BASIC GUIDELINES FOR THE ANALYSIS OF MORTALITY

Pan American Health Organization

World Health Organization
REGIONAL OFFICE FOR THE Americas

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These guidelines were prepared by the Department of Communicable Diseases and Health Analysis (CHA) under the direct supervision of the Information and Health Analysis Unit (CHA/HAS) of the Pan American Health Organization (PAHO).

FOREWORD

The first edition of *Lineamientos básicos para el análisis de la mortalidad* was published in 1992 as part of technical cooperation activities implemented by the Pan American Health Organization (PAHO) to strengthen the competencies of health ministries and national statistics institutes at the local and regional levels, and of personnel involved in mortality analysis.

This new edition is the product of PAHO's regional Plan of Action for Strengthening Vital and Health Statistics (PEVS) (2008-2013, extended to 2016), which, through innovative technical cooperation among countries, created the Latin American and Caribbean Network to Strengthen Health Information Systems (RELACSIS). Promoting joint efforts among countries in the framework of South-South cooperation, RELACSIS prioritizes the preparation and analysis of subnational data on live births and mortality. This update responds to the need identified by the interinstitutional teams working in this area to contribute to evidence-based decision-making.

This edition presents historical background and current approaches to mortality analysis. Despite the problems entailed in using mortality to study health, mortality data are usually available and are widely used to measure population health. The purpose of these guidelines is to convey the basic elements of mortality analysis and serve as reference material at the subnational and regional levels, contributing to mortality analysis and a better understanding of the role of these data in the epidemiological profile of the population.

These basic guidelines have been in high demand in Latin America and the countries of the Region have long requested that they be updated. The Health Information and Analysis Unit of PAHO (CHA/HAS) fulfilled the commitment to update them, enlisting the support of professionals from various Latin American institutions. The goal was to keep the content simple in order to enable researchers to conduct basic mortality analysis. This document is the product of that effort and contains relevant updates and innovations that we hope will be useful both to decision makers and to those who work with mortality data every day.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACME: Automated Classification of Medical Entities
CELADE: Latin American and Caribbean Demographic Centre (acronym from the Spanish)
ECLAC: Economic Commission for Latin America and the Caribbean
EDR: Electronic death registration
ICD-10: International Statistical Classification of Diseases and Related Health Problems, Tenth Revision
ICD-11: International Statistical Classification of Diseases and Related Health Problems, Eleventh Revision
MDGs: Millennium Development Goals
MICS: Multiple indicator cluster survey
MMDS: Mortality medical data system
PAHO: Pan American Health Organization
REDATAM: Retrieval of data for small areas by microcomputer
RELACSIS: Latin American and Caribbean Network to Strengthen Health Information Systems (acronym from the Spanish)
SDGs: Sustainable Development Goals
UN: United Nations
UNDP: United Nations Development Programme
UNICEF: United Nations Children's Fund
WHO: World Health Organization
YPLL: Years of potential life lost

I. Mortality

This chapter presents historical background and current approaches to mortality analysis, noting the changes in both the conceptualization of the health disease process and the theoretical and methodological factors that influence approaches to the study of mortality. It also underscores the importance of this analysis for characterizing the health situation and for planning and evaluating policies based on the needs of populations.

1. INTRODUCTION

The tremendous advances in technology that marked the first decade of the 21st century have facilitated and increased access to death statistics and databases. For example, microdata on individual deaths in different countries in the Region of the Americas and around the world can be consulted online (preserving the identity of the deceased). In most cases, this includes basic information such as age, sex, and cause of death, as well as on other characteristics considered important for mortality analysis.

The effort to systematize death records dates back to 16th century London, England. In 1530, following of a series of epidemics, the city instituted a death reporting system, whereby parishes were required to submit weekly reports on the number of deaths from plague (the "Black Death") and all other diseases. In 1604, systematic publication of these death bulletins ("***bills of mortality***") began.

A summary of this information in a series of tables and its subsequent statistical analysis by John Graunt resulted in the report *Natural and Political Observations Made upon the Bills of Mortality*, published in 1662. In this report, Graunt analyzes the leading causes of death, identifying seasonal variations in mortality and other factors related to the plague. The book was a success and was quickly followed by other editions. Graunt's research was continued by William Petty, who recommended the creation of a government agency tasked with the systematic collection and interpretation of the information (Ruiz Guzmán, 2006).

In the late 1830s, the General Register Office for England and Wales took over the registration and dissemination of birth and death information. Compulsory registration of these vital events began in 1837 and, for deaths, included the cause and the occupation of the deceased, in addition to age. In 1839, in a letter annexed to the Office's *Annual Report*, its Director, William Farr, explained the importance of the information in these registries and expressed concern about the differences between sexes and ages and the influence of different social factors – occupation among them. These letters and articles would continue to appear in each *Annual Report*. Farr's contributions can be considered the foundation for the study of health inequalities (Whitehead, 2000).

When official civil registries did not yet exist in the Region of the Americas, births and deaths were recorded chiefly by religious institutions (parish records). These records were the primary source of data for the first pre-19th century demographic analyses, which studied population dynamics.

In the late 19th century, countries created national agencies (civil registries) responsible for recording births, deaths, and other vital events; for example, in Paraguay in 1880, Argentina in 1889 (Di Liscia, 2009), Bolivia in 1896 (Ruiz Guzmán, 2006), and Cuba in 1885 (López Serrano, 2002).

In the mid-20th century, in order to provide countries with uniform statistical standards, concepts, and definitions to improve international comparability, the United Nations Statistics Office (now Division) published a *Handbook of Vital Statistics Methods*. This was followed by the *Principles and Recommendations for a Vital Statistics System*, approved in 1970 and published by the UN in 1973, which included the following statistical definition of death:

> ***"…the permanent disappearance of all evidence of life at any time after live birth has taken place (post-natal cessation of vital functions without capability of resuscitation). This definition therefore excludes fetal deaths."*** [1]

It is worth mentioning that the Royal Spanish Academy's Dictionary of the Spanish Language (*Diccionario de la lengua española*) defines mortality as the "***The rate of deaths in a population during a given time, overall or from a given cause.***" This definition highlights the association of mortality with the population dimension, unlike the terms "death" or "demise," which are individual characteristics.

The first mortality studies more commonly referred to the distribution of deaths by age, sex, and cause and were centered on a qualitative and quantitative approach to the principal epidemics or diseases that heavily impacted specific population groups (e.g., children, women in childbirth, and the active male population).

Once civil registry-based vital statistics systems (described in the next chapter) had taken root in the countries of the Region, mortality information became a basic tool for characterizing the health status of the population and designing policies based on health needs.

1. In line with this definition, this document will exclude consideration of fetal deaths, in light of important differences among the countries, especially in legal terms.

The most commonly used health measurements reflect disease and mortality more than health. Furthermore, the traditional concept in which health was considered the absence of disease still prevails, supported by the greater availability of data and methodologies for measuring disease status rather than health status. In many countries in the Region, mortality information, although solely reflecting extreme harm, is the most complete and robust information available.

In the mid-20th century, this concept of health was supplanted by a definition that relates health to a state of well-being, not simply the absence of disease. This new paradigm embraced the idea that health is the outcome of a series of factors specific to the individual and others related to access to treatment and care, a healthy environment, educational opportunities, the meeting of basic needs (e.g., housing), and living conditions. Analysis of the social determinants of health grew out of this framework.

Thus, other dimensions or variables, such as educational level, health coverage, ethnicity, and birthweight and weeks of gestation in infant deaths, were not only included but considered essential for measuring the impact of social determinants on mortality. The health situation of populations is therefore considered a product of the interplay between the sociopolitical and economic context and the biological, psychological, and physical characteristics of individuals. In-depth studies have demonstrated, moreover, that social inequalities generate health inequalities.

A change in the mortality profile of populations also led to an interest in studying population subgroups such as children, adolescents, and women of reproductive age, resulting in strategies to improve and expand the measurement of mortality in these groups. At the same time, the aging of the population and the predominance of noncommunicable diseases (NCDs) will require additional information and/or new strategies for approaching the study of mortality in older persons. For example, since the traditional approach—based on the causes triggering the processes leading to death—provides only partial information about this age group, a multicausal analysis of the process is necessary.

In short, history and the current literature show that advances and changes in knowledge about the health-disease process require new approaches to mortality analysis.

2. IMPORTANCE OF MORTALITY DATA

Information on mortality, natality, and migration is fundamental to the study of a population's demographic dynamic. Together with information from population censuses, it also provides the basic data for estimating life expectancy and constructing other important sociodemographic and health indicators.

Mortality statistics are widely used in health situation analysis, whether for different populations at a single point in time or for a single population at different times. This analysis is usually accompanied by specific information disaggregated by age, sex, causes of death, etc.

Despite the problems entailed in using mortality as a proxy for health, mortality data are usually available and are widely used to describe the health of populations. Mortality-based health status indicators are very useful, notwithstanding their limitations when the objective is to compare different populations, due to differences in the distribution of the population, health services or health care, or the quality of registries.

Unfortunately, the data on diseases, accidents, acts of violence, and functional limitations in the population are insufficient, but this situation can be improved by using information on diseases and disabilities obtained through population surveys or the health services, as well as other sources, such as the social security system, educational institutions, and national population censuses.

Death is obviously a major event in the life cycle and stands as an event contrary to health, indeed, the definitive end of health. The significance of death, moreover, underscores the importance of mortality as an indicator, given the ease with which it is operationalized, in line with the conceptual definition given above. The difficulties involved in operationalizing the concept of health—compared to the ease of constructing indicators based on the definitions of different diseases and death—are well-known (Almeida Filho, 2000).

The importance of mortality data can be observed in the enormous production of knowledge about its association with multiple factors. Mortality is an endpoint (***"outcome"***) of studies that employ different theoretical and methodological approaches—for example, the biomedical model, centered on clinical aspects of disease and death (Sackett, Haynes, Guyart et al., 1994; Jenicek, 1996); the model centered on health services (Lalonde, 1977; Whitehead, 1991; White Kerr, 1992), or the Marxist model, centered on social determination (Breilh, 1979; Laurell, 1994). The theoretical and methodological approaches mentioned are designed to reveal the magnitude of the impact of different levels of determination on the outcomes of the health-disease-care process. More recently, theoretical and methodological models have been employed that apply the complexity theory to health, hierarchically integrating the different levels of determination (Almeida Filho, 2006).

Studies that yield knowledge about temporal trends in mortality should also be noted, because they attempt to explain its behavior in relation to the context using different theoretical and methodological models, such as the theory of demographic transition or epidemiological transition (Omrhan, 2005) and the discussions surrounding them (Frenk et al., 1991; Barreto et al., 1993).

Information on mortality is essential, moreover, for evaluating health programs and designing activities or strategies. Health policies should be based, even if only partially, on an assessment of health needs and health problems. Suppose we are proposing legislation to prevent injuries, hospitalization, and deaths from a particular disease or health problem. How could we present evidence to support this initiative?

A first step would be to measure the frequency of deaths from a given disease or health problem in the population for which the programs or policies will be proposed. The association between mortality and the sociodemographic factors that might be related to its incidence and distribution should also be described, for example. Having such information makes it possible to adopt preventive measures for the population groups most in need of them and thereby optimize allocation of the available resources, with the consequent improvements in health care.

Finally, it should be borne in mind that systematic mortality registries are important because of their widespread use in different scientific fields, such as the administrative sciences, sociology, political science, demography, geography, and economics. Hence, rather than being limited to the health field, they are useful in all areas of life.

In brief, mortality information is basic for knowing about health conditions, the standard of living, and access to quality medical services and is especially useful for policy- and decision-making on the accessibility and quality of health services.

II. Death Data

This chapter discusses aspects related to the collection, electronic compilation, and evaluation of the quality of death data.

The first section discusses data sources and vital statistics systems in particular. The second describes the characteristics of data capture instruments and their differences among countries, as well as matters related to electronic certificates and registries. The third discusses the activities necessary for creating databases. The fourth addresses a critical issue related to data storage and processing: confidentiality. The fifth and final section focuses on the main criteria for evaluating data quality.

1. DATA SOURCES

Below we present the sources of death data, from the standpoint of a statistics system that constructs national indicators. A well-operating system of this type will yield information that can be disaggregated to the subnational or local level.

While other data sources exist—such as notification or surveillance systems (e.g., for maternal or infant deaths, HIV/AIDS, etc.) and sources from local health systems, such as hospital death records or statistical reports that capture the information on hospitalized patients—these will be considered only in terms of their importance as supplementary sources for improving or evaluating the quality of data from vital statistics. This section also describes the characteristics of vital statistics systems and civil registries, as well as the legal and statistical roles of civil registries when a death is recorded and registered.

1.1 Vital statistics and civil registry systems

Vital statistics systems based on civil registration are the basic source of information for mortality (and natality) analysis.

The majority of countries in the Region of the Americas have vital statistics systems based on civil registration, an act whose legal purpose is the official registration of vital events (births, deaths, marriages, divorces, adoptions, etc.).

> ***"Civil registration is defined as the continuous, permanent, compulsory and universal recording of the occurrence and characteristics of vital events, in particular, events***

> ***concerning the marital status of persons, as provided by decree or regulation, in accordance with the legal requirements in each country." (United Nations, 2003:7)***

The documents (certificates) derived from this registration are legal instruments that enable individuals or their families to prove certain facts, such as age, marital status, or death, that engender rights or obligations. At the same time, they fulfill a statistical objective that serves as the origin for vital statistics systems, which, as mentioned in the previous chapter, are structured according to the United Nations Principles and Recommendations for a Vital Statistics System, currently in its third revision (United Nations, 2014).

> ***"A vital statistics system is defined as the total process consisting of a) collecting information by civil registration or enumeration on the frequency of occurrence of specified and defined vital events, as well as relevant characteristics of the events themselves and of the person or persons concerned, and b) compiling, processing, to analyzing, evaluating, presenting and disseminating these data in statistical form." (United Nations, 2003:5)***

Although, as we have already seen, civil registries in the countries of the Region date back to the late 19th or early 20th century, the development of vital statistics systems by the national governments occurred squarely in the second half of the 20th century.

The countries' legislation generally requires that deaths be registered through a medical death certificate that, in addition to verifying the death, must contain information on other characteristics of the deceased, the circumstances of the death, and, primarily, the cause or causes. Furthermore, the physician who attended the deceased should, in principle, be the one who certifies the death; in that physician's absence, another may do so. In addition, when the death is the result of a confirmed or suspected injury (i.e., caused by an accident, suicide, or homicide), it must be certified by a medical examiner, within the framework of a police and judicial investigation.

A look at the organization of vital statistics systems in the countries of the Region reveals different methodologies for capturing and processing mortality information. In terms of the responsibilities for preparing and analyzing this information, there are different ways of organizing vital statistics systems in the Region. In some countries, national statistics institutes are responsible for the standardization, analysis, and processing of information, either centrally or through comparable subnational institutions. In the majority of countries in the Region, the national ministry of health is responsible for this processing and analysis. A third organizational modality has also been observed, in which the ministries and national statistics institutes share the responsibility.

1.2 Supplementary records

Death registration—based on death certificates—can be supplemented with data from the different sources that make up the statistical or epidemiological information systems. Using a methodology known as ***"comparing"*** or ***"matching,"*** these sources offer broader and more detailed information on deaths, their causes, and the circumstances in which they occurred.

Additional data collection sources worth mentioning, which vary in importance, are (Becker, 1992):

- Civil registry records. Some of the countries in the Region even have regulations requiring civil registries to respond to queries from statistics offices when statistical instruments for capturing death data lack information.

- Health surveillance and compulsory disease reporting systems. These are a very important additional source for monitoring morbidity and mortality from diseases whose investigation and monitoring are considered a priority, as they are events or processes involving health problems that require immediate action or that are concentrated in specific population groups, such as children under 1, women of reproductive age, workers employed in work activities with occupational health implications, etc.

- Registries for diseases/conditions such as cancer and congenital abnormalities are also important sources of information.

- Health service mortality registries. From a qualitative and quantitative standpoint, death data can be expanded to include, in particular, deaths that occur in hospitals but that have either not been registered or have been incorrectly registered. The health services are an important additional source of information, especially with respect to the cause or causes of death and other data that may not have been entered on the death certificate.

Some places have civil registry offices or posts in the health services themselves (hospitals, sanatoriums), which can help reduce missing information, since most of the life events of public health interest—especially births—tend to occur in health facilities.

- The records of forensic medicine institutes. These records are an important source of information, chiefly with respect to knowledge about the underlying cause of violent deaths, since the death certificates completed by medical examiners often contain a description of the injuries found.

- For the study of violent deaths, other important sources outside the health sector can be tapped—for example, police records and media reports, when disasters strike or major accidents occur, and investigations that reliably determine causes of death subsequent to the preparation of death certificates.

1.3 Censuses and surveys

Censuses and sociodemographic surveys are an alternative and supplementary source of information for studying population dynamics and characteristics. When geared to households, they are a very important source of demographic information that, while not a substitute for the vital statistics system, can effectively supplement it.

Population censuses, which are usually conducted every 10 years,[2] — in years ending in 0 or 5, are an important instrument for analyzing natality and mortality in the intercensal period.

Today, in countries in the Region where the civil registry does not achieve the desired coverage of vital events for reasons of geographic, political, or cultural inaccessibility, population censuses are critical for learning about the demographic dynamic. To meet this objective, a series of specific questions should be included on the census form to obtain information on the death of household members in a given period, specifying the sex and age of the deceased. Deaths in adults are normally investigated separately, while deaths in children are investigated through questions on fertility—for example, the number of children born alive and the number of surviving children by age (CELADE, 2010).

In addition, there are many examples of countries with civil registry coverage problems where population surveys play a key role in estimating both natality and mortality and also address matters related to the causes of death in specific population groups (infant mortality, maternal mortality).

Demographic and health surveys are conducted to ensure that decision-makers in the public and private sectors (especially the former) with influence on health and population policy have up-to-date information when designing and evaluating programs. The main purpose of these surveys is to construct indicators on demographics, housing, fertility, general and reproductive health, the nutritional status of children, infant and child mortality, etc.

Multiple indicator cluster surveys (MICS) are a household survey program developed by UNICEF to help countries complete the information necessary for monitoring human development in general and the situation of children and women in particular. Statistically adequate evaluations can be obtained through MICS that permit international comparisons of social indicators, such as those corresponding to the Millennium Development Goals (MDGs) and the Sustainable

2. Depending on the laws and regulations of each country.

Development Goals (SDGs). The surveys include a household and family questionnaire, another for women aged 15-49, and a third one on children under 5, which is answered by the mother or another caregiver.

Another special type of survey used in the study of mortality is included in the methodology known as verbal autopsy (Soleman, Chandramohan, and Shibuya, 2006), where people in the household of the deceased are questioned about the person's life history and the process that led to death, especially in events where the role of the health services and social determinants is analyzed. This methodology is primarily used in the investigation of maternal deaths (Torres et al., 2014) and deaths from ill-defined causes (Ministry of Health of Brazil, 2008).

1.4 Mortality estimates

In countries where the coverage and quality of vital statistics are a problem, estimate-based methods are used to describe natality and mortality—for example, through demographic and health surveys and MICS surveys. Similarly, for countries in the Region that lack consolidated and operational statistics systems, the estimates produced by international organizations are another good alternative for approaching mortality analysis.

For more than five decades, a number of UN institutions (Population Fund, Economic Commission for Latin America and the Caribbean (ECLAC), Latin American and Caribbean Demographic Centre (CELADE), etc.) have issued population estimates and projections, along with estimates of total mortality and mortality in specific population groups. With the formulation of the Millennium Development Goals, methodologies have been developed to estimate different indicators for evaluating attainment of the targets set (World Health Organization, 2015).

More recently, an interagency group (World Bank, WHO, UNDP,[3] UNICEF) has been created that estimates and adjusts the mortality information supplied by the countries, based on specific criteria and methodologies to guarantee the homogeneity and comparability of the information (World Health Organization, 2015).

In concluding this section, it is important to emphasize once again that vital statistics systems based on civil registration are currently the best source of data, because they provide the numerators and denominators for calculating the most critical health and demographic indicators and make it possible to analyze and measure the degree to which health and well-being targets are met.

3. World Health Organization (WHO); United Nations Development Programme (UNDP).

2. DATA CAPTURE INSTRUMENTS

Most of the countries have adopted data capture instruments based on UN recommendations. Some differences are worth mentioning, however. Moreover, advances in information and communication technologies have also had an impact on the systems involving death registration, which has led to the automation of civil registries and, in some cases, the use of electronic death certificates.

2.1 Legal and statistical registration models

According to the current legislation in each country, when a death occurs, a physician or legally authorized individual completes a form known as a ***death certificate***, whose purpose is to register the event for legal purposes. In the majority of the countries, death certificates also have a statistical purpose, serving as the starting point for mortality statistics in the vital statistics system.

Some countries in the Region (e.g., Chile and Mexico) have a single data capture instrument with a dual (legal and statistical) objective. Prepared as documentation for the civil registry, the death certificate also provides information that will be used in the statistical processing and analysis of mortality data.

Other countries (e.g., Argentina) supplement the death certificate with a data collection instrument, known as a statistical report or bulletin, which contains a series of data aimed primarily at providing more detailed social and health information, in addition to the causes of death.

For reasons of professional competence, a physician—preferably the one who attended the deceased during the illness or injury that caused the death—is responsible for providing information on the causes of death, based on a model that will be described in the next chapter. Consequently, physicians are responsible for ensuring that the statistics reflect the profile of causes of death as faithfully as possible.

In some countries, a death can be recorded without medical certification, in which case, the informant is asked to indicate the probable cause of death.

As already mentioned, in developing this data collection instrument, nearly all the countries have followed the *Principles and Recommendations for a Vital Statistics System* (United Nations, 2003). Thus, they usually record data on the deceased, including age, sex, educational level, usual occupation or activity, place of residence, health coverage, etc. Furthermore, they also record data on the death that, in addition to the underlying, associated, and contributing causes, includes the date, geographic location and place where it occurred, and, for violent deaths, the circumstances, setting or place, and other pertinent information.

It should be noted here that in certain countries in the Region, such as Colombia and Paraguay, death certificates include not only deaths that meet the definition provided in the introduction, but fetal deaths as well, while in the majority of the countries, both the legislation and vital statistics systems require different registries for these events.

The 2016 edition of the *International Statistical Classification of Diseases* (often referred to as the ICD-10) proposes a single form for recording these events, but certain countries in the Region (among them Argentina and Mexico) have not accepted it for legal reasons.

2.2 Electronic registries

Several countries in the Region have advanced in the automation of their civil registries (e.g., Argentina, Paraguay, and Uruguay), making progress in two directions: first, in the digitization of their existing registries; and second, in the development of tools for automating the entire vital events registration process (from collection of the information for issuing certificates and legal registration of the events, to their storage).

In its *Principles and Recommendations for a Vital Statistics System*, the UN defines electronic records of vital events as "***the most effective and appropriate method of civil registration***" (United Nations, 2014: 84), noting that it facilitates the linkage of records with other information inside and outside the system (United Nations, 2014).

