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Ranking Risk Inequities

John D. Graham

Elizabeth Richardson

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Introduction

The methods of risk analysis have been recommended for setting priorities to allocate scarce scientific and regulatory resources.[1] According to the "worst-first" strategy, risks are ranked from most to least serious on the basis of technical information and/or value judgments of citizens. Rankings are then used (formally or informally) to influence the allocation of scarce resources (i.e., more dollars go to reducing risks high on the list; fewer dollars to risks low on the list).

The U.S. Environmental Protection Agency (EPA) has made some systematic efforts to rank human health and ecological risks that fall within its jurisdiction.[2] These led to the provocative conclusion that risks of most concern to the public (e.g., hazardous waste sites) were not the same as risks of most concern to environmental scientists (e.g., global warming and stratospheric ozone depletion). In a recent speech before Congress, William Reilly noted (with satisfaction) that during his tenure at EPA the fraction of its resources devoted to "high-risk" problems rose from roughly 15% to 30%.[3] Variants of the "worst-

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** Dr. Graham is Director, Center for Risk Analysis, Harvard School of Public Health. He received his B.A. (Economics) from Wake Forest University, his M.S. from Duke University and his Ph.D. from Carnegie Mellon University.

Ms. Richardson is a Research Assistant at the Center for Risk Analysis. Following undergraduate work at Princeton, she received her M.S. and is working on her Ph.D. (Health Policy) at Harvard University.

1 Carnegie Commission on Science, Technology, and Government, Risk and the Environment: Improving Regulatory Decision Making, New York, NY, June 1993.

2 U.S. Environmental Protection Agency (EPA), **Unfinished Business: A Comparative Assessment of Environmental Problems**, (1987); U.S. EPA, Science Advisory Board, **Reducing Risk: Setting Priorities and Strategies for Environmental Protection** (1990).

3 Statement of William K. Reilly, former EPA Administrator, Task Force on Environmental Risk, House Republican Research Committee, U.S. House of Representatives, Washington, D.C., June 27, 1994.

first" strategy are now being explored in numerous states as well as in several foreign countries.[4]

During this period, a growing number of environmental advocates and policy makers became concerned about "environmental racism" and the need for greater social justice in environmental policy.[5] Their concern is that low-income and minority populations seem to incur environmental dangers disproportionately, although scientific research on this subject is at an early stage of development.[6] Also, President Clinton, through an executive order, has recently sought to incorporate environmental justice considerations into the daily workings of the federal government.

People are only beginning to think about whether the "worst-first" and "environmental-justice" paradigms are compatible. At a recent conference sponsored by Resources for the Future, there was considerable analytical confusion about whether priorities based on risk ranking could accommodate concerns about inequity in the distribution of risks.[7] Several state "comparative-risk" projects supported by EPA have also struggled with this question.[8]

The purpose of this paper is to clarify how ranking risks based on degree of inequity might differ from a traditional ranking based on overall frequency of health impairments in the population. We examine two particular hypotheses.

The first hypothesis is that when the same risks are ranked according to different definitions of the degree of inequity, the same rankings emerge. If this condition holds, then risk inequity should be

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4 Richard Minard et al., State Comparative Risk Projects: A Force for Change, Northeast Center for Comparative Risk, Vermont Law School, 1993.

5 Commission on Racial Justice, United Church of Christ, Toxic Wastes and Race in the United States (1987); R. D. Bullard, Dumping in Dixie: Race, Class, and Environmental Quality (1990).

6 Rae Zimmerman, *Issues of Classification in Environmental Equity: How We Manage is How We Measure,* 21 Fordham Urb. L.J. 633 (1994); Rae Zimmerman, *Social Equity and Environmental Risk,* 13 Risk Anal. 649 (1993); J. A. Hird, *Environmental Policy and Equity: The Case of Superfund,* 12 J. Policy Anal. & Mgmt. 323 (1993); Douglas L. Anderton et al., *Hazardous Waste Facilities: "Environmental Equity" Issues in Metropolitan Areas,* 18 Eval. Rev. 123 (1994).

7 Worst Things First: The Debate Over Risk-Based National Environmental Priorities (Adam M. Finkel & Dominic Golding, eds. 1995).

