Multiple codings and tabulation of mortality data will be needed for the vital statistics of the future. It is expected that multiple coding of diagnoses on death certificates will maximize the use of available diagnostic information. Trial and experiment are needed in the production, interpretation, and use of multiple cause data. Some aspects are presented in this paper.

USES AND SIGNIFICANCE OF MULTIPLE CAUSE TABULATIONS FOR MORTALITY STATISTICS

Harold F. Dorn, Ph.D., and Iwao M. Moriyama, Ph.D., F.A.P.H.A.

ONE OF the first questions that arises in planning procedures for coding and tabulating mortality records is whether the resulting statistics shall be based on a count of persons who have died, a count of diseases and injuries that caused the death, or both. This question was first faced on an international basis over 60 years ago. Since death records at that time generally contained only a single diagnostic entry and since the primary problem was conceived to be agreement upon and adoption of a common classification of causes of death, the First International Conference for the Revision of the International List of Causes of Death in 1900 adopted the principle of coding only one cause of death.

A few persons called attention to the incomplete view of causes of death given by the arbitrary selection of only one diagnosis where two or more causes were entered on a death certificate, and pointed out the importance of studying all the conditions that contributed to death. However, the principle that a single cause of death must be attributed to each death was universally adopted. It be-

came accepted as an essential basis for compilation of national mortality statistics, and the practice has continued up to the present time.

In contrast to the International List of Causes of Death, which became widely adopted as the basis for classifying causes of death, different methods were developed by various countries for selecting the cause of death to be tabulated. The lack of agreement on the rules for selection is reflected by the fact that, although this subject was a perennial agenda item of the decennial revision conferences, no consensus other than to continue to study the matter was reached.

In 1935, the U. S. Bureau of the Census distributed a set of 1,032 death certificates, each having two or more diagnostic entries, to the statistical offices of several countries with the request that the primary cause of death be coded in accordance with the rules currently in effect. The replies showed a disagreement great enough to largely nullify the comparability of national mortality statistics that the adoption of the International List of Causes of Death was

thought to bring about. Nevertheless, these results did not seriously shake the faith in the existing system of compiling mortality statistics. The Fifth Decennial International Conference in 1938 merely requested the United States to continue its study of the question on a slightly broader basis and in consultation with representatives of other interested countries.

The Sixth International Conference in 1948 revised extensively the former International List of Causes of Death for classifying morbidity as well as mortality data and introduced basic changes in procedures for processing death records. For the first time, international agreement was reached on a uniform method for selecting the disease or condition to be tabulated when two or more causes were entered on a death certificate. The disease or condition to be tabulated was termed the "underlying cause of death" and defined as "(a) the disease or injury which initiated the train of morbid events leading directly to death, or (b) the circumstances of the accident or violence which produced the fatal injury." It was agreed that in so far as possible the statement of the physician should be accepted. The general principles and rules governing the selection of the cause of death for primary tabulations were set forth for application whenever the physician's statement should appear inconsistent or implausible.

Now that preparations are being made for the Eighth Revision Conference in 1965, the traditional practice of attributing a single diagnostic entity to each death is again being questioned. Why is it that this subject, like the proverbial cat, never dies? A long list of papers on this topic has been presented before this Association, and a querulous member with a long memory might wonder whether anything new remains to be said in still another paper.

Perhaps the main reason why this subject keeps recurring is the belief, at first held by only a few persons but now widely accepted, that a single cause, no matter how selected, no longer adequately describes the morbid conditions responsible for a large proportion of deaths. The leading causes of death in an increasing number of countries are chronic or degenerative diseases whose etiology, although largely unknown, is believed to be due to multiple factors. Due in part to the increasing average length of life, a large proportion of persons have more than one active disease at the time of death. Three out of every five death certificates filed in the United States show two or more diagnostic entries.

Although this criticism of mortality statistics has been made frequently in the past, it has not been accompanied by a clear statement as to how a tabulation of multiple causes of death would improve the existing data. Some, if not most, of the advocates of multiple cause tabulations have felt that the additional information would not justify tabulations on a regular basis. For example, the Committee on Medical Certification of Causes of Death of the Statistics Section of this Association only four years ago concluded that "Because of the problems and the cost involved in producing multiple cause tabulations, such tabulations should not be undertaken lightly or as a routine function."[1]

In view of the lack of a clear conception of how such data might be used, it is not surprising that so little use has been made of past tabulations of multiple causes of death. The Bureau of the Census first published tables of primary and contributory causes in 1917. These tabulations were repeated in 1924, 1925, 1936, and 1940. There is no evidence that anything more than casual use has ever been made of these tabulations. It is apparent from the published tabulations that even those who designed them had a very limited conception of how

such data might be used to extend the value of mortality statistics and to correct deficiencies in the information provided by single cause tabulations. The successive tabulations followed a similar pattern—the cross-classification of the underlying cause of death and a contributory cause without reference to age, sex, color, and other items considered essential in the presentation of single cause statistics.