As already indicated, there are different modalities for collecting statistical data on mortality, regardless of whether it is done in conjunction with the legal registration of vital events or independently by statistical support systems.

Whatever the modality, most countries still use paper forms, which implies the need for physical and human resources to enter the data in computer systems for subsequent processing, tabulation, and analysis. Nonetheless, data capture on paper is a less costly alternative that requires no computers equipment or software for the generation of statistical data, meaning that the people who record the deaths do not need to be trained in the use of modules for uploading the data.

There are cases where progress has been made in ***electronic death registration*** (EDR). In qualitative terms, the difference between EDR and traditional systems lies not only in the nature of the data capture instrument but in the fact EDR eliminates paper in the entire statistical data generation process.

The following are the main advantages of EDR:

- For civil registration of vital events, electronic support offers the possibility of enhancing security measures to protect legal aspects of the registry.
- It eliminates the need for human and physical resources to transfer data from paper forms to computer systems for information processing and management.
- Digital files with the information are more secure and economical than paper files and facilitate access to the original data when the need to correct processing inconsistencies arises.
- Electronic forms make it possible to apply permit content filters and integrity controls to prevent the uploading of incomplete and inconsistent information.
- EDR facilitates linkage of mortality information with other information systems.
- EDR improves the timeliness of information by substantially shortening uploading and processing time.

In the United States, some states began introducing EDR systems in the late 1990s. Today, the majority of the states have done so (Trasatti Heim, 2010).

ADVANTAGES	CHALLENGES
+ Greater efficiency through electronic user interaction	+ Lack of nationwide connectivity
+ Greater timeliness of the information	+ Procurement of funds for their implementation
+ Improvements in the quality of information	+ Training the people involved users
+ The possibility of real-time publication	+ Administration of roles and permits for system users
+ Greater security and fraud prevention	+ Quality of the stated causes of death
+ Ability to use mortality statistics as input for epidemiological surveillance.	

The gradual implementation of EDR systems in the United States is part of a larger project to interconnect health information and integrate standards to ensure the quality and comparability of vital statistics information among states (Trasatti Heim, 2010).

In Uruguay, the use of ***electronic death certificates*** for all deaths registered in the country was approved by Presidential Decree No. 140 of 8 December 2011. In the rationale for this regulation, priority is given to preserving the confidentiality of the clinical data on death certificates, systematizing the information on the causes of death, facilitating the preparation of vital statistics, and implementing epidemiological surveillance tasks (Uruguay, Ministerio de Salud Pública, 2011).

In Colombia, progress has been made in developing ***systematized statistical death registration*** with online data capture to generate an electronic death certificate. Health professionals who certify deaths upload information through a computer application in a health information system known as the ***Unified Member Registry,*** which helps link vital events information with other health information (Colombia, Departamento Administrativo Nacional de Estadística, Dirección de Censos y Demografía, 2011).

The spread of new technologies and the gradual improvement of vital statistics systems in the countries of the Region have created a positive scenario for tackling the challenge of implementing EDR systems. However, in addition to the costs, certain technical considerations must be properly evaluated, including those mentioned above, and others that require the availability of a digital signature.

3. CREATION OF DEATH RECORD DATABASES

The countries' death information is usually compiled in electronic files containing all registered deaths. As mentioned earlier, every subnational area uniformly collects the information—that is, using identical operational definitions, data capture forms, and coding and procedures consistent with international recommendations designed to facilitate the comparability of information among countries.

It is customary to have national agreements on the basic information to be collected in each subnational area and sent to the national level, giving each small geographical area the opportunity to include additional relevant information about the population and local administrative needs.

3.1 Compilation and validation of electronic death data

The structure of vital statistics systems usually includes a national level that compiles information on deaths throughout the nation. The United Nations

Statistics Division describes the compilation and validation process as six activities that should be conducted at the national level:

- **Control of the receipt of reports:** in this stage, the information sent by the subnational areas is verified as complete. The statistical reports are generally compared with the legal death registries to prevent the receipt of incomplete, redundant, or partial information.
- **Editing:** this involves computer monitoring to minimize errors. In this stage, an analysis is performed to detect inconsistencies among variables (causes of death by sex, by age, etc.).
- **Correction:** any errors found in the previous stage are corrected through consultation with the office responsible for the subnational area where the information originated, since traditional systems are where the paper forms are archived.
- **Imputation of missing or inconsistent information:** in cases where the corrections are inadequate or the missing information is unavailable, imputation can be employed. Two modalities are usually used: the imputation of one unknown value through another, or through other known values in the same registry (e.g., the imputation of age through the date of birth); or imputation through other sources of information (e.g., medical records or statistical reports on hospitalizations).
- **Coding:** this consists of converting qualitative information to numerical values to facilitate processing. This process is generally used for variables such as the level of education achieved, marital status, cause of death, etc.
- **Conversion of the information to an electronic format:** this refers to the creation of a national archive that compiles the information on all deaths registered in the country (United Nations, 2014).

It should also be emphasized that countries apply these recommendations differently. With the advances in information management technology, many countries have moved toward decentralized information generation and processing. Within this context, editing and coding activities often take place in subnational areas, which send pre-processed electronic files to the national level—for example, in Colombia (Departamento Administrativo Nacional de Estadística, Dirección de Censos y Demografía, 2011), Argentina (Dirección de Estadísticas e Información de Salud, Programa Nacional de Estadísticas de Salud, Ministerio de Salud y Ambiente de la Nación, 2005), and the United States (Siri and Cork, 2009). Some information systems on vital events, in contrast, have a more centralized structure, where only the subnational area collects the information (for example, Chile) (Instituto Nacional de Estadísticas, n/d).

3.2 Death record repositories

In the majority of the countries in the Region, Internet access facilitates the procurement of statistical information on mortality. Files containing microdata on deaths can easily be downloaded from numerous sources—that is, databases with detailed information on registered deaths, by year. These files can be processed with computer software for the tabulation and analysis of statistical information.

The available data are coded to facilitate their storage and processing. In all cases, the databases mentioned in this section have detailed descriptions of be the file structure, thus facilitating access to the information. It should be borne in mind that, when accessing a database repository, the information available in it may be in a final file on deaths occurring in a specific time period or in a provisional or preliminary file that does not yet contain all registered deaths or that may be modified in the future.

Another variant of available online information involves interactive consultations. In this case, the user does not download a file, but instead inputs the details of the required information in a dialogue box; the system then retrieves the information requested in table, figure, or map format (depending on the data source).

The World Health Organization (WHO) provides ***raw data files*** on its website[4] These files contain a regional mortality database. The data are presented in a standard format that can be processed with most of the available computer software. The data contain annual information on deaths for each country in the Region, disaggregated by country of origin, sex, age of the deceased, cause of death (through various groupings), and details about the information sources and their availability (some countries submit information from estimates and others, from permanent universal registries) (World Health Organization, 2015).

The website of the Pan American Health Organization (PAHO) provides a function to search national mortality databases. Through a simple interface, users can apply filters to the information from the Region and create death databases according to selected variables: sex, age group, groups of causes of death, and year the death was registered, depending on the information provided by each PAHO Member State (Pan American Health Organization, 2015).

Some national offices offer microdata files or online consultations through the network. A case in point is the National Statistics and Geography Institute of Mexico, which offers users interactive online consultations and the ability to download the databases (Instituto Nacional de Estadística y Geografía, 2015). It should be pointed out in this case that the microdata files include all the variables found on death certificates; thus, the potential for analysis varies widely.

Furthermore, the Colombian National Statistics Administration Department has made a web application available to users through ECLAC's REDATAM 7 statistical

4. http://www.who.int/healthinfo/statistics/mortality_rawdata/en/#

package[5] (developed by CEPAL) which offers access to death data through online consultations (National Statistics Administration Department, 2015). The salient feature in this case is the fact that through the application, users can request more sophisticated statistical processing (e.g., cross-tabulation of variables, filters, geographic segmentation, etc.) without manipulating the microdata files. The same system can be found on the websites of the National Statistics and Census Institute of Ecuador and the National Statistics Office of the Dominican Republic for the vital statistics of those countries.

The Ministry of Health of Brazil has developed one of the most complete interfaces for the online processing of databases. Its website provides an interactive tool for consulting statistics on vital events, with access to aggregate mortality data in table, figure, or map format, which includes the ability to work with variables related to the vital event, the deceased party, and geographical area (DATASUS, 2015).

3.3 Database matching

In mortality analysis, ***"database matching"*** is understood as the use of statistical information from two or more sources to describe vital events and/or improve the quality of information. One example of this matching would be the combined use of information from the vital statistics system and hospital discharge records to obtain information on prior hospitalization (if applicable) for each registered death or to obtain more information on the cause of death in cases where it had been improperly entered on the medical death certificate.

In academia, there are experiences that show that database matching is a valid option for these purposes (De Castro, Assunçao, and Durante, 2003; Marsh and Jackson, 2013; De Souza et al., 2008). Countries usually adopt programs to reduce the fragmentation of information systems in order to systematize them for total linkage (Friedman and Gibson Parrish, 2015); in this case, the death information could be enhanced with information from other documents, such as medical records, and information from the health services and other areas such as education, labor, and the justice system. Although this situation appears to be fairly remote today, depending on the situation in each country, it should be noted that these processes often encounter difficulties, including:

- Disparities in information capture procedures for different sources.
- Difficulty harmonizing conceptual and operational definitions of the events measured.

5. REDATAM: ***RE***trieval of ***DAT***a for small ***A***reas by Microcomputer.
https://www.cepal.org/cgi-bin/getProd.asp?xml=/redatam/noticias/paginas/3/7343/P7343.xml&xsl=/redatam/tpl/p18f.xsl&base=/redatam/tpl/top-bottom.xslt

- Legal mechanisms that regulate and limit the personalization of records, and thus the identification of records in the information systems that are to be linked.

In this context, database matching poses a methodological challenge that must be tailored to the conceptual requirements and current regulations of each country.

Data is matched through an algorithm that establishes how the records of the data sources used will be connected. This procedure, known as ***"linkage,"*** will make it possible to recognize related records in the respective data repositories. For example, through linkage, information on prior hospitalization of the deceased can be associated with each death.

The operational dimension of database linkage is facilitated by a unique shared identifier for each event in the sources involved (e.g., document number, clinical history number, household, etc.). In this case, the matching is done deterministically—that is, through exact parity. There are methods that, in the absence of a unique identifier, do the matching probabilistically—that is, by similarities in the records (which necessarily results in a considerable level of error). For more information on these techniques, see *Data Quality and Record Linkage Techniques* (Herzog, Scheuren, and Winkler, 2007).

4. ASPECTS OF DATA CONFIDENTIALITY

In 2014, the United Nations General Assembly adopted a resolution endorsing the *Fundamental Principles of Official Statistics*, established in 1994 and reaffirmed in 2003. These principles consist of 10 postulates, the sixth of which refers to the issue of data confidentiality. The resolution states that:

> ***"Individual data collected by statistical agencies for statistical compilation, whether they refer to natural or legal persons, are to be strictly confidential and used exclusively for statistical purposes." (United Nations, 2014: 2)***

Every country in the Region has regulations protecting the confidentiality of statistical information, although the scope of these regulations differs. To cite but one example, in some countries, a request for information for judicial, tax, or conscription purposes can override the statistical secrecy policy, while in others it cannot (Economic Commission for Latin America and the Caribbean—ECLAC, 2015).

Given the growing demand for microdata by investigators, coupled with their greater availability through the Internet and the growing interest in analysis and international comparisons, the ECLAC Statistics Commission issued principles and guidelines for managing statistical confidentiality and access to microdata

(*Principios y directrices para la gestión de la confidencialidad estadística y el acceso a los microdatos* (ECLAC, 2015) to facilitate user access to microdata, improve country procedures for this access, and standardize practices. Within that framework, several countries, including Chile, Colombia, Ecuador, and Peru, have prepared ***"good statistical practice codes"*** which, inspired by the European version developed by Eurostat (2011), are designed to increase the confidence of statistical data users and improve the quality of procedures.

In the case of Chile, for example, the fifth principle states that:

> ***"The privacy of data providers (households, businesses, administrations, and other respondents), the confidentiality of the information they provide, and its exclusive use for generating statistics should be absolutely guaranteed." (National Statistics Institute, 2013: 2)***

The regulations governing statistical confidentiality and secrecy and the adoption of standard practices to ensure confidentiality and improve the quality of information production are key tools for statistics offices. Moreover, the domestic and international circulation of microdata, coupled by the need to link information from different sources for research, management, and public policy-making, call for extra efforts to ensure confidentiality, bearing two issues in mind:

- Personalizing data not only identifies the deceased, but its disaggregation can jeopardize statistical secrecy. For example, in geographical areas where a particular event occurs very infrequently, a piece of information with no identity attached can also identify the deceased.
- Offering microdata requires procedures that guarantee users more detailed mortality data than what is provided in the tables, without losing the unique objective of statistical information, i.e., cluster analysis (rather than the analysis of individual cases, as occurs, for example, in epidemiological surveillance).

5. QUALITY OF DEATH DATA

An inescapable issue for studying mortality through information generated by vital statistics systems and civil registries or other sources is data quality. Prior to analysis, any errors that could affect the data must be detected. It is currently recognized that quality issues are multivariate in nature. Furthermore, they can be present at all stages: design, collection, processing, preparation, analysis, or dissemination of the information.

There are different approaches to evaluating the quality of demographic data (United Nations, 2014). This section discusses two main components of error in death data found in the collection and processing stages: the coverage and content of the information. Chapter IV discusses another approach to quality evaluation connected with the overall quality of indicators and the statistical systems that produce them.

5.1 Coverage

When discussing quality, one of the most important stages is coverage analysis. Errors are usually related to the failure of vital statistics systems to systematically include deaths. Duplication (over-registration) is a less common problem but should not be ignored.

> ***"Coverage errors occur when individuals or events are not registered, when they are registered when they should not have been, or when they are registered more than once. These situations give rise to quantitative errors, resulting in the undercounting or overcounting of the people or events being registered." (United Nations, 2014)***

According to the current literature, when evaluating this dimension, differences are seen in the degree of population access to civil registry offices in the country, measured by the availability of these offices (coverage), and the reach of the system in terms of the ability to register all deaths that occur in the population (completeness) (World Health Organization, 2010).

We will define the magnitude of events not captured by the registration system as ***"omission of registration"*** or ***"under-registration."*** Nonregistration of deaths (legal and statistical) may be due to countless factors, the most important being:

- The inability of the population to register the events for geographical, socioeconomic, or cultural reasons. This impediment is greater when a significant number of deaths occur outside health institutions.

- The lack of civil registry offices. In some countries in the Region, the civil registry does not fully cover the nation's territory due to geographic, political, or funding issues.

- Lack of linkage between the civil registry and vital statistics systems and their inefficiency. This can lead to sloppy processes—for example, events captured by the civil registry are not transmitted or reported to the vital statistics system (undertransmission of data).

In the section on data sources, mention was made of supplemental sources for the vital statistics system and civil registry that can be used to identify and quantify the degree of under-registration or undertransmission.

Under-registration can be evaluated by comparing clusters of data or by individually matching events between different sources. When the source of comparison is considered complete, the percentage of events that the vital statistics system captures can be calculated. However, when the source of comparison is incomplete, under-registration can be estimated using certain assumptions, based on the method proposed by Chandrasekaran-Deming, also known as the capture recapture approach (United Nations, 2014; AbouZahr et al., 2010).

Given this context, one of the first things to do is to establish a baseline with the expected number of deaths. In establishing that expected mortality baseline, supplementary sources and population estimates and projections can be used, as well as the mortality tables prepared by the country or international organizations. Comparing the expected deaths with the number of registered deaths will yield a preliminary estimate of under-reporting and the need to search for other data collection sources.

An important prerequisite for achieving quality is for the national and subnational levels to use a single definition for each vital event and uniform registration standards and procedures. Ignorance of or failure to apply these definitions, standards, and procedures may be other factors contributing to the under registration of deaths. Furthermore, several studies have shown that under registration is not homogeneous in all age groups, with proportionately more deaths registered for adults than for children.

One of the most common errors stems from incorrect recording of the event due to incorrect understanding of the definition. For example, when infants are born alive but die immediately after birth, there is a tendency to record these as fetal deaths. In other words, there could be under-registration of both live births and infant deaths, which directly influences measurement and analysis of the infant mortality rate.

Many infants may be registered as stillbirths, based on the longstanding medical principle of ***"viability."*** Newborns with very low birthweight or multiple birth defects usually live only very briefly after birth, but if they breathe or show any other sign of life, under the current definition they should be considered live births and registered as such.

The under-registration of births and infant deaths is also influenced by cultural factors. In practice, a newborn who dies shortly after birth is not always a person who was born, lived, and died.

One way of detecting errors of this type is to count infant deaths in the first two days of life. Whatever the health situation or quality of the services, when the number of deaths in the second day is equal to or higher than those in the first day, it is highly suggestive of incorrect application of the concept of ***"live birth."*** In other words, children who were born alive and died a few minutes or hours later are being considered fetal deaths.

Several countries in the Region have adopted strategies to reduce the under registration of births and deaths. Significant among them are the creation of civil registry offices in health facilities, the use of intentional search methodologies for the detection of deaths, and infant and maternal mortality surveillance systems. For example, a study involving an active search for births and deaths was conducted in the north-northeastern region of Brazil that led to the adjustment of infant mortality rates in all municipalities (Landmann Szwarcwald et al., 2011).

5.2 Errors in content

Even when a death has been registered, answers to one or more items in the data collection instrument may not have been provided or the responses entered may be incorrect. These errors may stem from numerous causes, such as problems in the design of the instrument, poor training of the individuals who complete the forms, the informant's lack of understanding, or, also, the intentional concealment of certain information.

> ***"Content errors, meanwhile, refer to all cases in which people or events have been counted, but their characteristics have been improperly recorded. The errors involve the quality of the information—in other words, they are qualitative." (United Nations, 2014)***

5.2.1 Integrity and validity

It is important to evaluate the extent to which valid or acceptable responses are provided for each variable, attribute, and item included in the mortality data capture instrument. It also is important to emphasize that *each country should have a single national data collection instrument to permit data comparability* and thus, regional and national consolidation.

In data capture instruments, medical certification of the cause of death usually follows the international model created by WHO, which will be described in the next chapter. Questions with respect to other data (demographic, socioeconomic, place where the death occurred, etc., as well as those on the physician who issues the certificate) have different formats. Some are open, while others provide responses with predetermined categories or value intervals.

The number of variables or items with no response or the rate at which each of them have no response (missing information) will serve as an indicator of the integrity of the mortality information. Furthermore, a mortality statistics system with data capture instruments that include variables and attributes that are very important for the analysis but have high rates of ***"no response," "missing,"*** or ***"unknown,"*** indicates the need to review the system.

The situation becomes substantially more critical when incompleteness affects the causes of death. With respect to the requirement that death certificates be completed by a physician, the legislation in the countries of the Region differs. Where this requirement exists, incomplete data on the causes of death greatly affects the ability to analyze these causes and offers a way to indirectly evaluate the quality of resources in the health sector. The next chapter includes more information on this aspect of quality.

When regard to the *validity or specificity of the data*, it is understood that the information provided adequately describes the matter being investigated. For example, if the response to the question about the occupation or activity of the deceased is ***"employee"*** or if the response to the question about his educational level is ***"primary"*** or ***"basic,"*** these responses are not considered very specific.

Identity and demographic variables, such as sex and place of residence, are usually answered completely and are fairly reliable. At the same time, when the question is about the age of the deceased, problems sometimes arise that should be evaluated. The rounding of age to values ending in 0 or 5 is a known phenomenon. Furthermore, for people of advanced age, the information tends to be less accurate. Notwithstanding, the quality of the age variable is usually acceptable.

When not omitted altogether, the quality of the responses for socioeconomic variables is lower, for two basic reasons:

1) The data is harder to obtain, either because respondents have only partial information or they have difficulty understanding what is being asked; and

2) It is difficult to arrive at a uniform definition of criteria and concepts that facilitates the operationalization of this type of variable. Consequently, these variables are less often used, resulting in less opportunity to evaluate the data and, thus, improve them.

5.2.2 Consistency

Evaluating the consistency among variables is another important aspect. Designing a consistency plan that establishes the relationships among the variables involved in death registration is another requirement for the agencies tasked with the production of mortality information.

Thus, the logical relationship between age, sex, and cause of death must be considered. The limitations of causes by sex are specified in the *International Statistical Classification of Diseases and Health Problems, Tenth Revision (ICD-10)* and in the next chapter, while the limitations by age are not standardized internationally, and each country generally constructs them on its own. The updates section of the PAHO website contains a reference on age limitations for the causes detailed in the ICD-10[6].

In the case of variables such as educational level and occupation, the coherence between that level and the age of the deceased should be confirmed. Furthermore, when analyzing infant mortality, consideration should be given to the relationship between weeks of gestation and birthweight according to reference tables, level of instruction, age of the mother, etc.

In concluding this section, it must be underscored that the quality of data in vital statistics systems must be improved and strengthened—not replaced by other sources, such as surveys, for example. However, these latter methodologies are extremely valuable supplementary sources that make it possible to address issues that cannot be included in routine systems.

6. http://www.paho.org/hq/index.php?option=com_content&view=article&id=9178%3A2013-actualizaciones-cie-10&catid=1777%3Anorms-standards&Itemid=40291&lang=es

III. RECORDING AND CLASSIFICATION OF CAUSES OF DEATH

This chapter discusses two issues essential to the production and analysis of mortality statistics: registration of the cause of death and the statistical classification of diseases or health problems.

The first section provides the basic guidelines for recording the causes that intervene in a death, prioritizing them on the **"International Form of Medical Certificate of Cause of Death."** The second discusses the general features of a classification of diseases, subsequently detailing the major characteristics of the International Statistical Classification of Diseases and Related Health Problems Tenth Revision (ICD-10), which is the most recent version, and reviewing its history. The third section discusses issues related to recording causes of death that impact the quality of mortality statistics. The fourth section reviews automated systems for coding and selecting the underlying cause of death (UCD). The chapter ends with a brief discussion of the World Health Organization's work on the Eleventh Revision of the ICD.

1. RECORDING THE CAUSES OF DEATH

In the section in Chapter II on vital statistics systems, it was mentioned that death registration was originally for legal purposes and that, while there are subtle differences among countries in the Region of the Americas, death certificates generally combine legal and statistical aspects of the vital event in question.

One of the most valuable statistical elements in the certification of a death is the recording of its causes. In some countries, the certification of deaths is not the exclusive province of physicians, and other health professionals can be involved. However, in most, it is one of the responsibilities of physicians and the obligation to certify a death, regardless of whether it occurred in a health institution, rests with them.

In these cases, for every natural death—that is, one that is not violent or suspicious—the death certificate must be issued by a physician. However, when the death occurs under suspicious circumstances, the responsibility for certification is passed to a medical examiner or forensic pathologist, through judicial intervention.