8 California Environmental Protection Agency, Toward the 21st Century: Planning for the Protection of California's Environment (1994).

considered a fairly robust analytical concept. If not, then the various definitions of risk inequity need to be scrutinized to determine which is the most ethically sound for use by policy makers. Insofar as subtle differences in plausible equity concepts cause radical changes in rankings, we should expect that it will prove difficult to achieve consensus on how to incorporate equity considerations into the worst-first strategy.

The second hypothesis is that when the same risks are ranked according to degree of inequity and overall frequency, the two sets of rankings are identical. If that were the case, allocation of scarce resources (priority setting) would not be affected by equity considerations. If the two sets of rankings do differ, then the priority setting process must address what the late Arthur Okun called "the big tradeoff" between efficiency and equity. Okun suggests that this unresolvable dilemma will always be with us.[9]

Data

To explore these methodological issues, we compare the most recent available data on age-adjusted death rates for blacks and whites in the U.S. Operationally, "risk" is defined as the frequency of death from a particular disease category. These data have several attractive features. First, mortality information by cause — though subject to vagaries in death certificates — is among the highest quality information that risk analysts have. Second, we expect no disagreement with the assumption that blacks are a disadvantaged group in the U.S. that should be considered in any analysis of risk equity. By focusing on hard mortality information on blacks and whites, we seek to eliminate extraneous technical controversies about data quality and choice of subgroups for analysis that often plague public debates about environmental justice. We acknowledge that many factors may contribute to differing mortality patterns among blacks and whites, such as genetics, behavior and environment. Also, mortality patterns within a given race vary according to geography, income level and other factors. However, our definition of a simplified analytical problem is intended to focus attention on the two specific hypotheses stated above.

9 Arthur M. Okun, **Equality and Efficiency: the Big Tradeoff** (1975).

Obviously, a more complex analysis is necessary to determine whether *environmentally-induced* mortality is inequitably distributed.

Data on 32 major causes of death (31 for males and 30 for females) for 1991 were obtained from the National Center for Health Statistics (NCHS). These were compiled by NCHS for its annual publication **Vital Statistics of the U.S.** Although the 1991 edition is still unpublished, the data correspond to the format used in previously published volumes. Death rates used are based on the major category headings from the table entitled "Age-adjusted death rates for 72 selected causes by race and sex: United States, 1991" as well as the corresponding death rates for human immunodeficiency virus infection, reported separately. The category "Residual" as well as the five major categories with "other" in the title were excluded, along with any category for which death rates were not reported due to the small number of deaths (a minimum of 20 deaths is required for the rate to be reported). The causes of death are identical for males and females with the exception of "Complications of pregnancy, childbirth" and "Hyperplasia of the prostate," that are included only for females and males, respectively; and "Syphilis," excluded for females because the death rate for white females was too small to be reported.

Traditional Ranking by Frequency

We generated national rankings of the causes of death by age-adjusted death rates per 100,000 population separately for males and females. In Table 1, the top ten causes of death from this ranking are reported by sex. Using the same data, we also generated rankings for blacks and whites by sex. Table 2 sets forth the top ten causes of death for each group.

Several observations are noteworthy. When risk is measured by the age-adjusted mortality rate, heart disease and cancer are by far the largest risks for males and females. The top five causes of death are the same for males and females, although the ordering varies, while causes five through ten diverge for men and women in important respects. Heart disease and cancer continue to dominate the rankings when broken down by sex and race, with the remaining causes varying by group. Interestingly, homicide is present in the top ten for blacks of both gender but absent for both white males and females, while the reverse is true of suicide. In fact, this is the only difference in the contents of the top ten rankings for black males and white males. Black and white women share eight of the top ten causes of death, with the notable exception being HIV infection, which ranks seven for black females but is not included among the top ten for white females.

