
H	18	20	17	17	14	21	15	15	30	17	28	18	21	16	15	34	16	29
HO	17	18	15	18	17	17	16	14	29	34	15	17	17	17	14	30	37	18
O	9	12	8	6	9	9	8	7	14	18	3	9	9	9	8	16	20	4
Remainder	35	33	35	40	26	36	35	29	67	55	37	35	35	34	29	66	57	38
Subtotal	*80*	*85*	*77*	*82*	*68*	*84*	*76*	*68*	*144*	*126*	*83*	*81*	*84*	*77*	*67*	*149*	*133*	*89*
HYPERTENSION (B)																		
Hyper. Only	2	1	1	5	2	2	3	2	4	3	3	2	1	2	2	4	3	3
Remainder	15	8	11	23	33	14	16	13	29	8	18	14	14	14	12	27	10	19
Subtotal	*17*	*9*	*12*	*28*	*35*	*15*	*19*	*15*	*33*	*12*	*22*	*16*	*15*	*16*	*14*	*31*	*13*	*22*
ALL OTHER (O)																		
All Other only	180	143	134	249	328	207	161	184	180	126	154	176	211	149	176	186	131	159
H	110	75	84	157	209	128	96	111	114	84	86	105	128	88	105	114	87	89
HS	7	2	6	13	13	8	7	7	10	7	9	6	7	6	6	9	7	9
HF	8	2	4	14	28	9	8	8	8	13	15	7	9	7	7	7	14	17
HR	11	7	10	16	14	16	7	11	9	8	18	10	16	6	10	7	8	21
HB	7	4	5	11	16	6	8	7	6	7	3	7	6	6	7	6	6	3
HO	62	42	49	80	135	71	55	61	74	52	65	59	72	50	57	75	53	65
C	10	10	11	12	6	17	5	10	13	5	9	10	17	5	10	13	5	8
S	14	6	12	22	26	13	15	15	14	5	9	13	12	13	13	13	5	10
SO	11	6	8	16	29	12	10	11	11	10	9	10	12	9	10	11	12	9
R	12	8	13	13	12	15	9	13	5	12	9	11	15	9	12	6	12	9
F	17	6	12	25	49	20	14	17	19	15	6	15	20	12	15	18	17	7
FO	10	8	5	15	31	16	7	11	10	5	3	10	17	6	11	10	4	4
O	100	79	76	144	160	114	90	98	127	74	86	98	115	85	93	131	81	90
Remainder	111	68	101	153	172	133	95	111	132	94	59	104	127	88	101	130	98	56
Subtotal	*672*	*467*	*530*	*940*	*1228*	*786*	*588*	*674*	*731*	*518*	*543*	*641*	*784*	*538*	*632*	*736*	*541*	*557*
Total	3118	2388	2625	4144	4840	3757	2653	3136	3484	2231	2133	3008	3733	2473	2986	3504	2310	2171

[a]Cause combinations with 100+ total deaths. Shaded cells indicate rates based on 25 or fewer deaths. See Table 1 for description of study population and method. Mortality rates are per 100,000 person years.

Table 4. Mortality Rates[a], Unadjusted and Age Adjusted, from Combinations of Underlying Cause and Associated Medical Conditions by Age, Sex and Race (Ages 55+).