The term ***"cause of death"*** is subject to different interpretations. In the days when there were no suggestions or international consensuses on how causes of death should be recorded, health professionals had different understandings what constituted the cause of death. Some of them recorded signs or symptoms prior to death or entered a single cause, while others believed it could be beneficial to enter several diseases as the ***"cause of death."*** In that case, they noted all pathologies considered to have been involved in the death (Moriyama et al., 2011).

If death is understood as a process that usually begins with a health problem that worsens and facilitates the emergence of another disease, more than one cause is likely to be detected in this process (known as the causal chain). Which, then, should be considered the ***"cause"*** of death?

In its 6th Revision, the International Classification of Diseases, which is described in the next section, included recommendations for recording the causes of the death and defined the underlying cause of death (UDC) 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."***

1.1 International Form of Medical Certificate of Cause of Death

The World Health Assembly recommended a specific methodology for certifying the causes of death and, to this end, in 1967 designed the ***"International Form of Medical Certificate of Cause of Death."*** It furthermore tasked physicians responsible for certification with entering on this form all the diseases, morbidities, or injuries that caused or contributed to the death and the circumstances of the accident or violence that produced the injuries.

This form, which has been in use for several years and is internationally recognized, has a design that facilitates the physician's task of recording all the causes in the process and not simply the last one, which is often the most easily recognizable. The form also facilitates selection of the UCD, which will usually be the one located on the last line (World Health Organization, 2010) if the causes were properly recorded.

This certificate consists of two parts: Part I, devoted to the causes intervening in the causal chain, and Part II, devoted the causes that, outside the chain, contributed to the fatal outcome.

From the first to the last line, Part I indicates the following:

- **The last, final, or direct cause of death:** the one that finalizes the process and, without leading to another cause, directly ends the person's life.

- **Intermediate or intervening cause(s):** as the name indicates, the cause or causes in the middle of the process. There is generally only one, although if Part I has four lines, there can be two intermediate causes.

- **Originating antecedent cause (OAC):** this is what is entered on the last line, because it engendered all the causes entered on the lines above it.

If the causes were entered correctly, the cause on the last line (OAC) will be the one selected as the UCD. However, in some cases, the ICD states that the OAC should be replaced with another cause indicated on the certificate—one that is more precise for tabulation purposes, such as the UCD, since from the standpoint of the use of mortality statistics, there is another cause that is more useful and more precise. (World Health Organization, 2010).

If the causes were entered incorrectly and the causal chain was not respected, the ICD has detailed selection rules to guide coders in choosing the cause that leads to the others as a basic step for selecting the UCD. Furthermore, in cases where the physician considers a disease or pathological state by itself to have caused the death, a single cause will be entered on the first line of Part I—and that will be the UCD.

In short:

Part I can list one, two, three or, in some countries, four causes, but not more, since there should always be one cause per line.

Part II of the certificate will record other pathological states or diseases that, not having been part of the causal chain, contributed to the death simply because they were present. These states are known as contributing causes.

In all cases, the time between the onset of the disease and death can be entered. Let us suppose that a 72-year-old man underwent surgery for stomach cancer 10 months ago. He subsequently experienced pulmonary metastases, and one week before his death, developed pneumonia. The patient had been hypertensive for years. When entering these causes on an International Form of Medical Certificate, pneumonia should be listed as the final cause (noted on the first line), produced by pulmonary metastases (reported on the middle line) from stomach cancer (noted on the last line). Hypertension can be entered in Part II if its presence contributed to the fatal outcome without having been part of the causal chain. Stomach cancer, entered on the last line of Part I, is the UCD, since it triggered the chain of events that lead to death. This example is illustrated in Table 1.

Table 1. Example of completed International Form of Medical Certificate of Cause of Death.

Cause of death		Approximate interval between onset and death
I Disease or condition directly leading to death*	**a) PNEUMONIA** due to (or as a consequence of)	**7 days**
Antecedent causes Morbid conditions, if any, giving rise to the above cause, stating the underlying condition last	**b) PULMONARY METASTASES** due to (or as a consequence of)	**Months**
	c) STOMACH CANCER due to (or as a consequence of)	**Years**
	d)	....
II Other *significant conditions* contributing to the death but not related to the disease or condition causing it	**HYPERTENSION**	**Years**

*This does not mean the mode of dying, e.g., heart failure, asthenia, etc. It means the disease, injury, or complication which caused death.

It is especially important to mention the 1990 recommendation of the World Health Assembly that deaths from causes related to or exacerbated by pregnancy or its care be identified on the death certificate. The Assembly called on countries to include a question in the certificate to ascertain whether the deceased was pregnant at the time of her death or had been so in the previous year. This recommendation helps identify maternal deaths, regardless of the causes entered on the death certificate.

Implementation of the International Form of Medical Certificate of Cause of Death has not only standardized the recording of causes but facilitated selection of the UCD, which is used for analyses or tabulations by a single cause. Annex 1 shows, by way of example, how this form is integrated in Mexico's current Death Statistics Report.

2. INTERNATIONAL STATISTICAL CLASSIFICATION OF DISEASES

To produce mortality statistics by cause, an instrument is needed to organize all the causes entered on the medical death certificate.

The International Classification of Diseases meets this requirement, since it is useful for storing the causes entered on death certificates in summary form.

This makes it possible to retrieve the information and facilitates its analysis, interpretation, and comparison between regions or time periods. The ICD defines itself as ***"a system of categories to which morbid entities are assigned."*** Although the number of categories is limited and they are mutually exclusive, the classification by itself is capable of covering all existing or potential entities to be recorded.

The categories are organized according to a public health-based statistical criterion. If a disease is infrequent but very important from a population health standpoint, it has its own category; the same holds true for high-frequency entities. Furthermore, there are disorders that will be represented in a category with other related disorders. The classification also has residual categories for diagnoses that cannot be assigned to specific categories.

In addition to grouping diagnoses, the ICD has developed guidelines to standardize the entry and coding of morbid conditions and causes of death, along with rules for selecting the underlying cause of death and principal condition in morbidity registries.

2.1 History of the ICD

The ICD's origin dates back to the late 19th century. In 1893, French statistician Jacques Bertillon presented the first Classification of Causes of Death to the International Statistical Institute. However, interest in studying causes of death from a statistical standpoint had already been present a century before. The forerunners of the Classification included the works of John Graunt and William Farr, mentioned in the Introduction. Farr laid the foundations for a statistical classification by emphasizing the need to adopt uniform criteria when referring to diseases. At the same time, he designed a classification to divide diseases into five groups: epidemic diseases, constitutional diseases, local diseases arranged by anatomical site, developmental diseases, and diseases that were a direct consequence of trauma (World Health Organization, 2010).

While this classification was never officially recognized or universally adopted, it served as the reference and starting point for *Bertillon's Classification of Causes of Death*, a title that represented what was actually an international list of causes of death. The assembly that approved this classification also established the rule that the international classifications be revised every 10 years, which occurred more or less regularly in 1900 (First revision), 1910 (Second revision), 1920 (Third revision), 1929 (Fourth revision), and 1938 (Fifth revision).

The Sixth revision (1948) is considered emblematic, because significant changes were made, such as the definition of the method for selecting a ***"single"*** cause of death when more than one was reported. Up to that point, there had been no uniformity among countries. At the same time, there was debate on the need to include another list in the ICD to classify diseases that did not cause death (morbidity). That is why the Conference for the Sixth Revision marked the dawn of a new era in international health statistics. At the same time, WHO was created, and the First World Health Assembly approved the Sixth Revision in 1948 under the title International Classification of Diseases, Injuries and Causes of Death. Organized in two volumes, its content included a list of nearly 1,000 categories, a form for certification of the causes of death, rules for selecting a single cause of death, special lists for tabulation, and an alphabetical index for locating diagnostic terms.

Subsequent revisions of the Classification continued to be issued with few modifications. Thus, in the Seventh (1955) and Eighth (1965) Revisions, errors and inconsistencies were corrected. When the time came to discuss the Ninth Revision (1975), interest in the ICD had grown, not only in the institutions that produced national health statistics but among physicians represented in associations of specialists. Changes were therefore made to increase the detail in some categories and favor users interested in producing statistics related to medical care—changes that included the ***"dagger and asterisk"*** dual coding system.

For the Tenth Revision, WHO considered it necessary to extend the 10-year interval between revisions. Some countries could not begin evaluating the current ICD because they hadn't used it long enough. Thus, it was decided to postpone the Conference for this revision until 1989.

Finally, after lengthy discussions, expert meetings, exchanges of drafts, and a range of test documents, the ICD-10 was published in 1992. The main innovation of the ICD-10 was the alphanumeric system, which increased coding options and tremendously expanded the diagnostic base. There were also new chapters that had once been considered secondary, such as the Supplementary Classification of External Causes of Injury and Poisoning. This was included in the ICD in two separate chapters, one on trauma, injuries, and poisonings, and the other on external causes. The same thing happened with the Supplementary Classification of Factors Influencing Health Status and Contact with Health Services, which was included as part of a complete chapter of the main classification.

Finally, it should be mentioned that during the International Conference for the Tenth Revision, an agreement was reached to include a mechanism for updating between revisions. This new development meant that the ICD-10, whose first edition in Spanish appeared in 1995, would have new editions with continuous updates prepared by WHO[7]: in 1999 (ICD-10 2nd Edition), 2003 (ICD-10 3rd Edition), 2008 (ICD-10 4th Edition), 2013 (ICD 10 5th Edition), and 2015 (ICD-10 6th Edition).

2.2 Tenth Revision of the Classification (ICD-10)

International use of the Tenth Revision of the International Statistical Classification of Diseases began in 1995 and continues today. The ICD-10 contains

7. Updates can be accessed on the WHO website:
http://www.who.int/classifications/icd/icd10updates/en/

22 chapters that follow different criteria to facilitate epidemiological analysis. Some conditions are located in chapters according to the bodily system they affect, while others are organized from an epidemiological standpoint and assigned to different chapters. Such is the case, for example, with infectious diseases and neoplasms, which appear in special chapters.

In each chapter, the diagnoses are divided into categories, which can, in turn, be subdivided into subcategories that are generally more detailed and specific diagnoses. In other words, the ICD-10 has a hierarchical structure that displays the information with different levels of detail: the chapters are the more general form of this organization, while the subcategories are more detailed (Table 2).

Table 2. Structures of the International Statistical Classification of Diseases and Related Health Problems, Tenth Revision (ICD-10)

Chapter	**A00-B99** Certain infectious and parasitic diseases
Category grouping	**B15-B19** Viral hepatitis
Category	**B15** Acute hepatitis A
Subcategories	**B15.0** Acute hepatitis A, without hepatic coma **B15.1** Acute hepatitis A, with hepatic coma

Source: International Statistical Classification of Diseases and Related Health Problems, ICD-10.

The ICD-10 provides a specific category and code for each cause entered on the death certificate, considering the diverse ways in which the different causes can be stated by the physician. The cause of death for primary tabulation by a single cause will be the underlying cause of death (UCD).

From a public health standpoint, the objective of reducing the number of deaths in the population is why selecting a single cause makes sense. Therefore, selecting the UCD makes it possible to know which diseases should be targeted for prevention activities. Thus, health policies and programs that have measures to prevent the etiology that engenders to other disorders that lead to death will be more efficient and effective.

The details on how to enter the different components of the causal chain on the death certificate have already been mentioned. When a single cause is entered, it will be the UCD; however, when several causes are entered, it will be necessary to select one, based on the criteria and rules spelled out in the ICD-10 (see World Health Organization, 2010).

2.3 Equivalencies between revisions

Mortality statistics by cause can be affected when there are changes in the coding of the causes of death. Each revision of the ICD results in changes, both structural and in the guidance for selecting the UCD. The most important structural changes are related to the increase in the number of headings and the transfer of some diseases to a different chapter.

The number of categories in the classification has grown from approximately 200 in the First Revision to more than 2,000 in the ICD-10. Of all the revisions, the Sixth and Tenth contain the most substantial changes, and the implementation of each of them is acknowledged to have had the greatest impact in the history of the classification (Anderson, 2011).

When analyzing mortality by cause in periods that include years of revision change, equivalencies must be established between the different revisions of the classification to determine which codes best represent the causes of death under study in each revision. Furthermore, when explaining the changes observed in the trends in mortality from certain causes—when time series affected by a change of revision are analyzed—it is essential to consider the changes in the revisions and their potential consequences.

Although it is hard to establish equivalency between revisions for each of the codes, it is feasible to compare by codes grouped in specific lists of causes of death (Cirera Suárez et al., 2006). These codes, in turn, make it possible to conduct ***"bridge studies"*** during the transition between revisions. These comparability studies start with coding a pool of deaths with the two revisions and then calculating and estimating the frequency of deaths by groups of causes, using each of the revisions to establish continuity in the statistics by cause of death (Anderson, 2011).

In this regard, several countries have established equivalencies in the lists of causes of death that they use to present their mortality statistics. Those that published the results indicated the equivalencies used (Cirera Suárez et al., 2006; Martínez Morales et al., 2005). For example, Annex 2 contains the list with the coding equivalencies between the ICD-9 and the ICD-10 used in Colombia. Other countries, among them the United States and Spain, have developed equivalencies and search material and code equivalencies for the revisions available online (CMS.gov, 2016; Eciemaps.mspsi.es, 2016).

With the collaboration of Dr. Roberto Becker, the Spanish Society of Epidemiology issued a series of recommendations for assessing the impact of the transition from the ICD-9 to the ICD-10 on geographic and temporal trends in mortality statistics by cause of death (Cirera Suárez and Vázquez Fernández, 1998). This is a valuable reference for people seeking more information about these subjects.

3. QUALITY IN THE CERTIFICATION OF CAUSES OF DEATH

This point is directly related to the physician's task of entering the causes of death when completing a medical death certificate.

The quality of the information on causes of death will be compromised to the degree that the physician who enters the causes of death fails to follow the recommendations of the ICD-10. The reliability of the causes of death reported can also be affected if the causes are entered correctly but the coding and selection of the UCD are incorrect.

As the next chapter will demonstrate, analysis of the causes of death is critically important for public health, making it necessary to evaluate the quality of certification as a measurement of the reliability of those data. A first approach to evaluating quality can be the analysis of deaths by groups of causes, sex, and age. Preparing tables showing the causes of death in terms of these variables makes it possible to detect many situations with significant distortions in the medical certification of the cause.

Many studies are described in the literature that analyze the quality of mortality statistics in general (Sendals and Pardo, 2011; Great Álvarez et al., 2010; Paes, 2007), while others focus specifically on examining the quality of the causes of death reported (AbouZahr et al., 2008).

3.1 Evaluating quality in the certification of causes of death

Some of the methods for measuring and evaluating the quality of information on causes of death are mentioned below. It should be noted that the classification used is proprietary and strictly for instructional purposes.

A) Quantification of specific groups of causes of death

This group contains indicators constructed as the proportion of deaths from given causes over the total deaths or a group of them. The use of this type of indicator to measure quality—at the regional, national, or subnational level—is based on the recommendations issued on medical certification of the cause of death. As we have seen, the causes of death should be defined diseases or clinical entities, and not signs or diseases that correspond to ways of dying.

- **Percentage of deaths from ill-defined causes:** Chapter XVIII of the ICD 10, Symptoms, signs, and abnormal clinical and laboratory findings, not elsewhere classified (R00-R99), reflects the UCDs on death certificates where poorly defined medical terms were used to give the causes of death. When this is a frequent occurrence, the proportion of deaths from ill-defined causes increases, becoming a direct indicator of poor quality in the recording of causes of death. This means that the quality of the certification of causes of death is inversely proportional to the percentage of ill-defined causes. Some 3.1% of causes of death in the Region of the Americas are ill-defined (circa 2013). Although this percentage varies from country to country, the percentage of ill defined causes exceeds 10% in only a few (Pan American Health Organization, 2015b).

- **Percentage of deaths from unspecified causes:** There are other conditions classifiable in other chapters of ICD-10 that are considered vague or imprecise diagnoses. In recent years, a number authors have developed lists of codes for this purpose (AbouZahr et al., 2010; Lopez, 2006; Mathers et al., 2015; Naghavi et al., 2010). In the Spanish-speaking countries of the Region, it was decided to use a list adapted by PAHO with the heading *Causas poco útiles* (useless causes) to overcome the difficulties posed by the original English term ("garbage codes") used by Murray and López (1996). It should be noted that this classification covers a range of causes that constitute defined clinical entities but contribute little information about the cause of death from a population standpoint and as a result, are of little use for the analysis of public health data on causes of death.

These causes can be divided into five groups, based on the reasons underlying their lack of usefulness, because they are:

1. Causes unlikely to cause death,
2. Causes that would actually act as final causes in the causal chain that leads to death,
3. Intermediate causes in the same process,
4. Ill-defined causes, and
5. Poorly defined diseases in a larger group of causes.

For example, the quantification of events of undetermined intent within external causes of death belongs to this latter group. Here, it should be recalled that in external causes of death, the UCD should be reported as the circumstances of the accident or violence that triggers the fatal injury. The ICD-10 has a chapter devoted exclusively to the coding and classification of these deaths that includes not only the mechanism that produced the injury but the intent in some cases. For events in which the intent could not be determined or was not reported, the classification has specific categories in this chapter.

It should be mentioned that one indicator used to evaluate the quality of external causes includes the quantification of deaths coded as ***"events of undetermined intent."*** This residual category is populated by a set of deaths where the statistical recording of the underlying cause of death is deficient and the real intent behind the event remains hidden. The origins of this deficiency in recording the information are multiple and have been studied by some authors, who found greater concealment of intentional deaths (suicides and homicides) than accidental deaths in this residual group (Arán Barés et al., 2000; Schottenfeld et al., 1982; Zunino, Spinelli, and Alazraqui, 2006).

B) Analysis of the medical certification of causes of death

Some studies directly evaluate the physician's work in recording the causes of death. They generally involve a comparison of death certificate data with other potential data sources. Thus, death certificates can be compared with autopsy results or clinical information provided by other physicians or taken from medical records. Interviews of relatives of the deceased can also contribute data on habits and illnesses for these types of analysis (see verbal autopsies in Chapter II, Section 1.3).

In these studies, consistency among the different sources can be analyzed in terms of the causes reported, and where each cause of death was entered on the certificate (Lu, Hsu, Bjorkenstam et al., 2006). Calculating the percentage of deaths with incorrectly certified causes or errors in the causal chain yields an excellent indicator of the quality of the physician's work in certifying the causes of death.

Within this group, special mention should be made of the ***analysis of omitted causes***, i.e., where the underlying cause entered on the medical certificate is a disease, injury, or condition other than one that actually triggered the chain of events that led to death, or where additional information is omitted that would make it possible to correctly code and select the real UCD.

One of the paradigmatic examples of this is the omission or under-registration of maternal causes if, when certifying a woman's death, the physician fails to indicate her pregnancy or puerperal status or its specific stage. This omission impedes the identification of direct or indirect obstetric causes in subsequent analysis and coding. For example, if hypertension was entered and its association with the reproductive process was not indicated, the underlying cause selected will not be correct.

C) Cause-of-death coding analysis

This section includes studies that specifically analyze UCD coding and selection. These procedures are generally based on the selection of a sample of deaths to establish the UCD, but done by someone other than the individual who did it the first time or by an automated system, with subsequent comparison and analysis of the differences in the coding of the causes. This is an important point, because even if physicians correctly enter the causes of death, if the UCD is incorrectly coded and selected, strictly following the rules and standards set in the ICD-10, errors can be introduced in the information that alter the quality of the data.

3.2 Strategies for improving the quality of information on causes of death

A good strategy for improving the quality of information on causes of death and mortality statistics in general is the ongoing training of physicians to keep them up to date in certification (Myers and Farquhar, 1998). Training in how to enter causes of death should focus not only on medical degree programs but on professional practice as well. It should also be borne in mind that the studies included in the aforementioned group B not only make it possible to evaluate the quality of certification, but in many cases, can help to improve it, since based on the data obtained, errors can be corrected.

There is abundant literature in the Region with a range of studies on the under reporting of maternal causes, how to quantify it, and the methodology for reducing it. Worth mentioning in this regard is the intentional search for maternal deaths and their reclassification, promoted by Mexico's Secretariat of Health since 2002 to correct the statistical information on maternal mortality. This initiative investigates the deaths of women of reproductive age from obstetric and other causes that could conceal maternal deaths in order to verify the deaths reported and capture the ones omitted (Health Information Department, Ministry of Health, 2010). PAHO recommends this practice as a strategy for improving the quality of the data and statistics on causes of death. Also noteworthy is a strategy adopted in Brazil to reduce deaths ascribed to ill-defined causes, which consists of a verbal autopsy based on questionnaires (Ministry of Health, 2008).

Finally, implementation of automated coding systems, which will be described below, can also help to improve the quality of information on causes of death, since they reduce inconsistencies among coders.

Within the framework of the Latin American and Caribbean Network to Strengthen Health Information Systems (RELACSIS), several countries in Latin America have collaborated in the development of training tools to help the countries of the Region improve the quality of health information:

- Virtual course on the proper way to complete a death certificate.
- Online course for coders and tutors for the coding of morbidity and mortality using ICD-10.
- On-site courses for instructors of the ICD-10.
- On-site courses for the Mortality Medical Data System (MMDS).
- On-site courses for coding of the CIE.
- "Dr. Roberto A. Becker" Forum for the ICD-10.
- The Ibero-American Network of the PAHO/WHO Collaborating Center for the Family of International Classifications.

For more information on these tools, visit: ***http://www.relacsis.org/***

4. AUTOMATED SYSTEMS FOR CODING AND SELECTING THE UNDERLYING CAUSE OF DEATH

Proper application of the rules for selecting the underlying cause of death requires highly trained personnel. Even so, there are inconsistencies among coders due to the subjectivity involved in the decisions involved in the interpretation of death certificates. The resulting heterogeneous information is an even greater problem in decentralized processing systems.

In the late 1960s, advances in information technology led the U.S. National Center for Health Statistics to develop an automated system to apply these rules. This system, called ACME (Automated Classification of Medical Entities), requires each cause appearing on the death certificate to be coded. With this information, the program selects the underlying cause of death and stores all the causes, permitting the analysis of multiple causes. Even so, it was necessary for users to be trained in medical terminology and coding. The next step was for the center to develop two additional systems (MICAR and SuperMICAR), which allow the literal text of the causes of death reported by the physician to be introduced. All these instruments were integrated into a single system called the Mortality Medical Data System (MMDS) (Centers for Disease Control and Prevention, 2015), which automatically codes a high number of deaths, with trained coders manually processing the remaining cases.

In 1993, the Department of Informatics of the Ministry of Health of Brazil and the Collaborating Center for the International Classification of Diseases in Portuguese developed a system similar to ACME for use in microcomputers. This system, called SCB (***Seleção da causa básica de morte***), was later updated as the ICD-10 (SCB-10) and is currently used to select the underlying cause of death at the municipal level in Brazil.