Table 1
Top Ten Causes of Death for Males and Females

Males Cause of Death	Age-adjusted Death Rate per 100,000	*Females* Cause of Death	Age-adjusted Death Rate per 100,000
Heart disease	201.0	Cancer	112.6
Cancer	165.0	Heart disease	106.3
Accidents	45.3	Stroke	24.7
Stroke	29.4	Accidents	17.2
Pulmonary disease	27.0	Pulmonary disease	15.5
HIV	20.1	Diabetes	11.1
Suicide	18.8	Pneumonia & flu	10.6
Pneumonia & flu	17.5	Perinatal conditions	5.7
Homicide	17.3	Liver disease	5.2
Diabetes	12.6	Homicide	4.5

Table 2a
Top Ten Causes of Death for Black and White Males

Black males Cause of Death	Age-adjusted Death Rate per 100,000	*White males* Cause of Death	Age-adjusted Death Rate per 100,000
Heart disease	272.7	Heart disease	196.1
Cancer	242.4	Cancer	159.5
Homicide	72.5	Accidents	43.9
Accidents	61.0	Pulmonary disease	27.4
Stroke	54.9	Stroke	26.9
HIV	52.9	Suicide	19.9
Pneumonia & flu	26.2	HIV	16.7
Pulmonary disease	25.9	Pneumonia & flu	16.6
Diabetes	24.6	Diabetes	11.5
Liver disease	17.4	Liver disease	11.2

Table 2b
Top Ten Causes of Death for Black and White Females

Black females Cause of Death	Age-adjusted Death Rate per 100,000	*White females* Cause of Death	Age-adjusted Death Rate per 100,000
Heart disease	165.5	Cancer	111.2
Cancer	136.3	Heart disease	100.7
Stroke	41.0	Stroke	22.8
Pneumonia & flu	26.2	Accidents	17.0
Diabetes	25.7	Pulmonary disease	16.1
Accidents	19.9	Pneumonia & flu	10.2
Homicide	13.9	Diabetes	9.6
Perinatal conditions	12.9	Liver disease	4.8
HIV	12.0	Suicide	4.8
Pulmonary disease	11.3	Perinatal conditions	4.3

The rank-correlation coefficients in Table 3 indicate a strong association between the frequency rankings for males and females, both as a whole and by race.

Table 3[10]
Rank Correlation Coefficients

Compared Rankings	*N*	*Spearman Rank Correlation Coefficient*	*p*
Male frequency and female frequency (both races)	29	0.959	< 0.001
Black male frequency and black female frequency	29	0.965	< 0.001
White male frequency and white female frequency	29	0.952	< 0.001
Black male frequency and white male frequency	31	0.952	< 0.001
White female frequency and black female frequency	30	0.906	< 0.001
Male ratio and female ratio	29	0.725	< 0.001
Male difference and female difference	29	0.926	< 0.001
Male ratio and male difference	31	0.412	< 0.05
Female ratio and female difference	30	0.549	< 0.005
Male ratio and male frequency	31	–0.240	> 0.50
Female ratio and female frequency	30	–0.091	> 0.50
Male difference and male frequency	31	0.633	< 0.001
Female difference and female frequency	30	0.649	< 0.001

There is also an association between the frequency rankings for black and white females and black and white males. Thus, if decision makers

[10] N = number of causes of death used in comparing each ranking. N differs between comparisons due to the inclusion or exclusion of gender-specific causes.

were to allocate resources based on rankings of cause-specific death rates, some consistent results would emerge for both sexes and races.

Inequity Ranking by Risk Ratio

A simple yet intuitively appealing measure of degree of risk inequity is the ratio of the black death rate to the white death rate for a particular cause of death. NCHS actually reports this measure of inequity in occasional issues of its publication *Mortality and Morbidity Weekly Report.*

Table 4

Ten Largest Ratios of Black to White Death Rate

Cause of Death	*Age-adjusted Death Rate per 100,000 Males* *Black*	*White*	*Ratio*	*Difference*
Syphilis	0.2	0.0	10.00	0.2
Homicide	72.5	9.4	7.71	63.1
Tuberculosis	3.0	0.4	7.50	2.6
Hypertension	6.9	1.7	4.06	5.2
Anemias	2.8	0.7	4.00	2.1
HIV	52.9	16.7	3.17	36.2
Perinatal conditions	16.6	5.5	3.02	11.1
Appendicitis	0.3	0.1	3.00	0.2
Septicemia	11.6	4.1	2.83	7.5
Nutritional defic.	1.1	0.4	2.75	0.7