Cause of Death	Unadjusted											Age Adjusted						
UC & AC Combined	Total Population					Sex		Race/Ethnicity										
	Total	55-64	65-74	75-84	85+	Male	Female	White	Black	Hispanic	Other	Total	Male	Female	White	Black	Hispanic	Other
H	458	309	363	644	853	562	382	460	530	291	318	436	560	338	431	529	304	309
HC	96	90	83	120	111	131	71	94	115	82	80	95	131	70	92	117	89	85
HCR	13	11	12	15	11	21	7	14	6	10	12	12	20	7	13	7	12	12
HCRO	11	6	12	15	9	17	7	12	6	5	0	10	16	6	11	5	5	0
HCD	7	4	8	9	10	9	6	8	6	7	3	7	8	6	7	6	6	3
HCO	69	56	57	88	112	92	51	69	84	45	12	67	93	49	67	86	44	11
HS	48	22	34	73	131	46	50	50	47	30	43	44	45	43	45	45	30	40
HSFO	7	2	6	13	12	10	6	7	11	5	6	6	9	5	6	10	5	6
HSB	11	8	8	15	22	11	11	10	17	7	6	11	11	10	10	18	8	6
HSBO	10	6	7	15	22	10	11	9	18	13	3	9	10	9	8	17	15	3
HSO	59	18	44	95	157	59	59	59	64	39	59	52	57	48	52	58	39	56
HR	57	42	54	84	44	85	37	62	40	22	28	54	82	35	59	38	22	27
HRO	68	44	63	97	81	92	50	72	45	44	62	63	88	46	68	44	44	63
HRFO	10	5	10	17	12	15	7	11	8	7	3	9	14	7	10	7	7	2
HF	22	5	10	38	90	25	20	22	21	27	9	20	26	16	19	20	30	9
HFO	42	12	26	72	127	49	37	43	37	29	37	37	47	32	37	36	30	39
HD	55	55	55	57	45	64	48	49	91	54	55	55	64	47	48	95	53	59
HDS	8	4	9	11	5	8	7	7	11	10	3	7	8	7	6	10	10	2
HDSO	10	5	10	14	9	10	10	9	17	7	6	9	9	9	8	16	8	7
HDB	15	17	15	16	7	15	15	12	28	29	15	15	15	15	12	29	29	16
HDBO	11	9	12	12	8	9	12	9	22	17	12	11	9	12	9	21	18	14
HDO	54	52	48	66	61	56	53	51	68	81	52	54	54	54	49	70	85	59
HB	31	20	27	44	52	35	29	30	47	17	18	30	34	25	28	47	18	20
HBO	35	20	24	55	75	35	35	33	52	25	18	33	34	30	30	53	25	17
HO	426	260	315	627	908	496	374	430	465	306	271	401	495	333	397	467	316	278
C	368	459	359	339	209	450	309	378	400	178	182	385	460	328	396	428	177	191
CSO	7	6	6	9	9	9	6	7	9	7	9	7	9	6	7	9	8	8
CR	18	20	20	16	5	28	11	20	10	5	3	18	27	11	21	11	4	2
CRO	20	20	21	22	13	29	14	21	18	10	6	20	29	14	21	17	11	6
CF	15	13	15	17	18	22	10	15	15	5	25	15	22	9	15	13	5	25
CFO	17	14	18	20	16	28	10	17	22	18	15	17	27	10	16	21	19	13
CO	180	191	176	190	141	241	136	179	217	133	123	182	242	139	181	215	132	130

[a]Cause combinations with 100+ total deaths, except for hypertension and diabetes alone. Shaded cells indicate 25 or fewer deaths. See Table 1 for study population and method. Mortality rates are per 100,000 person years.

Table 4. Mortality Rates[a], Unadjusted and Adjusted, from Combinations of Underlying Cause and Associated Medical Conditions by Age, Sex and Race (Ages 55+), continued.

Cause of Death	Unadjusted											Age Adjusted						
UC & AC Combined	Total Population					Sex		Race/Ethnicity										
	Total	55-64	65-74	75-84	85+	Mal	Female	White	Black	Hispan	Other	Total	Male	Female	White	Black	Hispanic	Other
S	50	25	38	79	105	45	54	52	49	20	22	46	44	47	47	49	19	20
SFO	12	5	7	21	31	15	9	12	11	13	0	11	15	8	11	11	14	0
SB	10	6	10	14	14	8	12	9	16	10	18	10	8	11	9	15	10	21
SBO	13	9	9	19	28	12	13	12	19	15	9	12	12	12	11	19	16	9
SO	71	27	51	118	167	72	70	73	65	50	37	64	68	60	65	62	53	37
R	15	11	16	16	20	19	13	17	11	2	3	14	18	12	16	11	2	4
RF	7	4	6	11	8	10	5	8	4	5	3	7	9	5	7	4	5	3
RFO	17	9	18	22	20	25	11	19	10	2	15	15	24	10	17	9	2	17
RO	55	46	54	66	47	71	43	59	36	39	34	53	70	41	57	36	41	37
F	16	3	8	31	51	18	14	17	11	7	6	14	18	12	15	10	8	7
FO	56	22	39	85	164	72	45	58	57	47	22	51	71	38	51	55	50	22
D	2	2	1	2	2	2	2	2	3	2	0	2	2	2	2	3	2	0
DSO	8	6	7	13	9	8	9	8	10	15	3	8	8	8	7	9	18	3
DO	19	19	16	21	22	18	19	17	29	29	12	19	18	19	16	31	30	13
B	2	1	1	5	2	2	3	2	4	3	3	2	1	2	2	4	3	3
BO	10	3	8	15	30	9	12	10	19	5	6	9	9	10	8	19	6	6
O	280	222	210	392	487	321	251	282	307	198	240	273	327	233	269	316	210	250
All Other	215	162	199	289	245	265	179	207	276	205	200	206	257	170	196	275	206	202
Total	496	384	409	681	732	586	430	489	583	403	441	479	584	402	465	591	417	452

[a]Cause combinations with 100+ total deaths, except for hypertension and diabetes alone. Shaded cells indicate 25 or fewer deaths. See Table 1 for study population and method. Mortality rates are per 100,000 person years.