In the first decade of the 2000s, Mexico's National Institute of Statistics and Geography (Instituto Nacional de Estadística y Geografía-INEGI) developed and tested a Spanish-language system based on the MMDS. This system was adopted nationally in 2007 for coding deaths from natural causes only. In recent years, within the framework of RELACSIS and with support from INEGI, several countries in the Region have been testing and implementing this instrument.

Finally, it should be mentioned that a new automated coding system called IRIS has been developed (Deutsches Institut for Medizinische Dokumentation und Information, 2015). Operated by the IRIS Institute, this innovative system collaborates with the national centers of several countries (Germany, the United States, France, Hungary, Italy, and Sweden). The software, which in the preliminary phase was based on ACME, is designed to work in several languages; in the latest version, IRIS includes internationally accepted decision tables consistent with the latest version of the ICD-10.

We should mention that implementing this type of tool requires adapting the data capture systems used in the countries, since the literal texts of the causes of death reported by the physician must be entered, and linking these systems with the coding systems (import/export of files). Changes may also be needed in the customary organization of the data processing. These aspects must all be considered before embracing these innovations.

5. TOWARD THE ICD-11

For several years now, the World Health Organization has been working on the 11th Revision of the classification. The Organization has enlisted the participation of the Collaborating Centers of the Family of International Classifications to begin transitioning from the ICD-10 to the ICD-11.

For the revision and transition to the 11th Revision, a virtual platform was created to facilitate ongoing work and efficient exchange among the participants. Unlike the annual revision conferences held prior to the implementation of the ICD-10, this mechanism enables several countries to simultaneously revise the classification in different languages.

Some Spanish-speaking countries in the Region, including Argentina, Chile, Colombia, Cuba, Mexico, and Venezuela, are cooperating in the English-to Spanish translation of the ICD 11.

Several pilot studies were planned for 2016 and 2017 to evaluate the adequacy of the ICD-11 for its multiple purposes (mortality and morbidity coding, etc.) and to assess the stability and comparability between the ICD-10 and the ICD-11. These tests will be used to evaluate both the Eleventh Revision's applicability and ease of use and its reliability—especially, the uniformity of the results and the probability that the same results will be obtained every time. The ICD-11's usefulness and added value, in terms of improvements over the ICD-10, will also be examined.

For more information on the development of this version, visit: ***http://www.who.int/classifications/icd/revision/en/#***

IV. MORTALITY MEASUREMENT AND ANALYSIS

In this chapter, we will discuss some dimensions related to the basic description and analysis of statistical information on mortality. We will present conceptual and practical tools, with special emphasis on basic statistical aggregates, the calculation of indicators, and the spatial and temporal description of mortality, in addition to instruments for presenting the information.

The first section presents basic criteria for tabulating the number of deaths by three variables central to the analysis: age, sex, and cause of death. The second discusses certain considerations that should be addressed prior to constructing high-quality indicators. The third section details the most common mortality indicators: general and specific mortality rates and adjustment methods, as well as other related indicators. The fourth section focuses on two high-impact areas: infant and maternal mortality.

The fifth section focuses on life tables and the indicators the they yield, especially life expectancy at birth. The sixth section, whose content is somewhat more specialized, introduces methods for quantifying the burden of mortality that could be attributed to a risk factor. It will then discuss the importance of mapping as a tool for analyzing geographic variations in both mortality and temporal trends in order to evaluate changes in mortality levels. The chapter closes with recommendations for reporting indicators.

1. BASIC DEATH STATISTICS

Annually issuing mortality statistics and making them available to the users of these statistics are two goals of the offices responsible for the vital statistics systems in each country.

The basic tables that each office should produce have been described in the *Principles and Recommendations for a Vital Statistics System* (United Nations, 2003). The information below is therefore organized according to the main variables involved in the exploratory or descriptive analysis of mortality statistics: age, sex, and cause of death.

1.1 Age and sex

As mentioned in Chapter I, the concept of health underwent profound changes in the second half of the 20th century, shifting from the biological concept of health based on the absence of disease to a broader, community based social concept that emphasizes well-being and the quality of life. Within that new context, health statistics registries progressively began to include variables that went beyond individual and biological factors to address living conditions (education, work, housing, etc.), with the object of measuring the associated phenomena that can determine the health status of populations.

These changes notwithstanding, age and sex remain variables central to the statistical analysis of health information in general and mortality analysis in particular. This is because the phenomena related to health occur differently in certain population groups due to the ways in which these two variables are combined. For example, some diseases are more fatal during the first year of life, while others more frequently affect the elderly; others are related to pregnancy, childbirth, and the puerperium (and thus, exclusively affect women and, almost exclusively, women in the potentially reproductive ages). Furthermore, ***"mortality,"*** ***"sex,"*** and ***"age"*** are three related concepts in demographic and epidemiological theory: low mortality levels are associated with older populations with greater average longevity and a relatively lower burden of communicable diseases. Moreover, mortality in older persons is always higher in men than in women (a phenomenon known as ***"excess male mortality"***).

The tabulation of vital statistics information on deaths by age and sex is found in all the publications issued by public health statistics offices. The most elementary tabulation is the number of deaths by sex and age group for a geographical area during a given time period, as seen in the following example from Paraguay (Table 3) (Statistics, Surveys and Census Department, 2013: 79).

Table 3. Deaths by sex, by age group. Paraguay, 2010

		Sex		
Age group	Both sexes	Male	Female	Unknown
Under 1 year	322	194	128	51
1-4 years	170	103	67	-
5-9 years	114	56	58	-
10-14 years	153	88	64	-
15-19 years	441	321	120	-
20-24 years	494	360	133	1
25-29 years	509	370	139	-
30-34 years	425	309	115	1
35-39 years	494	320	174	-
40-44 years	638	400	237	1
45-49 years	836	539	297	-
50-54 years	1,103	696	403	1
55-59 years	1,396	836	558	-
60-64 years	1,486	926	558	4
65-69 years	1,735	1,055	676	2
70-74 years	2,040	1,196	840	2
75-79 years	2,242	1,227	1,008	4
80-84 years	2,521	1,225	1,291	4
85 years and over	3,978	1,678	2,290	7
Age unknown	160	98	53	5
Total	21,257	11,997	9,209	51

Source: Dirección General del Registro del Estado Civil. Ministerio de Justicia y Trabajo.

Five-year age groups are usually used to present age in the form of intervals, simplifying understanding of the information and maintaining an acceptable level of detail. The 0-4 age group tends to be disaggregated into children under 1 and children aged 1-4 (as seen in the table), since the first year of life has particular characteristics in terms of the level of mortality, the morbidity and mortality profile, and the risk of death.

The analysis can be improved by disaggregating deaths in children under 1 year by the neonatal (early and late) and post-neonatal periods, since mortality in each of these groups is largely attributable to different determinants. These definitions and their importance are discussed in the section on infant mortality indicators.

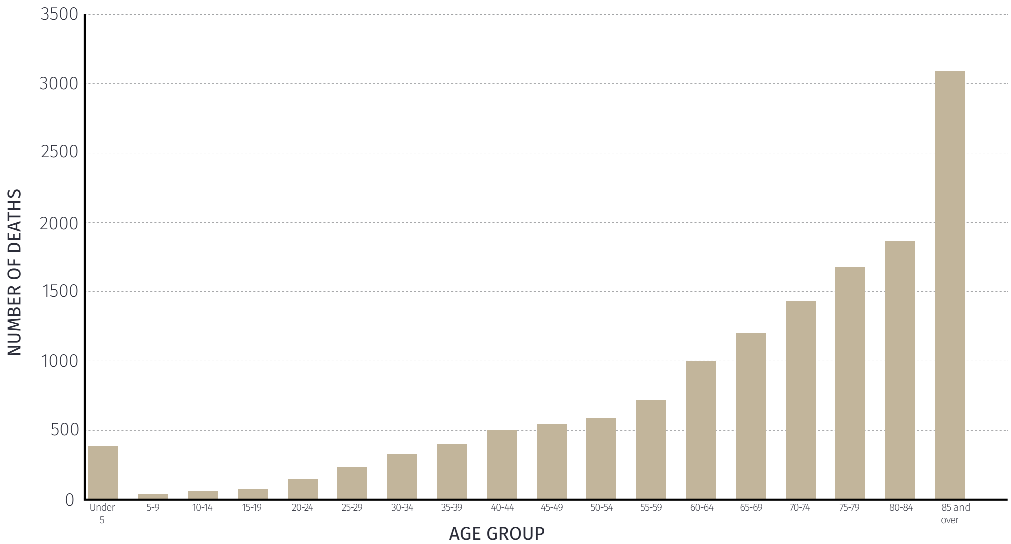
Another more succinct alternative is to tabulate deaths by sex and ***functional*** age group—that is, children and youths (under the age of 15), adults (aged 15-64) and older persons (aged 65 and over), although the definition of these groups changes over time, making comparisons difficult. For example, there is currently an emphasis on adolescents, defined as individuals between the ages of 10 and 19. In addition, due to the aging of the population, greater disaggregation of the older persons category is usually required. These are just a few of the alternatives; the limits of the age groups used in tables and figures need to be defined in terms of the objective of the analysis.

The presentation of mortality information by sex is recommended for virtually all the usual tables, except in the case of infant mortality, where (save in very exceptional situations) there are no significant differences between males and females. Tabulations should generate the number of deaths over the total population, disaggregated by sex; and the number of deaths from unspecified causes for each of the variables should be recorded, giving the user an indication of the quality of the information provided.

The analysis of age groups by sex for different causes of death is of particular interest, because its simplicity facilitates the user's understanding of the differential impact of a cause of death on different population groups.

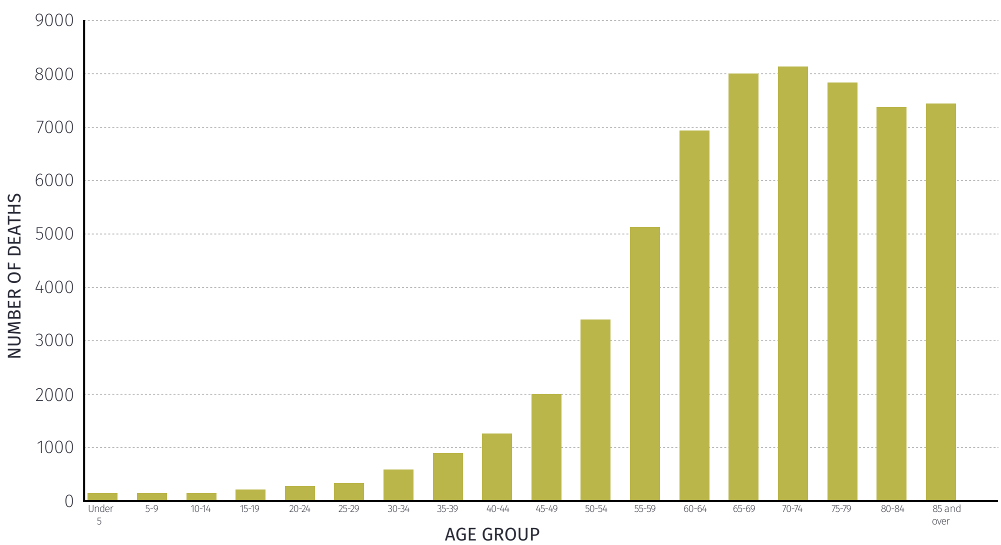
Figures 1, 2, and 3 provide examples of the number of deaths by sex and age group for three selected causes: certain infectious and parasitic diseases, malignant neoplasms, and assault. These figures clearly reveal the differences in the frequency of deaths in each age group and the marked variations among causes.

Figure 1. Number of registered deaths from certain infectious and parasitic diseases by age group. Argentina, 2013



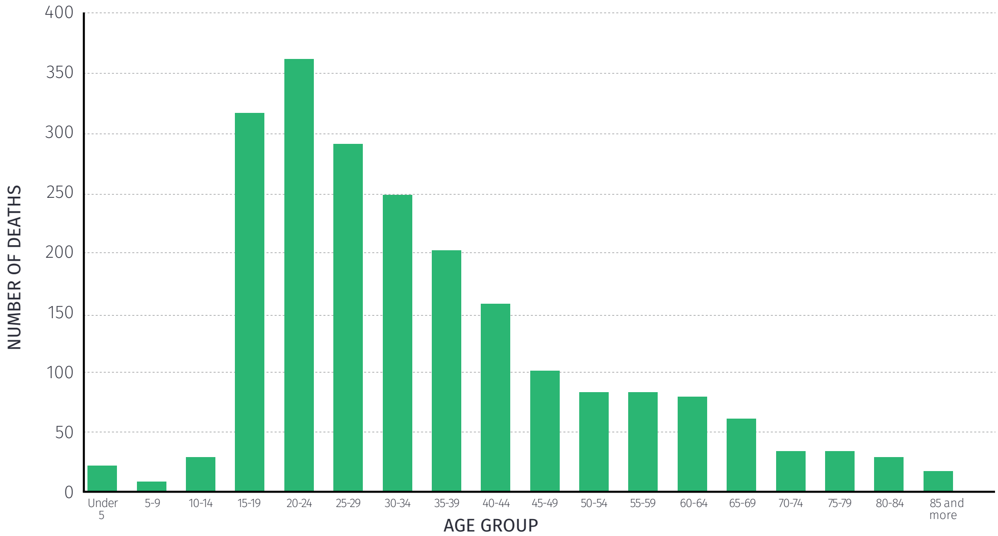
Source: PAHO, based on data from the Dirección de Estadísticas e Información de Salud, Ministerio de Salud de la Nación, Argentina.

Figure 2. Number of deaths from malignant neoplasms, by age group. Argentina, 2013



Source: PAHO, based on data from the Dirección de Estadísticas e Información de Salud, Ministerio de Salud de la Nación, Argentina.

Figure 3. Number of registered deaths from assault, by age group. Argentina, 2013



Source: PAHO, based on data from the Dirección de Estadísticas e Información de Salud, Ministerio de Salud de la Nación, Argentina.

Countless examples could be cited of tables and figures that combine sex and age for the presentation and analysis of death statistics. The ones in this section are important because of their potential for summarizing the information and making it understandable and because they are frequently used.

The need to define the ways of presenting the information in terms of its purposes and users should not be overlooked, since the population groups determined by the combination of the variables discussed in this section can be the object of interest in different areas in the field of health: public policy-making, government program management, scientific research, information dissemination, etc.

Concerning criteria for preparing and presenting tables and figures, we recommend that readers consult the publication *Making Data Meaningful. Part 2: A guide to presenting statistics* (United Nations. Economic Commission for Europe, 2009).

1.2 Causes of death

Mortality statistics by causes of death are generally the most reliable source of information on the health status of the population, and sometimes the only source. When discussing statistics on the causes of death, reference is commonly made to statistics that classify deaths by their underlying cause.

In measuring mortality, the importance of analyzing the cause variable lies in the possibility of determining what diseases or circumstances (in the case of deaths from external causes) trigger deaths in the population, their frequency, and associated factors. Knowledge of these processes aids in planning disease prevention and health promotion activities in the population to reduce mortality from certain causes.

As indicated in the previous chapter, the number of causes of a death is the same as the number of diagnoses or diseases reported when certifying the death, but only one of them will be the UCD—that is, the one used to indicate a single cause. All the other reported diagnoses or causes will be associated causes.

From an epidemiological and public health standpoint, it is important to know the multiple causes involved in mortality, although it is unfeasible to tabulate the information using so many variables. Priority is therefore given to knowing the cause that triggered the chain of events in order to determine the action needed to reduce mortality in the population.

When more than one cause of death is entered and codified, this information can be used for special analyses. Multiple causation is an important complement in mortality analysis, especially when dealing with chronic diseases or people over the age of 65, where it is harder to establish a single cause as the one responsible for the death.

In multiple causation analysis, the frequency with which certain diseases are mentioned in death certificates can be quantified, not only as the underlying cause but as associated causes. Thus, the frequency of some diseases will be much higher than in the analysis of underlying causes. This type of analysis is the only way that other causes will appear in statistics, because they are not selected as the underlying cause and, thus, they will not be tabulated in the statistics for a single cause (Becker, 1992).

1.3 Lists of causes of death

The ICD-10 is a statistical classification that contains more than 10,000 categories and subcategories. Preparing tables to describe the profile of causes of death using the codes entered is not very informative, since does not paint an overall picture of mortality. Furthermore, observing mortality at the ICD-10 chapter level may be of little use, since the chapters consist of large blocks of causes that do not contribute much information. In that context, the use of lists for tabulating the information is recommended.

Lists of causes are generally used to paint an overall picture of mortality in a particular region or to analyze the behavior of the different causes of death. They can also be used to learn which causes are most frequent or affect the population the most. There are more specific uses as well, such as the characterization of deaths from external causes or of deaths considered avoidable based on certain criteria, as will be seen below.

Whatever the purpose of the list of causes of death, it always consists of an aggregation of ICD-10 categories in a way that is effective for the purposes of a specific analysis. Ordinarily, the same list will not be appropriate for describing or analyzing, for example, the mortality of a country or health program or for specific research on selected causes.

Some of the lists customarily used at the international level are presented below. The ICD-10 includes lists whose design facilitates country comparisons of certain diseases and their role as causes of death. Four lists are recommended for this purpose:

- Two condensed lists, List 1 (World Health Organization, 1995) and List 3 (World Health Organization, 1995), one for general mortality and the other for infant mortality. The condensed lists are so designated because they contain all the three-digit categories condensed or aggregated into a manageable number of categories for all chapters. For each chapter, they define a residual group for all causes not classified in the groups.

- Two selected lists, one for infant mortality (World Health Organization, 1995) and another for general mortality (World Health Organization, 1995), that do not show the totals by chapters but contain selected causes from the majority of the chapters considered of interest for observing the health status of the population.

In addition to these lists, there is consensus on other special groupings. For example, the one created in 1990 by WHO to evaluate causes of death in order to determine the global burden of disease. On that occasion, deaths were classified under three major groups: Group I, ***communicable diseases***; Group II, ***noncommunicable diseases***, and Group III, ***injuries***. This simple grouping was enough to observe the differences in mortality patterns between the developed and developing countries at the time. Since the study included projections up to 2020, this short list of causes served to evaluate the effects of the epidemiological transition—that is, the reduction in communicable diseases and the increase in noncommunicable diseases (Murray and López, 1996).

Another group of causes used in tabulating mortality is the Pan American Health Organization's 6/67 list, found in Annex 2. This list is a useful starting point for mortality analysis, since it contains six major groups of causes with 67 subcategories that provide more detail within the groups (Pan American Health Organization, 2002b).

Another similar way of listing causes is found in the PAHO publication Regional Core Health Data and Country Health Profile Initiative, which classifies deaths into five large blocks: **"cardiovascular diseases," "neoplasms," "infectious diseases," "external causes,"** and finally, a residual group that includes all other causes. This list, which is useful for the purposes of the publication, facilitates the description of mortality in every country in the Region and comparisons among them (Pan American Health Organization and Ministry of Health of Argentina. Indicadores Básicos, 2014).

In the case of deaths from external causes, a special matrix was proposed that combines the means of the death with the intent (World Health Organization, 2004). The object of grouping and displaying the information in this way is to increase the usefulness of the data on deaths from external causes, especially in countries or areas with significant under-reporting of intent. This list makes it possible to observe the impact of firearms on mortality, for example, even when it is unknown whether these deaths were due to interpersonal violence or were self-inflicted.

It is important to stress that the selection of the list to use should be determined by the purpose of the proposed analysis. The advantage of using one of the predefined lists is that information summarized in that way will be comparable with that of other countries or regions where it has been used. Nevertheless, it may be necessary to create a special list—that is, to group or condense ICD-10 categories based on a particular criterion or in a way that improves the representation of the phenomenon to be described. Although this list will not be useful for comparisons with others, it may be very useful at the local level.

From an operational standpoint, when constructing lists, the categories of causes selected may not necessarily reflect the structure of the chapters in the ICD-10, but the list must be comprised of mutually exclusive groups. Moreover, the groups of causes in the list may correspond to the three-digit categories of the ICD, to groupings of them, or to chapters; it will all depend on the purpose of the list (Becker, 1992). It is important to verify the frequency of each group in the list prepared to detect potential errors in its construction (e.g., if residual groups are far more frequent than specific groups).

The criteria customarily used to define the categories in mortality lists include:

- The criterion of ***"frequency,"*** which indicates that emphasis should be placed on the causes of death that contribute significant numbers of deaths to the total in the area analyzed.

- The criterion of ***"relevance,"*** where emphasis should be placed on causes of death that, for one reason or another, are qualitatively very important—for example, diseases preventable by immunization, diseases that cause easily reducible or avoidable deaths, diseases subject to surveillance or whose prevention is the objective of government policies, etc.

- The ***"epidemiological"*** criterion, which suggests emphasizing new diseases (or diseases that were believed to have been eliminated) and diseases considered epidemic or pandemic when the information is tabulated.

As this section indicates, the preparation of lists of groups of causes of death is a complex and somewhat arbitrary task. A list of causes of death that permits a good description of mortality by cause will be the result of a balanced combination of the aforementioned criteria. By way of example, Annexes 3 and 4 contain lists for tabulating mortality by selected groups of causes in Argentina and Colombia.

Special mention should be made of the list of the unspecified codes (PAHO/WHO, 2016) mentioned in the previous chapter. This is a group of codes that does not cover all causes but is usually included in a list because it can be used to evaluate the quality of the information on causes of death.

1.3.1 Lists for presenting the leading causes of death

Publications with information on the leading causes of death in a country or region are common. This strategy for presenting mortality data is nothing but a tabulation based on a list of causes of death, where the purpose is to indicate which are the most frequent. Within this framework, all the general recommendations for preparing lists of causes for tabulating mortality are relevant.

Some commonly used options are not recommended for ranking causes of death. One of them is arrangement by the frequency of categories or subcategories of the International Statistical Classification of Diseases and Related Health Problems (ICD). This strategy generally yields rankings in which residual, nonspecific, or ill defined categories occupy positions of importance. In this case, excessive detail hinders good visualization of the leading causes. At the other extreme, tabulating mortality through ICD chapters is too limiting and generally contributes little significant information.

For the purpose of establishing a single criterion and given the need for an internationally comparable instrument after discovering that country criteria vary, Becker et al. (2006) designed a table for presenting the leading causes of death, based on the following recommendations:

- The list should be based on the classification used when presenting the leading causes, and the defined categories should be mutually exclusive.
- Residual categories should be avoided.
- Deaths from undefined causes should not be included in the list, but presented in a separate section instead.
- The defined categories should not follow the structure of the ICD chapters.
- The list may include categories that correspond to only one category of the classification, a set of categories from different chapters, or entire chapters.

- The list should be broad enough to provide a good description of the leading causes of death (not so short as to conceal specific causes, nor so detailed as to hinder interpretation) (Becker et al., 2006).