Cause of Death	*Age-adjusted Death Rate per 100,000 Females* *Black*	*White*	*Ratio*	*Difference*
HIV	12.0	1.3	9.23	10.7
Tuberculosis	1.2	0.2	6.00	1.0
Homicide	13.9	3.0	4.63	10.9
Hypertension	5.8	1.3	4.46	4.5
Childbirth/preg.	0.8	0.2	4.00	0.6
Anemias	2.3	0.6	3.83	1.7
Perinatal conditions	12.9	4.3	3.00	8.6
Meningitis	0.6	0.2	3.00	0.4
Kidney disease	8.6	3.0	2.87	5.6
Diabetes	25.7	9.6	2.68	16.1

The risk ratio measures the frequency of a particular cause of death among blacks relative to whites. Since a ratio of 1.0 implies perfect risk equality, we expected most ratios for blacks to exceed 1.0. In fact, the ratio exceeded 1.0 for 28 of the causes for males and for females. The exceptions were pulmonary disease for males (0.95) and females (0.70), suicide for males (0.63) and females (0.40), and artherosclerosis for males (0.86). We were surprised and disturbed to learn that a large majority of cause-specific ratios exceeded 1.5. In Table 4, we report the top ten inequity ratios for males and females.

Interestingly, there is no meaningful correlation (for males or females) between the ranking by risk ratio and the ranking by frequency (more below). This implies that the most frequent causes of death for men and women are not ones with the highest degree of inequity between blacks and whites (assuming inequity is measured using risk ratios). There is an association (0.725) between the overall risk ratio rankings for males and females (see Table 3), implying that racial inequity is strongest in the same causes of death for both. While HIV infection tops the ranking of ratios for women, other causes of death exhibit the highest ratios for men. Both sexes have high risk ratios for tuberculosis, hypertension, anemias, perinatal conditions and homicide.

Inequity Ranking by Risk Difference

Consider instead the absolute difference in the age-adjusted death rate for blacks and whites. In other words, how many lives would be saved from each cause if the black death rate were reduced to the level of the white death rate? Table 5 presents the top ten causes of death when risk inequity is gauged by this absolute difference in the mortality rate. In this case, there is a strong association (for both sexes) between the ranking by risk difference and the ranking by risk frequency (more on this below). In other words, using risk difference as the measure of inequity yields a ranking of the most racially inequitable causes of death which is not significantly different from the ranking based on overall frequency of specific causes of death.

There are some interesting differences in the rankings for males and females, particularly the differing relative positions of cancer, heart disease, accidents and stroke. However, there are seven causes of death that appear in the top ten for both males and females. Again, there is a strong association (0.926) in the overall rankings by risk differences for males and females (see Table 3).

Table 5
Ten Largest Differences between Black and White Death Rates

Cause of Death	Age-adjusted Death Rate per 100,000 Males Black	White	Difference	Ratio
Cancer	242.4	159.5	82.9	1.52
Heart disease	272.7	196.1	76.6	1.39
Homicide	72.5	9.4	63.1	7.71
HIV	52.9	16.7	36.2	3.17
Stroke	54.9	26.9	28.0	2.04
Accidents	61.0	43.9	17.1	1.39
Diabetes	24.6	11.5	13.1	2.14
Perinatal conditions	16.6	5.5	11.1	3.02
Pneumonia & flu	26.2	16.6	9.6	1.58
Kidney disease	12.8	4.7	8.1	2.72

Cause of Death	Age-adjusted Death Rate per 100,000 Females Black	White	Difference	Ratio
Heart disease	165.5	100.7	64.8	1.64
Cancer	136.3	111.2	25.1	1.23
Stroke	41.0	22.8	18.2	1.80
Diabetes	25.7	9.6	16.1	2.68
Pneumonia & flu	26.2	10.2	16.0	2.57
Homicide	13.9	3.0	10.9	4.63
HIV	12.0	1.3	10.7	9.23
Perinatal conditions	12.9	4.3	8.6	3.00
Kidney disease	8.6	3.0	5.6	2.87
Septicemia	7.9	3.1	4.8	2.55

Comparison of Inequity Rankings

When the complete rankings by risk ratio and risk difference were compared (see Table 3), we found a modest association (0.412 for males and 0.549 for females). The lack of a strong correlation is a hint that the precise measure of inequity can make an important difference.