The lesson that stands out from past experience is that if the tabulation of multiple causes of death has no more to offer than previously published data, such tabulations are not worth doing. It is not sufficient to assert that somehow the tabulation of multiple causes of death will describe more adequately than single cause statistics the morbid conditions leading to death. The pertinent question is, "How"? Until this is answered, additional multiple cause statistics are unlikely to be any more valuable than those of the past. The answer to this question may be found in the answer to a somewhat broader question: Why do we want statistics of causes of death?

The uses of mortality statistics are manifold. It is impracticable and not directly relevant to our purpose to attempt to enumerate them at this time. Even if we were able to ascertain all the purposes for which mortality statistics have been used during the past decade, this would not satisfactorily answer the question. The uses to which any sta-

Table 1—Number of Deaths for Which Selected Diseases Were Coded as Underlying and as Contributory Causes of Death, United States, 1955

ISC Code	Diagnosis	No. of Death Certificates with Diagnosis	No. of Deaths for Which Diagnosis Was Selected as		No. Underlying as % of Total
			Underlying Cause	Contributory Cause	
001–019	tuberculosis	21,331	14,779	6,552	69.3
020–029	syphilis	6,735	3,825	2,910	56.8
030–138	other infective and parasitic diseases	14,353	8,028	6,325	55.9
140–205	cancer	252,621	234,752	17,869	92.9
210–239	benign and unspecified neoplasms	8,342	5,278	3,064	63.3
241	asthma	13,047	5,904	7,143	45.3
260	diabetes mellitus	61,909	25,217	36,692	40.7
290–293	anemias	16,075	3,112	12,963	19.4
330–334	vascular lesions affecting central nervous system	304,004	173,541	130,463	57.1
340	meningitis	3,558	1,796	1,762	50.5
400–402	rheumatic fever	1,812	1,126	686	62.1
410–416	chronic rheumatic heart disease	25,130	18,823	6,307	74.9
420.0	arteriosclerotic heart disease so described	182,164	156,648	25,516	86.0
420.1	heart disease involving coronary arteries	326,248	245,633	80,615	75.3
420.2	angina pectoris	4,549	1,055	3,494	23.2
421	chronic endocarditis not specified as rheumatic	12,034	7,094	4,940	58.9
422	other myocardial degeneration	97,795	58,305	39,490	59.6
430–434	other diseases of heart	106,270	20,852	85,418	19.6
440–443	hypertensive heart disease	120,701	73,458	47,243	60.9
444–447	hypertension without mention of heart disease	91,301	11,316	79,985	12.4

(Table 1—continued)

ISC Code	Diagnosis	No. of Death Certificates with Diagnosis	No. of Deaths for Which Diagnosis Was Selected as		No. Underlying as % of Total
			Underly-ing Cause	Contribu-tory Cause	
450	general arteriosclerosis	241,628	32,207	209,421	13.3
480–483	influenza	3,600	2,719	881	75.5
490–493	pneumonia	116,579	42,173	74,406	36.2
500	bronchitis, acute	2,179	1,067	1,112	49.0
501–502	bronchitis, other	5,876	2,025	3,851	34.5
525	other chronic interstitial pneumonia	6,212	2,289	3,923	36.8
526	bronchiectasis	5,363	2,197	3,166	41.0
527.1	emphysema without mention of bronchitis	12,411	3,902	8,509	31.4
527.0, 527.2	other diseases of lung	16,814	2,129	14,685	12.7
540, 541	ulcers of stomach and duodenum	16,413	9,784	6,629	59.6
543, 571, 572	gastritis, enteritis, colitis	13,708	7,827	5,881	57.1
560, 561, 570	hernia and intestinal obstruction	26,549	8,678	17,871	32.7
581	cirrhosis of liver	25,175	16,630	8,545	66.1
590, 591	nephritis, acute	6,119	2,393	3,726	39.1
592–594	nephritis, other	29,876	16,186	13,690	54.2
640–689	complications of pregnancy and puerperium	3,012	1,813	1,199	60.2
722	rheumatoid arthritis	6,511	977	5,534	15.0
720–721 723–725	arthritis, other	7,588	699	6,889	9.2
750–759	congenital malformations	30,653	20,932	9,721	68.3
760–762	birth injury, asphyxia	35,320	28,938	6,382	81.9
763–768	infections of newborn	6,621	4,240	2,381	64.0
769–776	other diseases of early infancy	34,865	30,986	3,879	88.9

tistical data are put are basically determined by the available data. Hence, we will turn our attention to the question: What types of information may we reasonably expect statistics of causes of death to provide in order to maximize their usefulness for potential consumers?