Consideration should be given to the difficulty involved in setting a single criterion for tabulating mortality to organize the leading causes. In this regard, the tool developed by Becker et al. (2006) offers an opportunity to tailor the presentation to the characteristics of the population's epidemiological profile, offering the option of describing some categories in greater detail.

With regard to this method of presenting the information, Heron (2015) describes the classification used by the Centers for Disease Control and Prevention (United States) since 1949 to publish the leading causes of death in that country. This classification has categories predefined as ***"residual"*** that cannot appear in the arrangement of the causes. Concerning this type of definition, Heron notes that:

> ***Ranking causes of death is to some extent an arbitrary procedure. The rank order of any particular cause of death will depend on the list of causes from which the selection is made and on the rules applied in making the selection. Different cause lists and ranking rules will typically produce different leading causes of death. (Heron, 2015: 1)***

Regardless of the modality selected to present the leading causes of death, it should be borne in mind that a detailed description of the grouping used is a prerequisite for correct interpretation of the information by users.

The temporal dimension is also important. Although it is not one of the main objectives when designing a list for the grouping of causes, it should support analysis of the phenomenon over time. Since the ICD is a dynamic classification that is periodically updated and revised, the ability to establish equivalencies for all categories across the different versions of the classification is a highly valuable attribute.

As suggested for the preparation of lists for tabulating mortality, presenting the leading causes of death in specific population groups (women of reproductive age, children under 1 year, adolescents, the older persons, etc.) implies developing a group of causes tailored to each subpopulation.

As examples of the changes that can occur in the presentation of the leading causes of death, three tables are provided below in which the 10 most frequent causes were tabulated for deaths registered in Mexico in 2013. The list of diseases used in that country, the list proposed by Becker et al. (2006), and the list used in Argentina (Tables 4-6) were employed for this purpose.

Table 4. Leading causes of death according to the Mexican list, Mexico 2013

Groups of causes	Number of deaths
Heart diseases	116,375
Diabetes mellitus	89,469
Malignant neoplasms	75,240
Accidents	36,293
Diseases of the liver	34,826
Cerebrovascular diseases	32,762
Assault	23,063
Chronic obstructive pulmonary diseases	20,490
Influenza and pneumonia	17,480
Certain disorders stemming from the perinatal period	13,025
Total	623,599

Source: PAHO, based on data from the National Institute of Statistics and Geography (INEGI).

Table 5. Leading causes of death according to the list suggested by Becker et al. (2006). Mexico, 2013

Groups of causes	Number of deaths
Diabetes	89,469
Ischemic heart diseases	79,586
Cirrhosis and other diseases of the liver	34,826
Cerebrovascular diseases	32,762
Chronic lower respiratory diseases	26,039
Assault (homicide)	23,063
Hypertensive diseases	19,886
Diseases of the urinary system	19,307
Influenza and pneumonia	17,480
Land transport accidents	16,396
Total	623,599

Source: PAHO, based on data from the National Institute of Statistics and Geography (INEGI).

Table 6. Leading causes of death according to the Argentine list. Mexico, 2013

Groups of causes	Number of deaths
Heart diseases	103,120
Diabetes mellitus	89,469
Malignant neoplasms	75,240
Accidents	35,993
Cerebrovascular diseases	32,762
Chronic diseases of the liver and cirrhosis	28,462
Lower respiratory diseases	26,039
Assault	23,063
Pneumonia and influenza	17,480
Nephritis and nephrosis	14,158
Total	445,786

Source: PAHO, based on data from the National Institute of Statistics and Geography (INEGI).

1.3.2 Avoidable mortality

Indicators that are useful for epidemiological and preventive analysis can be constructed from age and cause-of-death variables. It is feasible to characterize mortality from the standpoint of deaths that could have been avoided or delayed, since effective measures exist to prevent or treat the causes that led to them.

The analysis of avoidable mortality has a long history. Many authors have contributed research and knowledge in this field since the 1970s. While the different lists or classifications of avoidable deaths coincide in grouping ICD categories with the criterion of avoidability, they vary in terms of the technological development and level of knowledge in the location where they were created, as well as the paradigm or concept of health employed in their design.

There is no international standard for the study of avoidable mortality. The results obtained with the different lists are not always comparable, because they have either been prepared with different editions of the ICD or they define different categories of causes. They may also consider different ages for mortality analysis.

It should be noted that the concept of avoidable mortality was coined by Rutstein in 1976 and was related to timely and appropriate medical care. Although medical care included primary prevention measures and treatment, it was primarily focused on medical technology. The list contained 90 conditions considered preventable (Rutstein et al., 1976).

Another research group subsequently emerged, headed by Charlton, who posited that avoidable deaths were attributable to causes susceptible or vulnerable to medical care. Thus, the list proposed was effective for evaluating treatment outcomes and included different causes in particular age ranges that in no case exceeded 64 years (Charlton, 1983).

Meanwhile, Holland developed another list designed to improve the relationship between causes of death and specific medical interventions, classifying avoidable deaths under two categories: causes sensitive to medical treatment or secondary prevention, called ***"medical care indicators,"*** and those vulnerable to primary prevention, called "national health policy indicators" (Holland, 1988).

Furthermore, in Latin America, specifically Chile, the Taucher classification was being developed, which grouped the causes of death under different categories, based on the type of intervention that could influence avoidability. This classification's approach was much broader than the one centered on medical care and included socioeconomic and environmental factors as determinants of the population's health situation. A preventive criterion predominated in the grouping of causes (Taucher, 1978).

In Colombia, Gómez designed a new grouping in 2006 that was tailored to the conditions of that country: an ***"Inventory of causes of avoidable death"*** (ICME, Spanish acronym), based on the Taucher and Holland lists (Gómez-Arias et al., 2009). A more recent classification is related to the work of Nolte and McKee, who have studied avoidable mortality in different European countries and compared it with that of the United States. This list has 33 causes that cut across 10 groups with a specific range of ages, the majority of which include people under 75, except for some causes that cover a narrower age range (Nolte and McKee, 2012).

The Pan American Health Organization has included an indicator related to avoidable deaths called ***"deaths from causes potentially treatable with timely health care."*** This indicator refers to a subset of deaths that should not have occurred in the presence of effective health services with routine examinations for early detection of diseases and the provision of specific treatments. The indicator is constructed using the Nolte and McKee classification (Pan American Health Organization, 2013b).

2. CONSIDERATIONS PRIOR TO CONSTRUCTING MORTALITY INDICATORS

Quality data are essential for constructing mortality indicators useful for research purposes (production of health knowledge) and management decision making (production of health action). Thus, all action aimed at improving data collection instruments and processes, registries, and the complete uploading of data to information systems is of the utmost importance (Mota and Alazraqui, 2014).

In Chapter II we described two errors (coverage and content) that affect the quality of data in information systems. The quality of indicators based on these data is evaluated in terms of different desirable properties. The first ones are ***validity*** (the ability to measure the phenomenon to be measured) and reliability (the ability to replicate the results under analogous conditions). Validity is measured through ***sensitivity*** (the ability to detect changes in the phenomenon analyzed) and ***specificity*** (the ability to detect only the phenomenon analyzed). Other desirable properties are measurability (based on available or easily obtainable data), ***relevance*** (response to health priorities) and ***cost-effectiveness*** (outcomes justify the investment of time and resources) (Pan American Health Organization, 2001).

Prior knowledge about the behavior of mortality will permit analyses of the information that can distinguish between deficiencies in the data, changes in trends, or significant changes in mortality profiles. When the information analyzed is periodic, continuous, or has at least been generated on more than one occasion, a comparison can be drawn between different periods. For example, the number of deaths in a geographical area in a year or month can be compared with those registered in previous years or months. Comparisons of this nature constitute the analysis of temporal consistency and are used to confirm the expected changes or uncover inexplicable inconsistencies or differences.

Useful guidelines for evaluating the quality of the mortality information to be analyzed are provided below. Their consideration facilitates the detection of problems that can affect the construction and final analysis of the indicators (AbouZahr et al., 2010; Becker, 1992). With regard to sex, excess male mortality is observed in all age groups in the majority of the countries. Deaths in males aged 15-30 may be double or triple those in females, due to the high proportion of deaths from violent causes, which affect males of these ages in particular.

Excess male mortality drops sharply after the age of 55. The number of deaths in females begins to be much higher after the age of 75 or 80. Mortality is concentrated in the extreme ages, except for populations in areas with infant mortality rates of more than 50 per 1,000 (AbouZahr et al., 2010). Whatever the health conditions and mortality by age, the 5-9 age group exhibits lower mortality than the 1-4 age group, and this latter group has lower mortality than the group under 1 year. During the first year of life, the risk is higher in the first month; and in the first month, in the first week; and in the first week, in the first day.

In evaluating mortality by cause, certain regularities can be pointed out to guide the analysis. Deaths from disorders stemming from the perinatal period are concentrated in children under 1 year of age and usually occur in the first month of life. Congenital abnormalities are also concentrated in early infancy, and their frequency declines markedly in the remaining age groups. Diseases of the respiratory system are concentrated in the early age groups, then decline in the intermediate ages, and increase again in old age. Neoplasms and diseases of the circulatory system, in contrast, exhibit a high and growing frequency at age 60 and over (Becker, 1992).

As a rule, countries with short life expectancy are characterized by high levels of mortality, especially in infancy, due primarily to infectious and parasitic diseases. They are also marked by high maternal mortality ratios and high mortality from violence. When life expectancy is medium or long, the most frequent causes of mortality are noncommunicable diseases, such as cancer and cardiovascular diseases, which, moreover, are concentrated in the older age groups (AbouZahr et al., 2010).

Another aspect that should be evaluated is the action taken when problems are found in the quality of the data, especially in terms of coverage or lack of integrity in the main variables. The absence of data for variables such as age and sex is generally uncommon; thus, these variables may not need correction. This will imply discarding some cases (e.g., when calculating the specific rate by sex, cases where the sex is not indicated will be discarded), but it will not have a major impact on indicator outcomes.

The lack of quality with the greatest impact on the construction of indicators is related to the specificity of the cause of death. A high proportion of deaths from ill defined causes affects measurement of the specific risk of death by cause. Furthermore, it is complicated to compare different areas with different levels of ill-defined causes or the monitoring of changes over time.

The most common methodology used to correct these problems is proportional distribution by cases with known causes within each age group and by sex. Deaths from external causes are excluded from this reassignment of deaths from ill-defined causes, since it is generally assumed that reference to this type of cause is unlikely to be omitted for legal reasons (although in many cases, intent is not specified). When the proportion of ill-defined causes is very high (e.g., over 50%), estimation or imputation methods should be considered with caution.

When constructing its **"core indicators,"** the Pan American Health Organization applies the criterion of simultaneous adjustment for under-registration and redistribution of ill-defined causes, based on the methodology spelled out in *Health Statistics from the Americas,* 2006 edition (Pan American Health Organization, 2006).

Other adjustment alternatives involve the application of special statistical tools such as regression models, empirical Bayesian methods, and others (Mujica, 2009).

Again, it should be noted that these methods should not be considered a substitute for continuous quality improvement strategies for data entry systems.

The rates obtained using small populations or low-frequency events (a small number of cases) reveal major variations that can affect correct interpretation of the outcomes. In these cases, the following alternatives can be used to construct or present indicators, either alone or in combination:

- Clustering of periods or geographical areas for calculating the indicators (e.g., triennial rates).
- Using the absolute number of cases as the indicator.
- Individual case analysis to evaluate changes in specific characteristics and contexts.
- Presentation of the variability of the indicators by calculating the coefficient of variation or confidence intervals. This alternative implies the use of more sophisticated statistical methods. Chapter V provides an introduction to some of these methods.

Before constructing the indicators, we would like to point out that, as stated in this section, multiple quality issues can affect mortality information. We are therefore noting a recent publication (Phillips, 2014) that proposes a composite index on the quality of mortality information. This index is interesting because it combines several dimensions: the quality of the reporting of the causes of death, age, and sex; internal consistency; coverage; degree of detail in the causes of death; and the accessibility/timeliness of the data. This indicator facilitates a more comprehensive classification of the information and better comparison among countries.

3. MORTALITY INDICATORS

The purpose of this section is to describe the uses and limitations of the principal mortality indicators. It is not intended to explore specific aspects of each of them in depth, nor to propose a complete set of mortality indicators. For those purposes, readers should consult specialized works that deal with the aspects of mortality they wish to explore, which will be mentioned further on.

Mortality indicators usually refer to three basic dimensions: time, place, and person. Time customarily refers to a calendar year; place, to a geographical (or institutional) space; and person, to particular characteristics of the population group in question.

3.1 General and specific mortality rates

Mortality rates are quotients whose components consist of: a numerator (generally, the number of deaths with certain characteristics of the group of people involved), a denominator (generally, the reference population of the numerator, if rates are involved), and an expansion factor. Mortality statistics are the source of information for the numerator, while population censuses and their estimates and projections are the source for the denominator.

The result obtained from dividing the numerator by the denominator of the mortality rate is multiplied by a constant (the expansion factor), so as not to obtain a fractional number that is difficult to work with and interpret. The purpose of the expansion factor is to turn the rate into an easily understandable value, and its choice depends on the frequency of the event in question. The most commonly used expansion factors are 1,000, 10,000, and 100,000.

Mortality rates can be classified as general and specific. The general mortality rate is defined as the ***"total deaths per 1,000 population in the population residing in a given geographical areas in the year considered"*** (Rede Interagencial de Informações para a Saúde, 2009: 84). That is, the crude mortality rate is calculated by dividing the total number of deaths by the total population in which they occur in a given geographical area in a year. In this case, 1,000 is used as the expansion factor.

The general mortality rate is an easy-to-calculate indicator, the data for which are obtained from information systems created years ago in the countries of the Region. It is an indicator that summarizes the risk of death in the general population, without differentiating by other important variables such as sex, age, or cause of death. Moreover, by not differentiating by age, it is influenced by the age distribution of the population, something that should be borne in mind when comparing rates among populations, as will be seen further on.

For a more detailed analysis of the risks of death in specific population groups, we can construct specific mortality rates according to characteristics of interest, such as sex, age, level of schooling, underlying cause of death, etc.

The specific mortality rate by sex makes it possible to know the risk of death for males and females. For example, the mortality rate in males is obtained from the quotient of the number of deaths in males and the number of individuals in the male population in a given area and time period. It is the specific risk of death among males and can be compared with the specific risk of death among females by similarly constructing the respective indicator.

The risk of death is strongly correlated with age, and age-specific mortality rates show increased risk at the extreme ages of life, such as mortality rates in children under 1 or in persons over 80, for example. Age-specific risks are dealt with further on in the discussion of age-adjusted mortality rates.

Specific mortality by cause is the quotient of deaths from a given cause and the number of people who could potentially develop it in a given place and time period. An example of this is mortality from cardiovascular disease or some type of malignant neoplasm, such as malignant cervical cancer in women.

As mentioned earlier, different characteristics can be combined. The differences in the risk of death between males and females are known and are more important in some age groups and for some causes, such as deaths from external causes in young men or women. In this case, the specific mortality rate simultaneously refers to sex, age, and the underlying cause of death.

3.2 Adjusted rates

Mortality rates can be subdivided into general mortality rates and adjusted mortality rates. As already stated, age is strongly correlated with the risk of death.

The general mortality rate is a weighted average of the specific risks of the different groups that make up the population. These risks correspond, among other things, to sex, age, and level of education. Each population group will contribute proportionally through its weight (size) and specific risk to the value of the general mortality rate. This should be considered when comparing general mortality rates, primarily in relation to the age distribution of the populations involved.

One way of comparing mortality rates, taking into account different age distributions between populations or within the same population in different periods, is to use standardized or adjusted mortality rates. The purpose of age standardization is to eliminate the influence of different age distributions on the mortality rates to be compared; according to Last, ***"an age-standardized mortality rate is an integrated measurement of the mortality rate that a population would have if its age distribution were standardized"*** (Last, 1989: 60). This is because, when comparing mortality between countries, the age distribution of each country operates conceptually as a confounding factor (Szklo and Nieto, 2003: 159).

The two methods used in standardizing rates are presented below: the direct method and the indirect method.

3.2.1 Direct method

In the direct method, the specific risk of death is first calculated for each age group. This requires data on the number of deaths in a given year for each of the age groups selected, as well as the population corresponding to each of these groups. Ideally, the age groups should be logical and homogeneous strata in terms of the risk of death. Several populations can be adjusted simultaneously for comparison purposes, but a simplified example with only two populations will be used below. Assuming that we wish to compare two regions, A and B, whose populations have a different age distribution, the specific risk of death in each age group (deaths/population) is calculated separately for regions A and B (Becker, 1992; Pan American Health Organization, 2002). Then, a standard population is selected. “Standard” is understood as something that is used as a basis for comparison.

Standard populations for the direct adjustment method can be the following: a) an entirely artificial population b) one of the study populations; c) the sum of the study populations; d) an external or reference population, and e) a standard population with minimum variance (Szklo and Nieto, 2003). External populations can, for example, be the population proposed by WHO or the International Agency for Research on Cancer (IARC).

The next stage will consist of calculating, always for each age group, the number of expected deaths in the standard population if it were subject to the specific risk found in population A, subsequently performing the same calculation for population B. Finally, the number of expected deaths in all age groups is totaled, and the result is divided by the standard population, thus obtaining the adjusted rate. All these procedures should be done separately for each population, A and B. If one of them has been selected as the standard population, the adjustment will be necessary only for the other one (Becker, 1992; Pan American Health Organization, 2002).

The expected number of deaths in a population corresponds to the deaths that would be expected in that population if the age distribution of mortality in that population (age-specific mortality rates) were applied to the age distribution (age composition) of the standard population selected.

In short, to compare two hypothetical populations A and B, the next the steps in the ***direct method*** are:

- Calculate the real mortality rates for each age group in population A;
- Select the standard population;
- Calculate the expected deaths for population A, if its real age-specific mortality rates are applied to the age distribution of the standard population;
- Calculate the total expected deaths in population A, as the sum of the values obtained in the previous bullet;
- Calculate the adjusted mortality rate for population A, where the numerator is the number of expected deaths and the denominator is the standard population;
- Perform the same procedure for population B.

Whatever the adjustment method, its purpose is mainly to compare the summary rates of two or more populations. It is neither necessary nor relevant to age-adjust the rates of two populations with the same age composition. In comparing mortality between populations, it is advisable to analyze the age-specific rates before adjusting the rates, although the analysis may be complicated if several populations and several age strata are compared simultaneously, for example among the countries of the Region.

The adjusted rates are ***"artificial"*** or ***"hypothetical"*** rates and are used exclusively for population comparisons. It should also be borne in mind that rates can be adjusted by characteristics other than age, as noted at the beginning of the section. When calculating adjusted rates, it is recommended that the absolute numbers and crude rates also be presented to help the reader correctly interpret the results.

Finally, the adjusted mortality rate is a summary measurement—a single measurement—of the mortality experience in that population if it had the standard age distribution.

3.2.2 Indirect method

Standardizing rates using the indirect method is an alternative when mortality data disaggregated by stratum (in this case, age groups) are not available or when each group is very small, in which case the data would be subject to wide variations with an increase or decrease of only a few deaths (Becker, 1992). It is also used in studies focused on occupations (Last, 1989)—for example, studies that compare the mortality experience of miners with that of the entire population.

Briefly, the ***indirect method*** for comparing two hypothetical populations A and B consists of the following steps:

- Obtain the real deaths observed in population A by age group;
- Calculate the age-specific mortality rates observed in population B that is, the rates in the reference population;
- Calculate the expected deaths for each age group in population A, if the age-specific mortality rates of population B (reference population rates) are applied to the age distribution of population A;
- Calculate the total expected deaths in population A;
- Calculate the standardized mortality ratio (SMR), using the observed deaths in population A as the numerator and the expected deaths in population A as the denominator if it had the mortality distribution (age-specific mortality rates) of population B.

Thus, the SMR is:

> ***"the quotient of the number of events observed in the study group or population and the number that would be expected if that population had the same specific rates as the reference population, multiplied by 100." (Last, 1989: 26)***

It should be noted that adjustment with the indirect method only permits comparison of a population with the population for which the reference rates are obtained. For example, if the indirect adjustment method is used for a group of subnational units (e.g., a country's provinces) and the rates for the country's population are used as the reference, each subnational unit can be compared only with the national rate. This computation would yield a dimension of the risk of each subnational unit in relation to the risk of the country as a whole, and the risk of each subnational unit could hypothetically be higher, equal to, or lower than that of the country. In the example above, it would be incorrect to compare subnational units with each other using the indirect adjustment method.

We recommend that interested readers consult the article ***"Standardization: A Classic Epidemiological Method for the Comparison of Rates"*** (Pan American Health Organization, 2002, which details the steps for comparing rates using examples. Readers may also be interested in the Epidat software (Servicio de Epidemiología de la Dirección General de Salud Pública de la Consellería de Sanidad-Xunta de Galicia, 2014), because, in addition to being a tool for adjusting data in spreadsheets, it contains an extensive methodological and instrumental explanation of the procedure.

3.3 Proportional mortality

Proportional mortality is defined as the quotient of deaths by some characteristic and the total deaths in a given geographical area in a given year.

Age-specific proportional mortality is the proportion of deaths in a specific age group in relation to total deaths (that is, for all ages). Proportional mortality from a specific cause is the proportion of deaths from a specific cause in relation to total deaths (that is, from all causes), and thus, can be used for any other characteristic of interest. Proportional mortality should not be confused with the mortality rate, since the latter is a measure of the risk of death, while proportional mortality is not (Gordis, 2005).

Only mortality data are needed (in both the numerator and the denominator) to construct the proportional mortality indicator. For this reason, it is used when data for the reference population are lacking. For example, if we have no information on the number of live births but we do on mortality, we can calculate the proportional infant mortality.

Despite its limitations, it is an indicator often used to show the relative weight of the different causes in total deaths. For example, interactive figures on proportional mortality by major groups of causes, age, and sex for different years and countries in the Region can be found on the PAHO website (Pan American Health Organization, 2015).

In particular, as mentioned in the chapter on causes of death, one indicator of the quality of the information is the proportional mortality from ***"ill-defined causes."*** In this case, the higher the value, the more deficient the quality of the certification of the causes of death.

3.4 Case-fatality rate

The case-fatality rate is the ***"proportion of cases of a given illness whose progression is fatal within a specific time period"*** (Last, 1989: 168). While the numerator consists of the number of deaths from a given disease, the denominator consists only of the number of individuals with a diagnosis of the respective disease. It is a measurement of the severity of the disease (Gordis, 2005), considering, moreover, age, sex, and other conditions of interest (Almeida Filho and Rouquayrol, 2008).

The case-fatality rate provides information about the prognosis of a disease, because it indicates the proportion of individuals who die from a disease out of the total individuals diagnosed with the disease, after a certain period of time (Gordis, 2005). Although case fatality does not explicitly reference the time between the diagnosis of the disease and death, it commonly alludes to acute diseases, where the time between diagnosis and death (if it occurs) is short (Gordis, 2005).