Perhaps more striking are the major differences in the top-ten rankings in Tables 3 and 4, which suggest that the measure of equity chosen could have a profound impact on the allocation of resources (if appearing in the top ten were a decision-sensitive outcome). For example, assume that a given number of dollars is available for reducing risk of death for the top ten causes of death for males. (Assume for simplicity that the percentage effectiveness and cost of risk reduction as well as the number of lives saved are the same for each cause of death.) When we compare the two equity measures based on the composition of the rankings above the "top-ten" threshold, we find that we are unable to reject the null hypothesis that the two rankings are independent (χ^2 = 0.034 with 1 d.f., p = 0.85). We reach the same conclusion with females (χ^2 = 1.83 with 1 d.f., p = 0.18). This independence implies that depending on where the threshold lies, the choice of inequity measurement can in fact affect composition of the rankings in a meaningful way.

Comparison of Rankings by Overall Frequency and Risk Ratio

Data in Tables 1 and 4 suggest that the two sets of rankings have little in common. In the case of males, only two causes of death (homicide and HIV infection) appear in the top ten of both. For females, three causes of death (homicide, diabetes and perinatal conditions) appear in the top ten of both rankings. The rank-correlation coefficient in Table 3 indicates that the two rankings are indeed quite different for both sexes. Using again the top ten as a hypothetical funding threshold to compare the two rankings, we reach the same conclusion that the two rankings are different for both males (χ^2 = 1.01 with 1 d.f., p = 0.31) and females (χ^2 = 0.13 with 1 d.f., p = 0.72).

The shared high ranking of a few causes provides an unambiguous signal to decision makers that both frequency and equity demand that priority be given to these causes of death. But if a decision maker were asked to allocate scarce resources among all causes of death on the basis of these two sets of rankings, the decision maker would have every right to express confusion.

Note that when the risk ratio is the measure of risk inequity, the most prevalent causes of death do not rank in the top ten. For any condition that is highly prevalent in whites (e.g., heart disease and cancer), it is virtually impossible for the risk ratio for blacks to exceed 2.0 to 3.0. That could occur only if all blacks were dying of the same cause. Likewise, causes of death that are not very prevalent in whites have the potential to have a high risk-ratio in blacks, since there is no effective constraint imposed by the total death rate.

Comparison of Rankings by Overall Frequency and Risk Difference

Comparing the rankings by frequency (in Table 1) with the rankings by difference (Table 5) reveals both important similarities and differences. Among males cancer, homicide, HIV infection and diabetes assume higher rankings (using the difference measure) while heart disease, stroke, accidents and pneumonia and flu assume lower rankings (using the difference measure). Among females heart disease, diabetes, pneumonia and flu and homicide are ranked higher, while cancer is ranked lower.

The rank correlation coefficients in Table 3 indicate that there is no major difference in ranking by overall frequency and risk difference for either males or females. When the threshold approach is applied here, we find that there is still an association between frequency and risk difference rankings for both men ($\chi^2 = 15.40$ with 1 d.f., $p < 0.0001$) and women ($\chi^2 = 9.03$ with 1 d.f., $p = 0.003$).

Limitations

In this article we have not addressed several important issues. First, mortality is only one aspect of risk. A fuller analysis would address morbidity, quality of life and ecological endpoints. The issue of equity versus efficiency is relevant to many other outcome measures besides mortality rates. For example, if air pollution rates were used, a similar question exists. Should we worry more about a pollutant with a high concentration that is only present in 5% of all communities, or a pollutant with a very small concentration but a much larger number of total person years of exposure. Second, rankings of death rates for disease categories may be less useful in the long run then rankings of solutions to cohorts of problems that can be addressed by a common intervention. For example, smoking cessation will reduce multiple diseases such as cancer and heart disease.

Finally, the question remains whether inequity should be incorporated into rankings subjectively or through explicit mathematical weights. In most of the state and local risk-ranking exercises, this problem was addressed by encouraging scientists or laypeople to subjectively consider how inequity should affect rankings. A more rigorous procedure might be helpful, but this must await clearer definitions of inequity and discussion of how much weight to give to inequity versus frequency. The insights from multiattribute utility theory might be helpful in future work.