We believe that statistics of causes of death should:

a. Accurately reflect the conditions that contribute to the fatal outcome in the opinion of the medical certifier;
b. Show the relative importance of the various diseases, injuries, and acts of violence as causes of death; and
c. Reliably represent the time trend of the frequency with which the various diseases, injuries, and acts of violence are reported as bringing about death.

Let us turn to the first point. For the data year 1955, the National Vital Statistics Division coded multiple diagnoses for a sample of deaths. A maximum of five conditions were coded which made possible the identification of about 99 per cent of the reported diagnoses. An average of 1.9 diagnoses were reported for each death. In other words, the traditional practice of coding only one cause of death discarded about one-half of the diagnostic information entered on death certificates for 1955.

The proportion of reported information that was lost varied widely by diagnosis (Table 1). More than nine-tenths of the diagnoses included in the category, arthritis other than rheumatoid,

were discarded. Among the cardiovascular diseases, hypertension and other vascular diseases are assigned a low priority in the rules for selecting the underlying cause of death. Only 12 per cent of the diagnoses of hypertension without mention of heart disease and 13 per cent of the diagnoses of arteriosclerosis were classified as the underlying cause of death. This situation was noted by the WHO Expert Committee on Arterial Hypertension and Ischemic Heart Disease which stated, "At present arterial hypertension is not coded as a cause of death when it is complicated by vascular disease, e.g., ischemic heart disease or cerebral vascular disease. The committee strongly recommends that this omission should be rectified. Arterial hypertension should be mentioned on the death certificate whenever it is known to be present, and the revised classification should make it possible to record the association of vascular lesions in various organs with high blood pressure."[2]

Another area where the underlying cause concept results in gross understatement is death due to therapeutic misadventure. According to the present coding procedure, a death is classified to the disease or condition for which treatment was given, or for which an operation was performed, rather than to the consequences of the therapeutic procedure. Therefore, unless no information is given on the disease or condition requiring therapy, the death is not classified to the therapeutic procedure even if so reported. In 1955, some 617 deaths were attributed to therapeutic misadventures. Actually, there were 2,644 additional deaths for which a therapeutic misadventure was specified. Of these, 837 were attributed to therapeutic misadventures in the administration of anesthesia, 795 in the administration of drugs and biologicals, and 432 misadventures in the process of infusion or transfusion.

With respect to operations, some surgical procedure was reported in about 140,000 deaths. Of these, some 127,000 mentioned incision or excision; 7,800 repairs; 4,500 amputations; and the rest operations of a minor nature. Again, this is an area where primary mortality tabulations give no information.

It is readily evident from the data presented that the selection of a single cause of death does not adequately represent the diagnoses reported on death certificates. There is a big loss of diagnostic information, particularly the less fatal diseases and significant conditions associated with the "underlying" cause of death. The proportion of the latter may shift markedly by changes in the rules for selecting the underlying cause of death or by the interpretation of these rules. For example, in 1958, when the Seventh Revision of the International Classification of Diseases came into effect, the National Vital Statistics Division coded a sample of death certificates, first according to the coding procedures for the Sixth Revision, and second according to the procedures adopted for the Seventh Revision. Both the Sixth and Seventh Revisions had identical rubrics for bronchitis (500-502), other chronic interstitial pneumonia (525), bronchiectasis (526), and emphysema and other diseases of lung and pleural cavity (527). However, the rules for selection were recast into a more understandable form and some slight changes made in the interpretation of some of the provisions for selection. As a result, in one year the recorded death rate for bronchitis was increased 7 per cent, that for bronchiectasis was increased 15 per cent, and that for emphysema and other diseases of the lungs and pleural cavity was decreased 15 per cent.

Vital statistics offices generally publish tables showing the leading causes of death. The usual interpretation of these data is that they indicate the relative importance of the various causes

of death. Yet, this rank order is largely determined by the rules for selecting the underlying cause of death and by the way the causes are grouped. In 1955, 13,609 deaths were assigned to the chronic respiratory diseases mentioned above, and 27,133 deaths were assigned to lung cancer as underlying causes of death. However, one or more of the chronic respiratory diseases were entered on 48,855 death certificates, and cancer of the lung on 28,213 death certificates. Opinions may differ as to which of these two sets of numbers more accurately reflects the relative importance of these two groups of diseases as causes of death. This should not divert our attention from the fact that the first set incompletely represents the information entered on the death certificates and that complete information is necessary for an informed opinion.