Generally, except in the case of some specific diseases or special epidemiological studies, case fatality is hard to calculate, because there are no data on the number of people who are sick. Moreover, the difference between the case-fatality rate and mortality from a specific cause, which is the denominator of the latter, consists of all individuals at risk of death from the disease, regardless of whether they have been diagnosed with it at that time.

3.5 Years of potential life lost

The ***"years of potential life lost"*** (YPLL) indicator is:

> ***"the losses suffered by society from the deaths of young people or premature deaths. The figure for years of potential life lost from a given cause is the sum of all people who die from that cause and***

the years they would have lived had they reached their normal life expectancy." (Last, 1989: 8)

The simplest way of calculating the YPLL for a given specific cause is to add, for all defined age groups, the product of the difference between the expected age limit and the median for a specific age group dividing the number of deaths from a given specific cause in that same age group.[8]

The result, which can be expressed per 10,000 population, represents the number of YPLL per 10,000 population. This indicator quantitatively shows the impact of premature mortality from one or more causes in relation to the life expectancy of a given population. Therefore, the criterion used to define the expected age limit for calculating how many years are lost per each premature death is important. There is no consensus on how to define the age limit, but some of the most commonly used definitions are:

- **As a fixed limit:** life expectancy at birth of the population itself: 65, 70, or 75 years;
- **As a variable limit for each age:** life expectancy by the age of the population itself.

Moreover, for the ages between 1 year and the limit (e.g., 70) or between birth (0 years) and the limit [TN: text missing] is considered. When limits defined by the population itself are selected, the comparison between populations becomes more difficult. As with mortality rates, age adjusted YPLL indices can also be obtained (Pan American Health Organization, 2003).

The origins of this indicator lie in a comparative study of mortality from tuberculosis and other causes conducted in the first half of the 20th century (Romeder and McWhinnie, 1977). It is increasingly used in research on differences in mortality from specific causes between two or more groups—for example, in clinical research on types of treatment or in research on occupational exposures (Almeida Filho and Barreto, 2011).

4. MATERNAL AND INFANT MORTALITY INDICATORS

These very important indicators are closely connected with the inalienable rights of persons and can potentially be reduced through effective interventions.

8. YPLL= $\sum_{i=1}^{n} a_i \times d_i$
where:
- i = 1…n corresponds to each defined age group;
- a_i expresses the difference between the expected age limit (e.g., 70 years) and the median of a given age group;
- d_i corresponds to the number of deaths from a specific cause in that same age group.

Reducing maternal and infant mortality is part of major international initiatives such as the Millennium Development Goals and the Sustainable Development Goals.

The infant mortality indicator recognizes maternal living conditions and access to care as determinants. The most important determinants of maternal mortality are poverty and social marginalization, low educational level, and ignorance about and violation of sexual and reproductive rights. The two indicators also reflect the disjointedness and segmentation of the health system, poor quality of care, and difficulties in handling obstetric and perinatal emergencies.

It should be added that the two indicators are also affected by coverage and quality issues, and problems in applying the operational definition of maternal death have led to a review of the definition by WHO.

4.1 The infant mortality rate and its components

The infant mortality rate is one of the most commonly used indicators, since it refers to a stage of life in which the risk of death is higher. It is defined as ***"the number of deaths in children under 1 year per 1,000 live births in the population residing in a given geographical area in the year considered"*** (Rede Interagencial de Informações para a Saúde, 2009: 108).

The infant mortality rate can be subdivided into the neonatal mortality rate and the late infant mortality rate (or post-neonatal mortality rate). In other words, the infant mortality rate is the sum of the neonatal and late infant mortality rates. This division is based on the fact that the predominant causes of death in each of these stages are different, and this distinction makes it possible to take specific action to reduce them. It has long been known that the predominant causes of death in the neonatal period are perinatal[9] and congenital causes linked to genetics, gestation, birth, factors related to the mother's health, and congenital abnormalities. In the post-neonatal period, on the other hand, they are linked to the physical and social environment, such as infections and nutritional problems (Becker, 1992; Behm, 2011).

The neonatal mortality rate is defined as the number of deaths occurring from 0 to 27 full days of life[10] per 1,000 live births in a population residing in given geographical area in a specific year (Rede Interagencial de Informações para a Saúde, 2009). The late infant mortality rate (or post-neonatal mortality rate), in contrast, is defined as ***"the number of deaths from 28 to 364 full days of life per 1,000 live births in a population residing in a given geographical area in a specific year"*** (Rede Interagencial de Informações para a Saúde, 2009: 114). As can be

9. It should be noted that, while related, the terms "perinatal period" and "perinatal causes" are different. "Perinatal period" refers solely to a period of time that corresponds to intrauterine or extrauterine life, while "perinatal causes" are an ICD-10 grouping (World Health Organization, 1995).

10. According to the ICD-10, when doing the calculation, day zero, the first day of the newborn's life, corresponds to at least a 24-hour period (World Health Organization, 1995).

observed, the common denominator of the two infant mortality rates is the total number of live births.

To understand what happens with mortality in the very early ages, the neonatal mortality rate can be divided into the early neonatal mortality rate and the late neonatal mortality rate. The former is defined as the ***"number of deaths from 0 to 6 full days of life per 1,000 live births in a population residing in given geographical area in a specific year"*** (Rede Interagencial de Informações para a Saúde, 2009: 110); and the latter, as the ***"number of deaths from 7 to 27 full days of life per 1,000 live births in a population residing in a given geographical area in a specific year"*** (Rede Interagencial de Informações para a Saúde, 2009: 112).

The denominator of the infant mortality rate and its components is live births corresponding to the geographical area and period, customarily a year.

> ***"Live birth" is understood as "the complete expulsion or extraction from its mother's body of a product of conception, irrespective of the duration of the pregnancy, which, after such separation, breathes or shows any other evidence of life, such as beating of the heart, pulsation of the umbilical cord, or definite movement of voluntary muscles, whether or not the umbilical cord has been cut or the placenta is attached; each product of such a birth is considered liveborn." (World Health Organization, 1995: 151)***

For an in-depth analysis of aspects of early neonatal mortality, it is necessary to investigate what happens with fetal deaths that occur near the probable date of birth[11].

It should be noted that strictly speaking, the infant mortality rate is not actually a rate, and some authors therefore prefer to use the term ***"infant mortality coefficient"*** (Almeida Filho and Rouquayrol, 2008). This is mainly because the numerator consists of the deaths of children under 1 year in a given area and year, which can include children born in the chronological year prior to that of the rate who died in the next chronological year, while the denominator includes the live births of the rate's reference year. That is, strictly speaking, due to the way the

11. "Perinatal mortality" is defined as "the number of deaths in the perinatal period per 1,000 live births, in a population residing in a given geographical area in a specific year." (Rede Interagencial de Informações para a Saúde, 2009: 116). The perinatal period is considered "to begin at 22 full weeks (or 154 days) of gestation and end 7 full days after birth—that, is, from 0 to 6 days of life (early neonatal period)" (Rede Interagencial de Informações para a Saúde, 2009: 116); and "total births" correspond to the sum of live births and fetal deaths (Rede Interagencial de Informações para a Saúde, 2009)." "Fetal death" is defined as "death prior to the expulsion or extraction from its mother of a product of conception, irrespective of the duration of the pregnancy; the death is indicated by the fact that after such separation, the fetus does not breathe or show any other evidence of life, such as a beating of the heart, pulsation of the umbilical cord, or definite movement of voluntary muscles" (World Health Organization, 1995: 151).

numerator and denominator are constructed, the concept of risk is not involved but an equivalency that can be calculated with the aforementioned methods.

It is useful to employ classifications of infant mortality by underlying cause of death, because it makes the event easier to understand and address with measures to reduce it. Here, classifications such as the one proposed by Erika Taucher, mentioned in Section IV.2, are worth noting.

4.2 Maternal mortality ratio

Maternal death is extremely important because it is largely preventable. It reflects the quality of health care in general and health services for pregnant women in particular. It also reflects the conditions of access by the female population of reproductive age to health services and family planning, as well as the precariousness of the socioeconomic situation of this population (Almeida Filho and Barreto, 2011). It should be noted that, by definition, maternal death occurs in women of reproductive age, an important point for considering this indicator from a rights perspective.

The maternal mortality ratio is defined as ***"the number of maternal deaths per 100,000 live births in mothers residing in a given geographical area in a specific year"*** (Rede Interagencial de Informações para a Saúde, 2009: 120). The definitions of maternal death and deaths from direct and indirect obstetric causes are worth considering:

- **Maternal death:** The death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and the site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management, but not from accidental or incidental causes.
- **Direct obstetric deaths:** Those resulting from obstetric complications of the pregnant state (pregnancy, labor, and puerperium), from interventions, omissions, incorrect treatment, or a chain of events resulting from any of the above.
- **Indirect obstetric deaths:** Those resulting from previous existing disease or disease that developed during pregnancy and which was not due to direct obstetric causes, but which was aggravated by physiological effects of pregnancy. (World Health Organization, 1995)

Maternal death should not be confused with death occurring during pregnancy, which is ***"the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the cause of death"*** (World Health Organization, 1995: 156). More-developed regions, which have higher levels of health, higher quality health services, and high levels of coverage and access, have lower maternal mortality ratios than less-developed regions.

The denominator of the maternal mortality ratio is the number of live births in the same geographical area during the same period, since by convention it is considered the highest quality denominator possible for the different countries for comparison purposes. The number of live births is an indirect way of defining the population exposed to the risk of death from maternal causes, because there is an operational difficulty in quantifying the total number of pregnant women in a geographical area in a given period. It should be noted that it is not the same as total births (the sum of live births and stillbirths), since stillbirths are excluded, due to the difficulties involved in quantifying fetal losses.

An expansion factor of 10,000 or 100,000 is customarily used for the maternal mortality ratio, depending on the frequency of the event in the location in question. In the literature, this indicator is also called the ***"maternal death rate"*** [12] or the ***"maternal mortality coefficient."***

In the Region of the Americas, different degrees of under-reporting of maternal deaths are observed for different reasons. One of them is problems related to characterizing deaths as maternal when they actually occur beyond the maximum period of 42 days after delivery.[13] At the same time, statistical death reports mention certain health problems (e.g., infection or hypertension) without indicating the presence of a pregnancy, thus obviating this mode of registration as maternal death (Becker, 1992).

5. INDICATORS DERIVED FROM THE LIFE TABLE

Life tables, also known as mortality tables, are a basic tool in demographic analysis (e.g., in population estimates and projections) and are used for the analysis and comparison of mortality in populations. An indicator whose use is very widespread in health is derived from them: life expectancy.

The most common life tables are the actuarial or period life tables which are based on the mortality situation observed in a year (or an average of years)—applied to a dummy cohort of 10,000 or 100,000 live births. Their calculation depends on the age-specific mortality rates. A ***"complete"*** life table is one constructed for every year of life, and an ***"abridged"*** life table is one that considers age groups, customarily in five year intervals (except for children under 5, which are divided into two groups, children less than 1 year and children aged 1-4).

The primary functions of the life table's structure include the probability of death or survival, as well as life expectancy (Pagano and Gauvreau, 2001; Pan American Health Organization, 2003).

12. "Use of the term 'rate,' though inexact in this context, is retained for the sake of continuity." (World Health Organization, 1995: 157).

13. If they occur afterward, they are considered a late maternal death, which is "the death of a woman from direct or indirect obstetric causes more than 42 days but less than one year after termination of pregnancy" (World Health Organization, 1995: 156).

Specific methods of analysis are derived from life tables, among them the decomposition of changes in life expectancy. This method measures the contribution of each cause of death or age group to the observed change in life expectancy. The Epidat 4.1 software has a module for performing the calculations of this methodology (Servicio de Epidemiología de la Dirección General de Salud Pública de la Consellería de Sanidad-Xunta de Galicia, 2014).

5.1 Probability of death

The probability of death between the ages of x and x+n is defined as the quotient of deaths between the ages of x and x+n and the number of individuals still alive (survivors) at the exact age x. The value is always between zero and one, and for the last age interval, it is always equal to one, since all individuals in the cohort must die.

The probability of death between these two ages is derived from the specific mortality rate for the age group (x;x+n) (known as the central rate in demography). This specific, or central, mortality rate is the quotient of deaths between ages x and x+n and the average population in those ages, known as the population at mid-year or at 1 July.

From an epidemiological standpoint, incidence is a probability. It is a measurement used to measure the occurrence of an event in the health-disease-care process and has traditionally been used to refer to a proportion of new (incident) cases of an event in this process, such as death (Szklo and Nieto, 2003). Therefore, the risk ***"is equivalent to effect, the probability of a pathology occurring in a given population, expressed through the paradigmatic indicator of incidence"*** (Almeida Filho 2009: 327).

Incidence can be divided into two types:

1. Incidence based on individuals at risk; and
2. Incidence based on person-time.

For both, the numerator is the number of new cases of a given event in the health-disease-care process, but each type of incidence has a different denominator.

The denominator for incidence based on the at-risk population, also known as cumulative incidence, is the number of individuals exposed to the risk of developing the event in question and is used in survival analysis, whether in classical life tables (life tables by intervals) or in the Kaplan-Meier method (events at exact times).

The denominator for incidence based on person-time, also known as incidence density, is the monitoring period for each individual at risk of developing the event in question. Person-time units can be based on aggregate data (average population in the period) or individual data and are similar when exits and events are uniform. The general death rate can therefore be considered an incidence rate based on aggregate data (Szklo and Nieto, 2003).

5.2 Life expectancy

For a group of individuals of a given age, life expectancy represents the average number of years that this group can still live if the probability of death remains constant. This concept should not be confused with maximum life span, which is related more to biological factors (Almeida Filho and Barreto, 2011).

Life expectancy at birth is defined as the ***"average years of life expected for a newborn if the existing pattern of mortality in the population residing in a given geographical area and specific year is maintained"*** (Rede Interagencial de Informações para a Saúde, 2009: 86). Its calculation derives from one of the functions that comprise the life table, although there are other methods for obtaining it (indirect methods).

Life expectancy at birth is a summary measure of mortality in a population. It is not affected by the age distribution, which makes it especially useful for comparing mortality levels of countries or regions. Life expectancy is a general indicator of living and health conditions that reflects a population's mortality pattern (Zare, Gaskin and Anderson, 2015). It is strongly associated with the living conditions of populations and, although it increases in a time series, it does so differently in the different social groups that make up society.

6. ESTIMATION OF ATTRIBUTABLE MORTALITY

Based on the epidemiological concept of risk described earlier, the presence of associations between a given exposure and the probability of death can be evaluated. Measurements of association can be based on absolute differences (subtractions) between groups (e.g., exposed and unexposed populations) or relative differences (ratios) (Szklo and Nieto, 2003).

Measurements based on absolute differences are often used in public health when the object is absolute risk reduction. The attributable risk (AR) in exposed populations corresponds to the difference in risk (difference in incidence) between the exposed and unexposed groups,[14] meaning that it is equal to the difference between the incidence rate (risk) in exposed populations, minus the incidence rate (risk) in unexposed populations.

14. In order to simplify and focus on the concepts described, only two levels of exposure were considered (exposed and unexposed populations). However, if it is of interest for the phenomenon being examined, various levels of exposure can be considered.

This measurement estimates the absolute excess risk due to a given exposure—in other words, how much lower the rate would be in the exposed group if the exposure were entirely eliminated. The attributable fraction in exposed persons and the etiologic fraction in exposed populations are synonyms of attributable risk.

Measurement based on relative differences is called relative risk, or the incidence ratio. It is obtained from the quotient of the incidence rate (risk) in the exposed population and the incidence rate (risk) in the unexposed population. When the relative risk is greater than 1, the exposure is considered a risk factor; when it is less than 1, it is considered a protective factor. If there is no association, the value is equal to 1. Methods for estimating the mortality attributable to various risk factors are based on the definition of attributable fraction. Their use requires knowing the excess risk of death of exposed persons—information that can be obtained through specific epidemiological studies (cohort or case and control studies).

One of the most extensive analyses conducted is the estimation of mortality attributable to tobacco use. In the simplest application, attributable mortality can be estimated using data on tobacco use by sex and age group and data on the number of deaths by sex, age group, and causes, assuming the risks derived from a cohort study conducted by the American Cancer Society, known as the Cancer Prevention Study II. The method can be extended to scenarios in which risk estimates based on epidemiological studies are available, and, under certain assumptions, to an independent method for estimating the prevalence of tobacco use.

Epidat 4.1 is a tool that facilitates the application of these methods and, as already noted, contains extensive assistance and examples (Servicio de Epidemiología de la Dirección General de Salud Pública de la Consellería de Sanidad-Xunta de Galicia, 2014).

7. GEOGRAPHICAL VARIATION OF MORTALITY: MAPS

Maps are widely used in describing mortality. The spatial dimension, moreover, is increasingly used in research on mortality. Spatial description of mortality is now of the utmost importance in health policy administration and design. Spatial analysis of mortality indicators is used in numerous disciplines, including demography, geography (historically, medical geography), epidemiology, and health statistics.

Spatial representation of the distribution of mortality has historically been used (Coast and Teixeira, 1999; Czeresnia and Ribeiro, 2000), showing with differences in mortality according to different spatial dimensions; one example of this is the classical study of John Snow, published in 1855, on deaths from cholera in London in the mid-19th century (Cerda and Valdivia, 2007).

In epidemiology, the spatial dimension is dynamic in nature, because ***"space"*** is understood as a social construct, more than a dimension related to geographical relief. It involves a ***"place"*** (space) for the construction of human groups, where interaction, whether amicable or contentious, occurs among groups in society. This critical approach considers geography a social science rather than a science of topography (Santos, 2000). Thus, the space is constructed by actors who, with their conflicts and agreements, alter it through their interaction (Santos, 1997).

The spatial heterogeneity of mortality indicators is accompanied by heterogeneous demographic and socioeconomic indicators, due to social and historical determination of the health-disease-care process. This heterogeneity is clearly observed in maps, which facilitate greater understanding of the mortality phenomenon in society.

In recent years, the description of mortality through maps has developed very rapidly with the advent of geographic information software and statistical methods with great technical potential. As a result of these innovations, multiple spatial analysis techniques are available and accessible to users with different levels of training (Barcellos and Santos, 2006; Vega et al., 2008).

When comparing mortality between different geographical areas, two factors should be taken into account:

1. Differences in the age distribution of the population in each area, which can act as a ***confounding factor***; and
2. The heterogeneity of population size in the areas, which implies different levels of precision in estimating mortality risk in each of them.

For example, in the first factor, standardized mortality ratios (SMRs) can be calculated; in the second, the SMR can be calculated with appropriate statistical methods for ***small areas***, which are described in the next chapter (Benach et al., 2001; Universidad Nacional de Lanús et al., 2005).

Mortality atlases, whose use is very widespread these days, show the distribution of mortality by geographic divisions, generally keeping to administrative/census boundaries. Atlases contain maps with crude and age-adjusted rates calculated with direct or indirect methods (Benach et al., 2001; Instituto Nacional de Salud Pública, 2003; Paes-Sousa et al., 2004; Pickle et al., 1996; Universidad Nacional de Lanús et al., 2005).

Mortality maps use color schemes to display the selected indicators more clearly. Choropleth maps assign colors to areas based on the value of the rate and the quantile method is one of the most appropriate for correctly interpreting maps (Brewer and Pickle, 2003). Color schemes can be sequential or divergent: those with sequential colors are used to represent orders of magnitude in a single direction for continuous variables, such as infant mortality rates, while the divergent ones are used to represent variable values with respect to a single reference—for example, when the standardized mortality ratio is used (values of over or under 1).

8. TEMPORAL TRENDS IN MORTALITY

The temporal mortality trend, which is frequently used, reveals the extent of the temporal variation in the different mortality indicators. Historically, it has been used by disciplines such as demography and epidemiology to study trends in specific indicators in long time series.

The demographic transition theory postulates that in a long-term temporal trend, a decrease in general and infant mortality, an increase in life expectancy, and a reduction in fertility will be observed. The epidemiological transition theory (Omran, 2005), in turn, shows a variation in the profile of mortality causes in the temporal trend, with a decline in mortality from infectious causes, causes preventable by immunization, and causes of infant mortality, accompanied by an increase in mortality from chronic degenerative diseases and violence. Both theories are based on theoretical models of the capitalist development that occurred in major countries.

The epidemiological transition theory sparked some criticism and rethinking (Frenk et al., 1991). The term ***"theory"*** was disputed, since it merely describes patterns in temporal mortality distribution by cause, which may be present in capitalist countries with a given model of development, but that cannot be extrapolated to other economic development models (Barreto et al., 1993).

It is suggested that the mortality trend be observed through long time series (of years), but these are hard to come by due to problems with the existence and quality of medical records, the classifications of causes of death used and their equivalencies, and the available variables and their modifications. An initial measurement of the change that occurred consists of calculating the relative variation (RV) in a single indicator—for example, the annual mortality rate between two periods (which could be, for example, the beginning and end of a series, or two consecutive periods).

If the final rate is t_n and the initial rate is t_0, the relative variation is $(t_n-t_0)/t_0$. That is, the difference between the final value minus the initial value, divided by the initial value.

Note that the RV value will be positive if the rate of the final period is higher than the initial rate (and reflects an increase), but negative (reduction) in the opposite case. This value is usually expressed as a percentage.

Attention should be paid to the fact that the rates sometimes vary markedly, which can result in RV values that are not very representative. It is advisable in such cases to use a longer period for calculating the rates—for example, to compare the average rate for the final biennium (or triennium) with the average rate for the initial biennium (or triennium). Chapter V describes a method for summarizing the change that occurred throughout the series, through the adjustment of a statistical model for it.

A ***secular trend*** is defined as the regular trajectory of an indicator in the temporal trend, while secular changes refer to modifications in the indicator's trend, which can be expressed through different ratios.

When analyzing the temporal trend of the mortality rate in a specific population group, it is important to consider whether an ***age effect*** or ***cohort effect*** is being observed (Frost, 1991). ***Age effect*** refers to changes ***"in the rate of a condition by age, irrespective of the birth cohort and calendar time,"*** while ***cohort effect*** refers to changes ***"in the rate of a condition by year of birth, irrespective of age and calendar time"*** (Szklo and Nieto, 2003).

9. RECOMMENDATIONS FOR INDICATOR REPORTING

Mortality indicators play an important role in decision-making, management, and public policy-making. In their construction and interpretation, consideration should be given to the information needed for decision-making, as well as the objectives of the social actors involved in their use. Correct interpretation of the indicators disseminated requires knowing what technical aspects must be made available to the users.