Conclusion

This straightforward analysis of 1991 cause-specific mortality data from the NCHS leads us to reject the first hypothesis stated at the outset of the paper, that the same rankings emerge when different concepts of inequity are applied. Although the rankings of all causes of death by the two measures of inequity did show a modest overall association (0.4 to 0.5), it is very important to note that this association is not in the range of 0.9 to 1.0. This means that a "worst-first" strategy would likely vary depending upon which measure is used by decision makers. Moreover, the rankings differed sharply when a "top-ten" threshold was imposed. Clearly, the level at which the threshold is set influences whether or not the two measures of equity produce different rankings. This indicates that the choice of equity measure may or may not have an effect on the allocation of resources depending on how the rankings are used by decision makers.

In fact, the choice of an inequity measure influences whether we can reject the second hypothesis of the paper, that identical rankings are generated regardless of whether frequency or degree of inequity is the criterion. Ranking cause-specific death rates by risk ratio yielded a dramatically different list, while ranking by risk difference led to a ranking that was not significantly different from the traditional ranking by frequency.

The contrast in the comparison of risk frequency versus these two measures of inequity highlights the ethical problems of incorporating equity considerations into the "worst-first" strategy of risk ranking. Few would advocate transferring large amounts of research dollars from cancer, heart disease and stroke into diseases such as syphilis, tuberculosis and meningitis which pose relatively small overall risks to both blacks and whites, despite the large inequities in the death rates for these illnesses. Using risk difference as the measure of inequity might provide a compromise solution, primarily reordering the most prevalent causes with an equity slant.

Risk ranking based on both equity and efficiency can be useful in identifying certain causes as top priority on both fronts, such as HIV infection and homicide for men and diabetes and perinatal conditions for women. However, problems clearly arise in identifying a systematic method for ranking causes of death which incorporates both frequency and equity. The issues arising from the analysis of these data suggest that when incorporating equity considerations into the "worst-first" strategy favored by professional risk analysts will require (a) agreement on a measure or measures of inequity, and (b) agreement on the relative weights to be assigned to frequency and equity. Since such agreements has been difficult to achieve in other facets of social policy, we should expect it also to be difficult in risk management.[11]

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11 An appendix follows. [Ed.].

Appendix
Causes of Death used in Study

Cause of Death	Disease classification (ICD-9 Codes)
Accidents	Accidents and adverse effects (E800-E949)
Anemias	Anemias (280-285)
Appendicitis	Appendicitis (540-543)
Artherosclerosis	Artherosclerosis (440)
Benign neoplasms	Benign neoplasms, carcinoma *in situ,* and neoplasms of uncertain behavior and of unspecified nature (210-239)
Bronchitis	Acute bronchitis and bronchiolitis (466)
Cancer	Malignant neoplasms, including neoplasms of lymphatic and hematopoietic tissues (140-208)
Congenital anomalies	Congenital anomalies (740-759)
Diabetes	Diabetes mellitus (250)
Gallbladder	Cholelithiasis and other disorders of the gall bladder (574-575)
Heart disease	Diseases of heart (390-398, 402, 404-429)
Hepatitis	Viral hepatitis (070)
Hernia	Hernia of abdominal cavity and intestinal obstruction without mention of hernia (550-553, 560)
HIV	HIV infection (*024-*044)
Homicide	Homicide and legal intervention (E960-E978)
Hypertension	Hypertension with or without renal disease (401,403)
Kidney disease	Nephritis, nephrotic syndrome and nephrosis (580-589)
Kidney infections	Infections of kidney (590)
Liver disease	Chronic liver disease and cirrhosis (571)
Meningitis	Meningitis (320-322)
Meningococcal infection	Meningococcal infection (036)
Nutritional deficiencies	Nutritional deficiencies (260-269)
Perinatal conditions	Certain conditions originating in the perinatal period (760-779)
Pneumonia and flu	Pneumonia and influenza (480-487)
Pregnancy and childbirth	Complications of pregnancy, childbirth and the puerperium (630-676)
Prostate	Hyperplasia of prostate (600)
Pulmonary disease	Chronic obstructive pulmonary disease and allied conditions (490-496)
Septicemia	Septicemia (038)
Stroke	Cerebrovascular disease (430-438)
Suicide	Suicide (E950-E959)
Syphilis	Syphilis (090-097)
Tuberculosis	Tuberculosis (010-018)
Ulcer	Ulcer of stomach and duodenum (531-533)