The selection of a single cause of death may affect reported differentials in mortality among various subgroups of the population. In 1955, 72 per cent of the diagnosis of hypertensive heart disease entered on certificates for non-white persons were selected as the underlying cause of death; the corresponding percentage for the white population was 59.

Enough evidence has been presented to demonstrate that single cause mortality tabulations cannot satisfactorily fulfill the requirements for mortality statistics listed above. It is no longer sufficient to ask, what is the cause of death, since a large proportion of deaths are due to the combined action of two or more diseases.

Some have said that it is not worth while devoting much time and energy to attempt to extend or improve mortality statistics, and what is needed are morbidity statistics. However, mortality statistics have a significance of their own as a consequence of an illness experience. Mortality statistics are now being used much more extensively than

in the past, and there is no indication that this use is likely to diminish in the future.

We believe that the only way to increase now the usefulness of mortality statistics and to correct for the inadequacies of statistics resulting from traditional methods of compilation is to code and tabulate all of the diagnostic information entered on the present death certificates. After sufficient experience has been gained on the problems of multiple cause tabulations, consideration should be given to the frame within which diagnostic information is reported. This may lead to a revision of the medical certificate form.

It is a false posing of issues now to suggest that single cause tabulations should be replaced by multiple cause tabulations. The majority of the countries of the world are not now in a position to produce multiple cause tabulations. Single cause tabulations are necessary and should be available for comparative purposes.

As a first step we suggest that the tabulations of single cause statistics be supplemented by two additional types of tabulations. Most publications of national vital statistics have a table showing for certain causes the number of deaths classified by age and sex. The first tabulation we propose is a modification of this standard table so as to show two frequencies for the various diagnostic categories—one the number of deaths for which the disease or condition was selected as the underlying cause, and the other showing the number of deaths in which the disease was involved but not selected as the underlying cause. The first frequencies are the standard tabulation now universally published and are an unduplicated count of deaths or persons. The second set represents the frequency with which each diagnosis was recorded as an associated or contributory cause of death. The combined frequencies present

the total diagnostic information entered on death certificates. A tabulation of this kind would correct many of the inadequacies of single cause mortality statistics which have been pointed out.

The second proposed tabulation is designed to make available a new type of data. The belief is becoming accepted that a single diagnosis, no matter how selected, cannot adequately describe the medical circumstances surrounding many deaths—in particular, those deaths from chronic or degenerative diseases where more than one disease contributes to the death.

In such cases, the cause of death can be adequately represented only by a composite diagnosis formed by combining two or more diagnostic terms; for example, a death from acute myocardial infarction, hypertension, and nephrosclerosis would be attributed to a combination of these three diagnostic terms. The tabulation would show the frequency with which certain groups of diseases are entered on death certificates. Individual diagnostic terms would be used for all deaths to which composite diagnoses are not assigned.

Considerable experimentation will be required to test the usefulness of this type of tabulation. It offers promise of enabling mortality statistics to more closely represent medical judgment concerning the cause of death of a large proportion of deceased persons and hence deserves a thorough trial.

In summary, it may be said that the multiple coding of diagnoses on death certificates will maximize the use of available diagnostic information. It will make possible a count of all diseases and conditions reported as well as an unduplicated count of deaths. Data not hitherto obtained will become available. It will provide a basis for assessment of mortality trends for various diseases which is not now possible because of the inevitable loss of information when a single disease entity is selected as the underlying cause of death.

The coding of all diagnoses will also permit the tabulation of data on disease complexes which will represent the present medical views on multiple causation of death.

Multiple cause tabulations will provide a good deal more data than are now available from single cause tabulations. They will get around some of the logical objections to the underlying cause concept. However, multiple cause tabulations will not be the panacea which some may believe. The use of computers will facilitate tabulation, but will not determine the usefulness and significance of the contents to be tabulated. Multiple cause tabulations will not eliminate selection rules. These will be different and possibly fewer than those now being used to determine the underlying cause of death. Trial and experimentation are needed in the production as well as in the interpretation and use of multiple cause data. However, it seems clear that multiple coding and tabulation of mortality data are needed to serve the purposes of the future.

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Dr. Dorn (deceased) was chief, Biometrics Research Branch, National Heart Institute, PHS, U. S. Department of Health, Education, and Welfare, Bethesda, Md. Dr. Moriyama is chief, Office of Health Statistics Analysis, National Center for Health Statistics, PHS, U. S. Department of Health, Education, and Welfare, Washington, D. C.