As mentioned in Chapter II, there are numerous approaches to quality evaluation. One of them is to evaluate the quality of the products produced by statistical systems. While there is no single frame of reference, "quality information" is usually understood as information that is ideal for use in terms of users' needs. Several statistics institutions in the Region have therefore adopted criteria based on the definition of quality established by the European Office of Statistics (Eurostat, 2007), which includes the following components:

- **Relevance:** satisfaction of users' needs.
- **Accuracy:** closeness of the value obtained to the (unknown) true value.
- **Timeliness and punctuality:** length of time between the availability of the results and the reference period.
- **Accessibility and clarity:** physical conditions under which users can obtain data and the availability of modalities to help interpret them.
- **Comparability:** the impact of differences in applied statistical concepts and definitions when statistics are compared between geographical areas, non-geographical domains, or over time.
- **Coherence:** the adequacy of the statistics to be combined in different ways and for various uses.

Under these criteria, it is important to consider the aspects below when reporting mortality indicators.

Concerning the clarity of data, we highly recommend the publication of metadata (***"data about the data"***) or fact sheets that users can consult as guidance for correct interpretation and use of the indicators disseminated. A very detailed model of these fact sheets is the one used in Brazil (Rede Interagencial de Informações para a Saúde, 2009).

When there is substantial under-registration, as defined in Chapter II, its magnitude should be reported when data and indicators are disseminated, so that they can be properly interpreted, adjusted, or corrected.

When constructing and interpreting mortality indicators based on death records obtained from sources other than the vital statistics system, their accuracy and comparability should be considered. For example, to use indicators calculated from reports of hospital discharges due to death or from epidemiological surveillance reports, in addition to determining whether low-frequency events are involved, consideration should be given to the reference population of the reporting health services, the subsector (public and/or private) reporting the data, the structure of the services, and other potential limitations of these sources. This makes it necessary to describe in detail the characteristics of the data sources used in constructing the indicators that could affect them.

The ICD codes that comprise the lists of groups of causes of death or the changes made in these lists over time should be clearly described to guarantee comparability. When a single indicator from different sources is published (e.g., estimates of the infant mortality rate based on different surveys) the coherence of the results should be evaluated and the characteristics of each source that could cause such differences should be specified.

The Pan American Health Organization annually publishes *Health Situation in the Americas: Core Indicators* ("Basic Indicators" prior to 2016). This report is an example of how to present indicators that includes explanatory notes, technical notes, data sources, measurements of under-registration of deaths, confidence intervals, and other tools that we have mentioned throughout this book.

V. STATISTICAL MODELS FOR MORTALITY ANALYSIS

In this chapter, we will provide an introduction to some of the most advanced statistical methods applicable to mortality analysis. Over the past two decades, these methods have become more sophisticated and widespread.

It is worth noting that, while the content of this chapter may be more complex than the previous ones, its purpose is to inform individuals involved in mortality analysis about a series of tools for presenting or analyzing mortality indicators. For example, we can mention that several ***statistics offices*** use confidence intervals when reporting mortality indicators. Thus, we believe it important to present the basics of these techniques and their interpretation, although we do not extensively discuss calculation methods.

Despite its introductory nature, it is advisable for readers who explore the contents of this chapter to have basic training in statistics. The first two sections present a probability model that can be used to describe the behavior of the number of deaths that occur in a given period and area. The third section shows how to obtain and interpret confidence intervals for mortality rates, a topic already mentioned in Chapter III. The final section introduces statistical regression models and their application to the analysis of temporal and spatial relationships and trends.

1. MORTALITY AS A RANDOM PHENOMENON

When applying these methods, it is necessary to assume that the number of deaths registered for an area and time period can be considered a random variable, even when the data are from registries of complete vital statistics systems—i.e., systems that capture a high percentage of the events that occurred.

It can be assumed, for example, that from a public health standpoint and for the targeting of interventions, it is not as important to know the exact number of deaths registered in a given period as it is to know the risk level of the area or group analyzed (Redelings, 2012; Public Health Observatories, 2015; Washington State Department of Health, 2015) and the fact that this risk level can be estimated from the observed deaths.

Numerous authors have debated the conceptual and theoretical basis for treating vital events as random. Brillinger, for example, posits that the biological variability of individuals, environmental diversity, epidemics, medical advances, accidents and violent deaths, and periods marked by climate extremes lead to natural variations in vital events. At the same time, he also mentions the existence of quasi deterministic events, such as labor induction or caesarean section. Based on these assumptions and considering that births follow a stochastic process, as does the life span, he demonstrates that the number of deaths occurring at a particular point in time constitutes a random variable that responds to a certain probability distribution (Brillinger, 1986).

Another possibility of modeling through a distribution of the probability of death lies in imagining that the observed values are actually a sample in time of a hypothetical population consisting of all possible deaths, present and future, that occur under the same conditions. Various experts discuss the limitations of these theories and suggest alternatives (Brillinger, 1986). Despite the discussions on the foundations of these theories, numerous studies today consider the number of deaths registered within a given time period or area to be the result of a random variable with a given probability distribution—the analyst's objective being to estimate the true underlying rate that yielded the result observed.

Many government agencies have embraced these criteria, which make it possible to complement the observed rates with statistical measurements of their variability[15]. These models, moreover, are the basis for a wide range of techniques with important applications in recent years (regression models, temporal and spatial mortality analysis, inequality measurement, etc.).

2. POISSON PROBABILITY DISTRIBUTION

The most commonly used mortality probability model is the Poisson probability distribution, named for mathematician Siméon Denis Poisson, who described its characteristics. This is the probability distribution of a discrete random variable characterized by a parameter, symbolized by the Greek letter λ, that corresponds to the average (expected value) of the distribution—in this case, the incidence rate of deaths per unit of time considered. The variance (that is, dispersion) in this distribution has the peculiarity of also being equal to λ. The example below shows how this distribution can serve as a model for describing the number of deaths that occur.

Based on vital statistics registries, the daily distribution of the number of deaths from cerebrovascular diseases was calculated in San Juan Province, Argentina, in 2012. Considering the number of days in which deaths were not registered, it was found that there were no deaths from this cause on 160 days, representing a fraction equal to 0.437 days of the year. The same thing can be done for days when there were 1, 2, 3 deaths, etc.

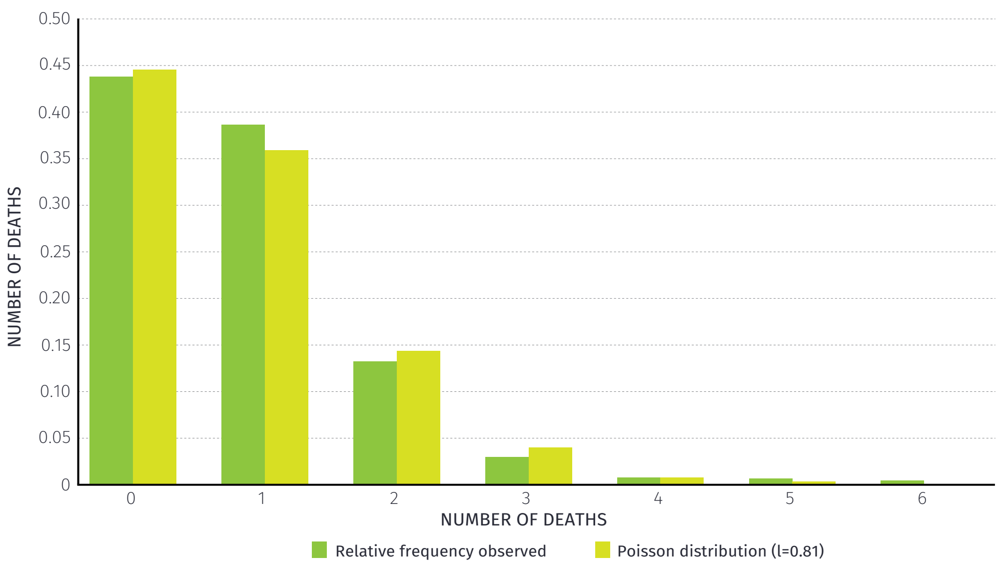
Estimating λ as the average deaths registered per day, we obtain a value of 0.81. Calculating the probability of obtaining the value 0 in a variable with a

15. For example, the National Center for Health Statistics and the Canadian Institute for Health Information in the Region of the Americas, the Association of Public Health Observatories in the United Kingdom, and the Australian Institute of Health and Welfare.

Poisson distribution for this value of λ, we obtain a probability equal to 0.445—a value very close to the one observed. This can be repeated for each number of registered deaths (1, 2, 3, etc.). Figure 4 shows the similarities between the relative frequencies based on the values registered in the vital statistics systems and those resulting from a Poisson distribution, where λ=0.81 for all the values of the daily number of deaths variable.

We can see that the Poisson probability distribution is a good model for describing the relative frequencies of the distribution of the daily number of deaths—in this case, from cerebrovascular diseases—in a given area during a year (Figure 4).

Figure 4. Daily number of deaths from cerebrovascular diseases (ICD-10: 160-154). Relative frequency according to the Poisson model. San Juan Province, Argentina, 2012



Source: PAHO, based on data from the Dirección de Estadísticas e Información de Salud, Ministerio de Salud de la Nación, Argentina.

One constraint in the application of this probability distribution is the equality of the variance value and the average that characterizes it. This is a requirement that may not be applicable to certain causes of death. In many cases, the variance is greater, and overdispersion is involved. It may also happen that a large number of zeros is obtained (that is, many more days without registered deaths than expected under the Poisson model). In these situations, other special probability models can be used that are not considered in this study (e.g., the negative binomial distribution or zero-inflated Poisson models).

3. INFERENTIAL TECHNIQUES APPLIED TO MORTALITY ANALYSIS

As stated earlier, using a probability model for deaths makes it possible to employ the tools of inferential statistics, which are used to quantify or clarify the uncertainty attributable to chance when estimating the true mortality from registered death data. The two basic tools are confidence intervals and significance tests. Here, we will describe the first of these methods.

The confidence interval consists of a pair of limits that define a range of values within which we can be confident that true mortality lies. The confidence level, which in most cases is assumed to be 95% (although other values can be used), indicates the percentage of times that, under the same conditions, the mortality rate will lie within the interval calculated. Larger intervals reflect greater variability and great caution should be exercised in using the observed value as an estimator of the mortality rate.

Confidence intervals can be used to compare different geographical areas or time periods. When two confidence intervals do not overlap, it can be said—with a degree of error related to the confidence level chosen—that the true mortality rates (in terms of the previous section, the λ values of the Poisson distributions) of the areas or periods are different. Not so when they overlap; thus, significance tests should be performed to corroborate this. However, it is generally assumed that there is insufficient evidence to say that the true rates are different.

The use of confidence intervals is especially important when the number of deaths is small, which is the case when considering infrequent causes of death, small geographical areas, population subgroups (e.g., infant or adolescent mortality), or combinations thereof. With ***"big numbers"***—for example, total deaths in a country with a large population—the use of confidence intervals will not contribute more information than the rate itself, although this is not a constraint.

Example of specific rates:

Orozco-Valerio et al. (2012) analyze the trends in mortality from burns in Mexico for the period 1979-2009, based on data from the National Health Information System (SINAIS). Table 3 of the article shows mortality from burns due to fire/flames by age group and sex for the period 2005-2009. In males, 31 deaths in children under 1 year were registered, for a rate of 0.64 per 100,000, while in females, the deaths numbered 38, for a rate of 0.81. Can we say that mortality from burns due to fire/flame in males under 1 year is lower than in females? The authors report that the 95% confidence intervals are 0.41;0.86 for males and 0.55;1.07 for females. This shows that the intervals overlap, and we can therefore conclude that there is not enough evidence to say that the risk of death from such burns before the age of 1 differs by sex.

Confidence intervals can be calculated for crude or age-specific rates, as well as for rates adjusted by the direct or indirect method. The statistical methods involved in these calculations vary: approximation methods, which are valid only for a large number of deaths; approximations with simpler formulas that yield adequate results even with a low number of deaths; and more sophisticated methods. Different alternatives have been suggested over the years, based on studies of statistical theory and the calculation capacity of computers. The most common and recommended methods are the exact method, based on the Chi-square distribution or the Byar approximation for crude or specific rates, the Dobson, Fay, or Tiwari approximation for rates adjusted by the direct method, and the Chi-square distribution or Byar approximation for standardized mortality ratios.

The Epidat 4 software (Servicio de Epidemiología de la Dirección General de Salud Pública de la Consellería de Sanidad—Xunta de Galicia, 2014) calculates confidence intervals using the Fay method for direct adjustment and the Byar approximation for indirect adjustment. Below are some examples with results obtained using this software.

Example of rate adjusted with the direct method:

One of the uses of adjustment with the direct method is to compare mortality in a population over time to control for any changes that may have occurred in age distribution and sex, especially in periods long ago. Table 7 shows the crude and adjusted rates for infectious and parasitic diseases in males in Chile during the years 2000 and 2010. The standard population used is the country's total population, male and female, in 2010. The rates are reported per 100,000, and confidence intervals of 95% were added. In principle, we can see that both the crude and adjusted rate show a decline. Furthermore, since the confidence intervals do not overlap, we can conclude that, if the age distribution of the male population is equal in both periods, mortality from infectious and parasitic diseases declined in this decade, making this difference not attributable to random variations (Table 7).

Table 7. Crude and age-adjusted mortality from infectious and parasitic diseases and confidence intervals of 95%, in males. Chile, 2000 and 2010

Year	Crude rate	Adjusted rate	Lower limit (CI 95%)	Upper limit (CI 95%)
2000	17.6400	22.1053	20.8923	23.4067
2010	13.7274	15.0524	14.2083	15.9688

Source: PAHO, prepared with Epidat 4.1, based on death data from the Pan American Health Organization and population data from the United Nations.

Example of standardized mortality ratio:

It is often of interest to analyze the mortality situation in subnational areas in terms of the overall country average. In these cases, the measurement commonly used is the standardized mortality ratio (SMR), which compares the deaths observed in a given area with the expected deaths in that same area if the mortality in each age group is equal to that of the country. Table 8 shows the number of observed and expected deaths and SMR for three groups of causes for Alajuela Province, Costa Rica, in 2012. The national rate was used as the reference for each age group for the respective cause. In this case, we can see that for both neoplasms and respiratory diseases, the risk of death is lower in Alajuela than in the country as a whole (SMRs of less than 100), while for circulatory diseases, it is higher (SMR of more than 100). However, when we analyze the confidence intervals, we see that for the two causes with SMRs of less than 100, the confidence interval includes the value 100; we can therefore conclude that there is insufficient evidence to say that Alajuela population's risk of death from these causes is lower than the country average. For circulatory diseases, in contrast, because the confidence interval (CI) does not include the value 100, we can say that in 2012, there was a greater risk of death from this cause for Alajuela's population than for Costa Rica's total population.

Table 8. Number of observed and expected deaths, standardized mortality ratio, and confidence intervals for three groups of causes of death. Alajuela, Costa Rica, 2012

Cause-of-death group	Observed cases	Expected cases	Standardized mortality ratio	Confidence interval (95%)	
Neoplasms	384	4,030,039	95.2844	85.9911	105.3082
Circulatory	537	4,865,698	110.3644	101.2260	120.1063
Respiratory	141	1,370,114	102.9111	86.6251	121.3687

Source: PAHO, with Epidat 4.1, based on data obtained from the National Institute of Statistics and Censuses. (http://www.inec.go.cr/Web/Home/GeneradorPagina.aspx).

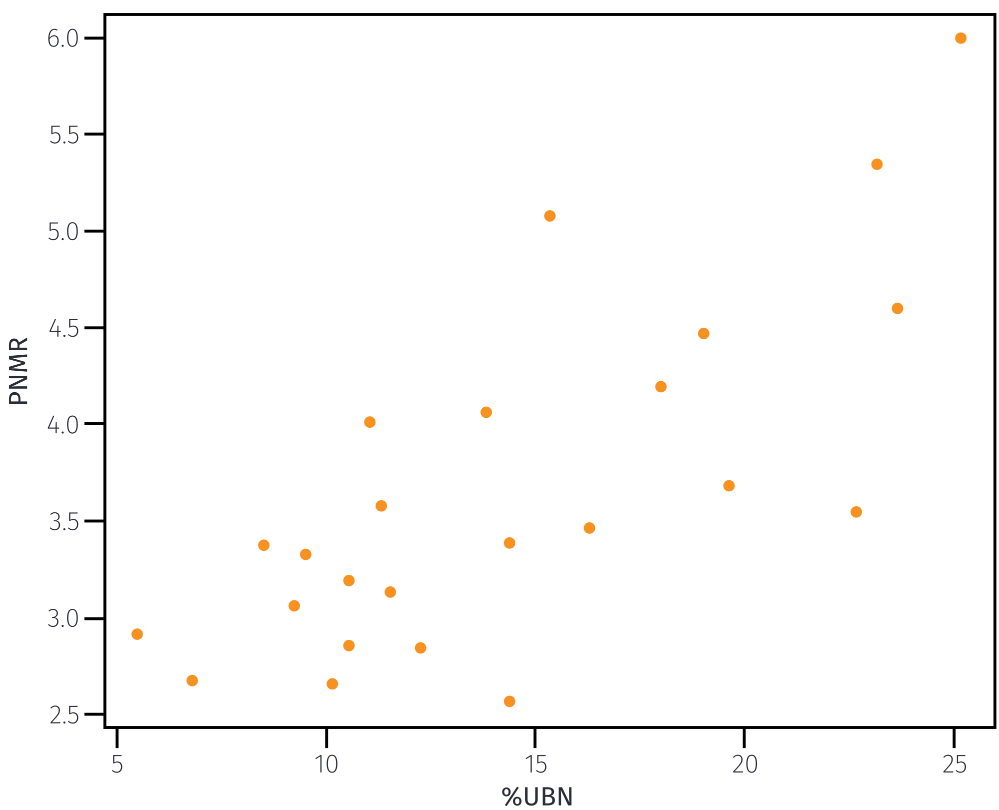
4. REGRESSION MODELS FOR MORTALITY RATES

Regression techniques are appropriate when the object is to describe the behavior of a variable (known as a dependent or response variable) in relation to one or more predictive variables (also called covariables or independent variables). The simplest mathematical formula for these models is the linear function—that is, one that models (or alters) the response variable as a linear function of the predictors.

In studying mortality, when modeling results in individual observations, a model traditionally used in epidemiology is the logistic regression model, which is applicable when the response variable is nominal with only two values, in this case: living or dead. In contrast, when clusters are studied, which occurs in an ***"ecological"*** epidemiological design, the response variable is the number of deaths and, hence, mortality.

Take the following example: In studies of social inequalities in mortality, the object is to analyze the variation in mortality in relation to variations in an indicator of socioeconomic status. Suppose we wish to describe the relationship between the post neonatal mortality rate (PNMR, a dependent variable) and an indicator of the poverty level (the percentage of the population with unmet basic needs—% UBN, an independent variable) in Argentine provinces. Figure 5 shows the point cloud formed by the PNMR of 2012 and the percentage of the population with UBN that was obtained with 2010 census data. We can see that, generally, as the independent variable increases, the value of the rate appears to increase.

Figure 5. Relationship between the post-neonatal mortality rate (PNMR) and the percentage of the population with unmet basic needs (% UBN). Argentine provinces, 2012



Source: PAHO, based on data from the Dirección de Estadísticas e Información de Salud, Ministerio de Salud de la Nación, Argentina.

We can model the relationship between these two variables, but in the analysis how can we include the fact mentioned earlier—that is, that deaths in each province are a random variable? We can consider that the adjustment of the trend line to these data would also vary with the randomness of the rates and, therefore, we would need to obtain a measurement of uncertainty to estimate the model's parameters.

Application of the simple linear regression model assumes that the response variable is a continuous variable, and we know that a trend line takes values in the entire set of real numbers. Thus, the values of the response variable—in our case, the rate or number of deaths—could be either negative or positive. One function that always yields positive values for the dependent variable is the exponential function:

$$Y=\exp(\alpha+\beta x)$$

It is therefore customary to use a change in the mortality rate through the logarithmic function (natural or with a base equal to the constant e). Thus, the resulting model relates the logarithm of the rate (or in fact, of the expected value of the rate) to a linear function of the independent variable.

$$\log(rate)=\alpha+\beta*independent\_variable$$

In this context, exp(β) is interpreted as an increase or multiplier effect (or relative variation) in the rate: for each unit increase in the independent variable, the rate increases exp(β) times.

The best-known linear regression model assumes a normal probability distribution to describe the error component—that is, the part of the dependent variable that cannot be captured by the linear function. The technique that enables us to include the probability model that we have described for deaths is the Poisson regression. Its application (using appropriate statistical software) enables us to calculate both the values of the coefficients (estimates of α and β) and their confidence intervals. For the example in question, the result of the adjusted[16] model is:

$$\log(PNMR)=-5.93394+0.02406*\%NBI$$

We can calculate exp(0.024)=1.024, which shows us that for each percentage point increase in UBN, the rate increases by 2.4%. From this, we also derive that, for a 10 percentage-point increase, the rate increases by 27%.

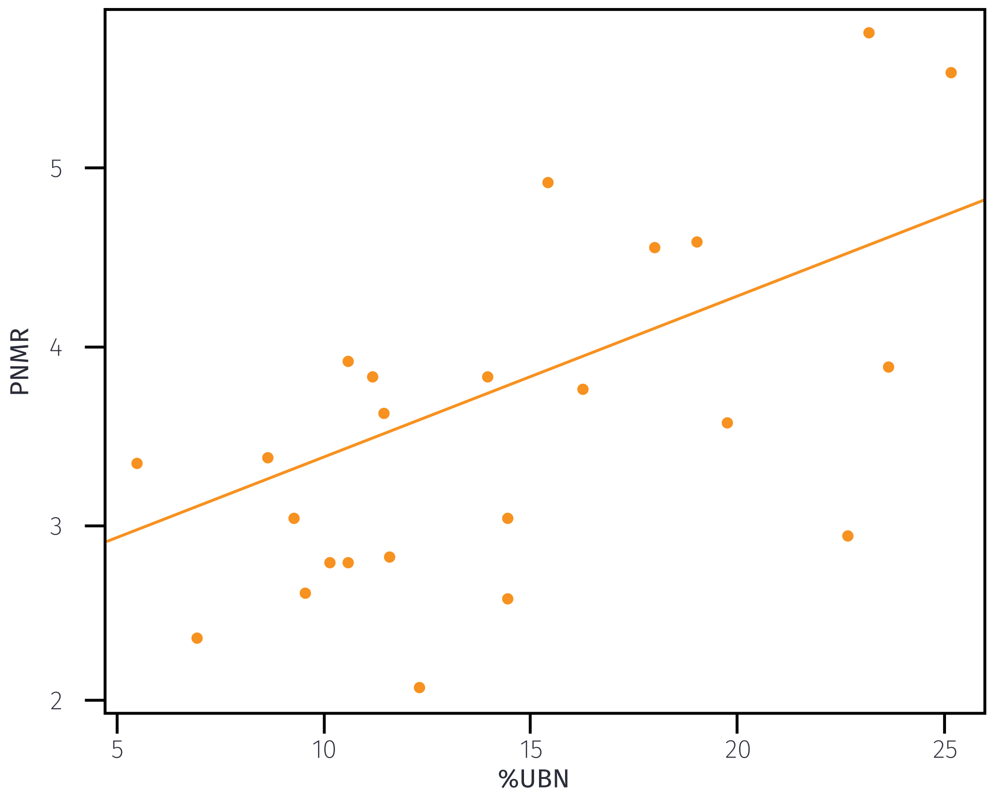
We are especially interested the confidence interval for β:

IC 95%=(0.01644; 0.03157)

Or, applying the exponential function, CI 95%=(1.017; 1.032); thus, we can say that the increase in the PNMR for each additional percentage point of UBN is a value between 1.7% and 3.2%.

16. Using R software (R Core Team, 2013), with the GLM function.

Figure 6. Regression model for the relationship between the post-neonatal mortality rate (PNMR) and the percentage of the population with unmet basic needs (% UBN). Argentine provinces, 2012



Source: PAHO, based on data from the Dirección de Estadísticas e Información de Salud, Ministerio de Salud de la Nación, Argentina.

The Poisson regression model can be extended to more than one independent variable. If we are considering the mortality rate for all ages, we can include an age variable in the model. Likewise for sex or other variables. For example, the study on avoidable deaths conducted in Mexico (Franco-Marina, Lozano, and Villa, 2006) uses the Poisson regression model to compare differences in the risk of death among health regions and includes adjustments for differences in the age distribution and sex of the populations.

4.1 Temporal analysis

As seen in Chapter IV, time is an important independent variable in mortality studies: we often wish to analyze the trend of a cause of death across the years.

Poisson regression models can be applied to these studies, enabling us to include the variability of deaths based on the probability model that we have described. This is of particular interest when attempting to analyze infrequent causes of death, due to their high variability.

In this case, the model for the (expected value) of the rate is:

$$\log(Rate)=\alpha+\beta*Year$$

from which we obtain that (exp(β)-1)*100 can be interpreted as the annual percentage change in the rate. If β is positive, this change is an increase; if negative, a decrease.

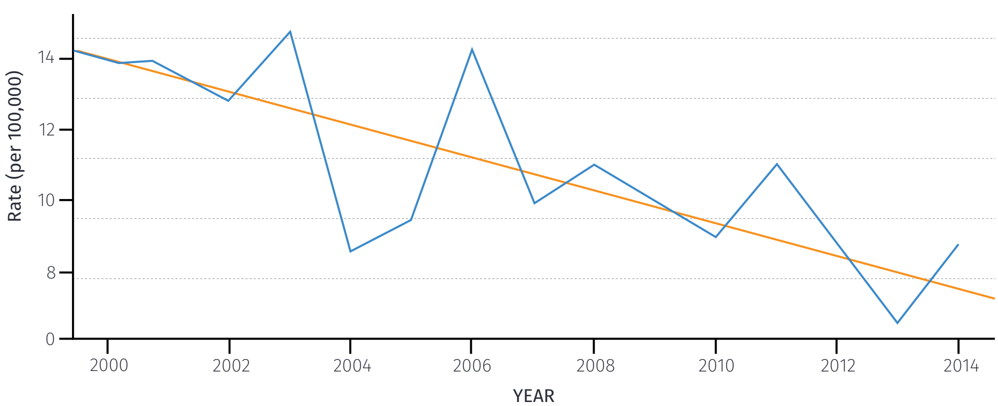
Let us consider now the clinical evolution of mortality from AIDS in men aged 30 to 39 in Costa Rica for the period 2000-2014, shown in Figure 7.

As we can see, the trend for this series can be summarized by adjusting a simple model like the one mentioned. The adjustment of this model, obtained with appropriate statistical software, yields:

$$\log(Rate)=68.7635- 0.03882*Year$$

This adjustment shows that the average annual reduction in the rate was 3.8% during the period in question. Furthermore, the statistics derived from this adjustment enable us to conclude that that result is significant (P= 0.000114). That is, we can assume that the decrease was greater than the natural random variation in the death data. The figure shows the observed data and the adjustment obtained.

Figure 7. Mortality from AIDS in men aged 30-39. Costa Rica, 2000-2014

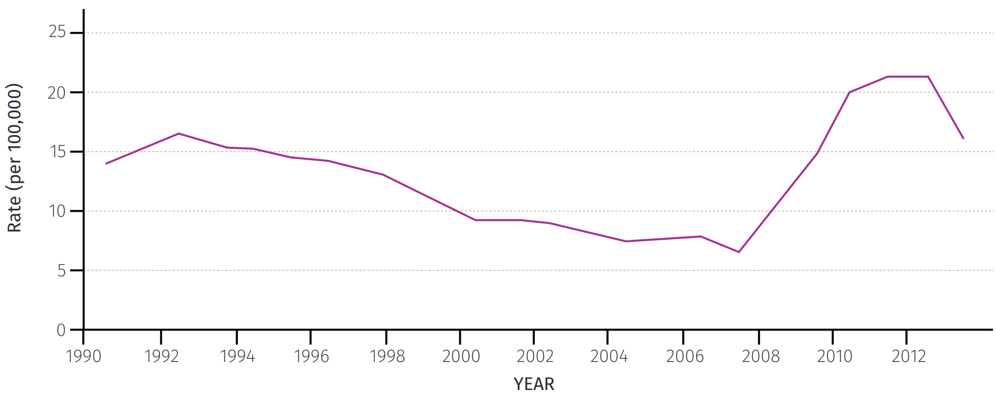


Source: PAHO, based on data from the Pan American Health Organization.

What happens when we consider long periods of time, where changes in the mortality trend can occur? In this case, a model that can be tailored to these changes would be necessary. One statistical technique that can adjust different trend lines by tranches while identifying the number of tranches necessary for describing the phenomenon is the Joinpoint regression (Surveillance.cancer.gov, 2015). The Poisson model for deaths can also be included. This technique has been widely used to analyze trends in mortality from different types of neoplasms. The software for its application can be accessed at no cost.

Figure 8 shows the trend in the homicide rate among adolescents aged 15-19 in Mexico during the period 1990-2013. We can see a clear change in the trend of this rate, especially starting in 2007.

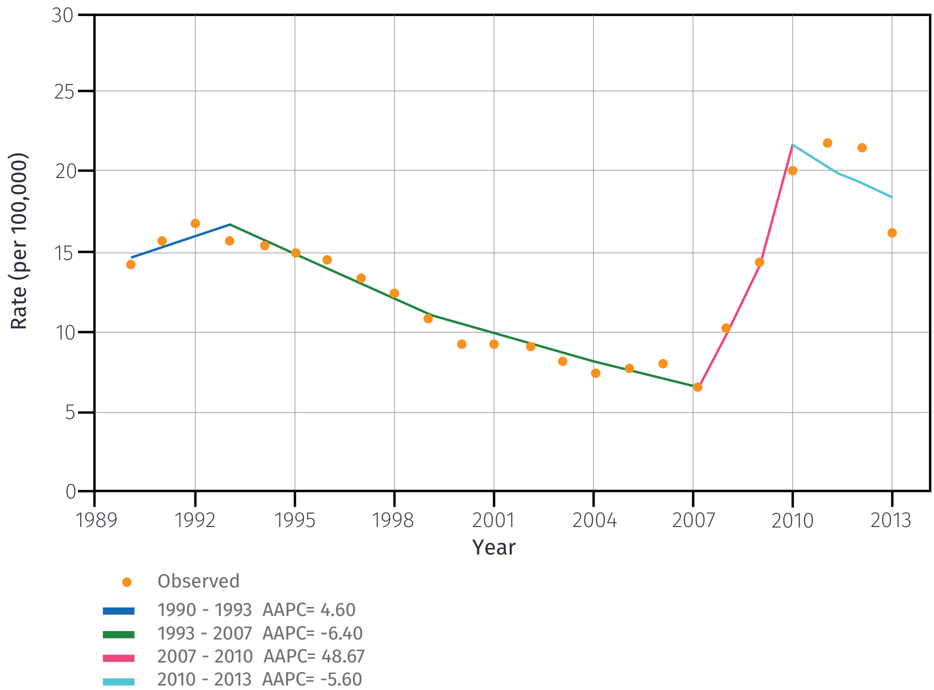
Figure 8. Mortality from homicides in adolescents aged 15-19. Mexico 1990-2013



Source: PAHO, based on data from the National Institute of Statistics and Geography. (INEGI, México)

Application of the Joinpoint regression to this series, including the Poisson model, yields three points of intersection for the four lines representing different trends: 1990-1993, 1993-2007, 2007-2010, and 2010-2013. It also yields the average annual percent change (AAPC) for each period, or 4.60; -6.40; 48.67, and 5.60, respectively. The figures corresponding to the periods 1993-2007 and 2007-2010 are statistically significant—that is, we can conclude that the decrease and increase in these periods are not exclusively attributable to the random variability of deaths.

Figure 9. Results of applying the Joinpoint model to mortality from homicides in adolescents aged 15-19. Mexico, 1990-2013



Source: PAHO, based on data from the DGIS, Mexico.

Table 9 shows the confidence intervals for each AAPC, where we can see that both the first and fourth interval have the value zero.

Table 9. Annual percent change and 95% confidence intervals for the trend in mortality from homicide in adolescents aged 15-19. Mexico, 1990-2013

Period			Confidence interval (95%)	
Initial year	Final year	Annual percent change	Lower limit	Upper limit
1990	1993	4.6	-4.7	14.8
1993	2007	-6.4	-7.5	-5.3
2007	2010	48.7	21.4	82.1
2010	2013	-5.6	-12.8	2.3

Source: PAHO, based on data from the DGIS, Mexico.

4.2 Spatial analysis

In the previous chapter, we mentioned that maps are valuable for spatial representation of mortality and analysis of its geographical variations. However, when analyzing smaller geographical areas or infrequent causes of death, the variability attributable to chance can distort interpretation of the maps.

This is because in smaller areas, the relative random variability of deaths will be greater and, as a result, the rates for these areas will be less accurate estimates of the risk of death. Small areas, therefore, will be those whose values can be more extreme than the rates, making it harder to distinguish true geographical variation from random variation if appropriate methods are not used (Silva Ayçaguer, Benavidez Rodríguez, and Vidal Rodeiro, 2003).

The purpose of applying statistical models to this problem is to reduce random variability through better estimation of the rates in small areas and to obtain a map that shows the spatial distribution of mortality.

In geographical mapping, specific or adjusted rates can be represented. The most commonly used adjusted indicator is the standardized mortality ratio (SMR), and the standard rates selected are those corresponding to the total for the country or global geographical area being analyzed for each age group. Statistical models make it possible to obtain better SMR estimators for each area, based on global information or information for neighboring areas, since it is known that spatially proximate areas usually have similar characteristics. Through a process called ***"smoothing"*** or ***"shrinkage,"*** rates or SMRs are obtained, where estimates for the smallest areas will be buttressed with the global information or information for neighboring areas. In estimates for larger areas (and, hence, those with less variability), information for the area itself will predominate.

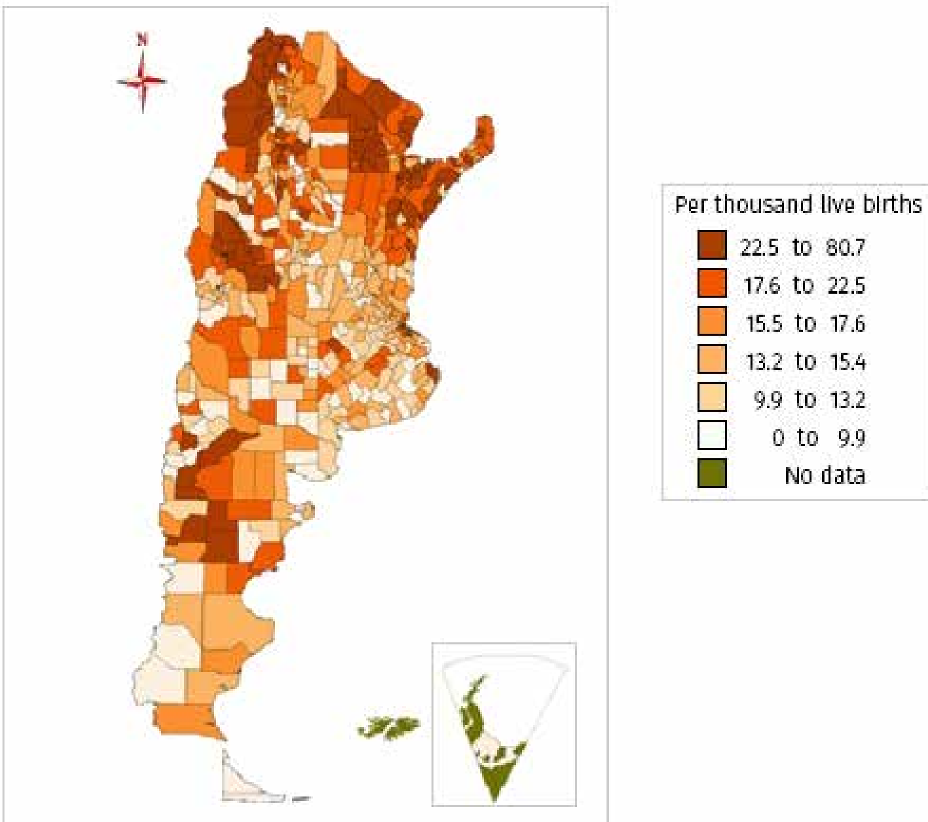
A methodology for obtaining these smoothed rates has been developed that enables deaths to be described with a Poisson probability distribution. Known as the ***"Bayesian model for disease mapping"*** and proposed by Clayton and Kaldor (1987), it has been widely adopted and applied, for example, in mortality atlases for small areas: Atlas de mortalidad en ciudades de España 1996-2003 (Atlas of mortality in cities of Spain 1996-2003) Atlas de mortalidad de Argentina (Atlas of Mortality in Argentina) (Universidad Nacional de Lanús et al., 2005); Atlas de mortalidad en Chile 2001-2008 (Atlas of Mortality in Chile 2001-2008) (Icaza et al., 2013), etc. Mapping of these smoothed rates permits better visualization of the geographical mortality pattern (Silva Ayçaguer, Benavidez Rodríguez, and Vidal Rodeiro, 2003).

Bayesian models can include independent variables, including time, permitting simultaneous consideration of spatial-temporal variations in mortality.

A simple alternative for implementing these Bayesian techniques, known as the empirical Bayes method, is the one proposed by Marshall (Anselin, Lozano, and Koschinsky, 2006), because it provides explicit formulas for calculating the rates, making sophisticated computational processes unnecessary. Using GeoDa software (GeoDa Center, 2015), which can be obtained at no cost, smoothed rates can be calculated with this technique, with global or local adjustment.

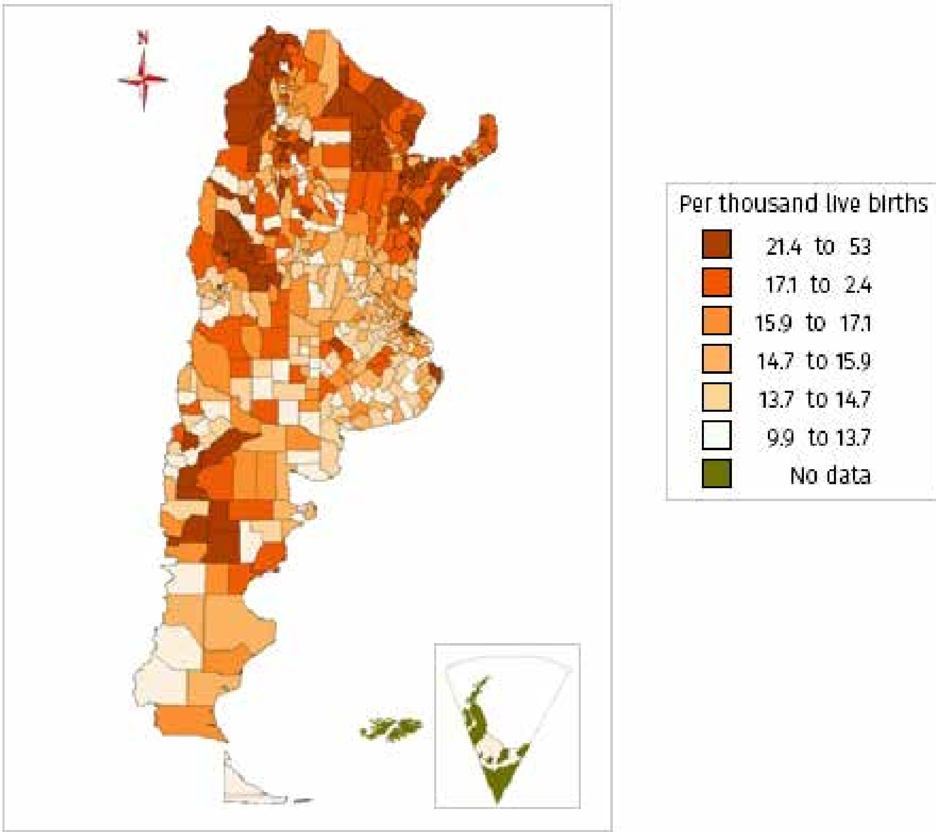
Figures 10 and 11 show the effect of smoothing techniques on spatial representation of the infant mortality rate at the departmental level in Argentina in the quadrennium 1999-2002. The figure shows the maps produced with the reported rates and with globally smoothed rates (Universidad Nacional de Lanús et al., 2005).

Figure 10. Example of the effect of rate smoothing used in the Atlas of Mortality in Argentina. Infant mortality by departments, triennium 1999-2002



Source: National University of Lanús (2005).

Figure 11. Example of the effect of rate smoothing used in the Atlas of Mortality in Argentina. Infant mortality by departments, triennium 1999-2002



Source: National University of Lanús (2005).

To conclude, it should be emphasized that the purpose of this chapter was to introduce a number of statistical techniques for a more in-depth study of mortality. Judgement should be exercised in their use, and points that we have not addressed here should be considered, such as validating the adjustment of the models and verifying compliance with the assumptions involved in these techniques. This is especially important, since as we mentioned, the Poisson distribution may not be a suitable model in some cases (due to overdispersion, excessive zeros, etc.).

ANNEXES

Annex 1: Mexico Death Certificate (only in Spanish)

SECRETARÍA DE SALUD
CERTIFICADO DE DEFUNCIÓN
ANTES DE LLENAR LEA LAS INSTRUCCIONES EN EL REVERSO

Modelo 2017
FOLIO
170000001

DEL FALLECIDO

1. NOMBRE DEL FALLECIDO(A)
Nombre(s) — Primer Apellido — Segundo Apellido

2. FECHA DE NACIMIENTO
Día — Mes — Año

3. SEXO
Hombre ○1 Mujer ○2 Se ignora ○9

4. ENTIDAD DE NACIMIENTO
Entidad federativa o país (si nació en el extranjero)

5. CURP
Se ignora ○99

6. ¿HABLABA ALGUNA LENGUA INDÍGENA?
Sí ○1 No ○2 Se ignora ○9

7. NACIONALIDAD
Mexicana ○1 Otra ○2 → Especifique
Se ignora ○9

8. EDAD CUMPLIDA
Para menores de una hora: Minutos
Para menores de un día: Horas
Para menores de un mes: Días
Para menores de un año: Meses
Para personas de un año o más: Años cumplidos
Se ignora ○9

Para menores de 28 días anote:
8.1 Folio del Certificado de Nacimiento:
8.2 Semanas de gestación:

9. ESTADO CONYUGAL
Separado(a) ○6 Viudo(a) ○2 Casado(a) ○5
En unión libre ○4 Divorciado(a) ○3 Soltero(a) ○1 Se ignora ○9

10. RESIDENCIA HABITUAL
Anote el domicilio permanente donde vivía el fallecido (a)
10.1 Tipo de vialidad — 10.2 Nombre de la vialidad
10.3 Núm. Exterior — 10.4 Núm. Interior — 10.5 Tipo de asentamiento humano — 10.6 Nombre del asentamiento humano
10.7 Código Postal — 10.8 Localidad — 10.9 Municipio o delegación — 10.10 Entidad federativa o país (si residía en el extranjero)

11. ESCOLARIDAD
Ninguna ○1 Preescolar ○12 Primaria ○3 Secundaria ○5
Bachillerato o preparatoria ○7 Profesional ○8 Posgrado ○10 Se ignora ○99

11.1 La escolaridad seleccionada es:
Completa ○1 Incompleta ○2

12. OCUPACIÓN HABITUAL
Se ignora ○99
12.1 Trabajaba Sí ○1 No ○2 Se ignora ○9

13. AFILIACIÓN A SERVICIOS DE SALUD
Ninguna ○1 ISSSTE ○3 SEDENA ○5 Seguro Popular ○7 Otra ○8
IMSS ○2 PEMEX ○4 SEMAR ○6 IMSS PROSPERA ○10 Se ignora ○99
13.1 Número de seguridad social o afiliación

DE LA DEFUNCIÓN

14. SITIO DONDE SUCEDIÓ LA DEFUNCIÓN
Secretaría de Salud ○1 IMSS ○3 PEMEX ○5 SEMAR ○7
IMSS PROSPERA ○2 ISSSTE ○4 SEDENA ○6 Otra unidad pública ○8 Unidad médica privada ○9
14.1 Nombre de la unidad médica
14.2 Clave Única de Establecimientos de Salud (CLUES)
Vía pública ○10 Otro lugar ○12 Hogar ○11 Se ignora ○99

15. DOMICILIO DONDE SUCEDIÓ LA DEFUNCIÓN
15.1 Tipo de vialidad — 15.2 Nombre de la vialidad
15.3 Núm. Exterior — 15.4 Núm. Interior — 15.5 Tipo de asentamiento humano — 15.6 Nombre del asentamiento humano
15.7 Código Postal — 15.8 Localidad — 15.9 Municipio o delegación — 15.10 Entidad federativa

16. FECHA Y HORA DE LA DEFUNCIÓN
Día — Mes — Año — Horas — Minutos

17. ¿TUVO ATENCIÓN MÉDICA DURANTE LA ENFERMEDAD O LESIÓN ANTES DE LA MUERTE?
Sí ○1 No ○2 Se ignora ○9

18. ¿SE PRACTICÓ NECROPSIA?
Sí ○1 No ○2

19. CAUSAS DE LA DEFUNCIÓN (Anote una sola causa en cada renglón. Evite señalar modos de morir - ejemplo: paro cardíaco, astenia, etc.)

Intervalo aproximado entre el inicio de la enfermedad y la muerte — Uso exclusivo del personal codificador: Código CIE

PARTE I
Enfermedad, lesión o estado patológico que produjo la muerte directamente
a) Debido a (o como consecuencia de)

Causas antecedentes
Estados morbosos, si existiera alguno, que produjeron la causa consignada arriba, mencionándose en último lugar la causa básica
b) Debido a (o como consecuencia de)
c) Debido a (o como consecuencia de)
d)

PARTE II
Otros estados patológicos significativos que contribuyeron a la muerte, pero no relacionados con la enfermedad o estado morboso que la produjo

21. SI LA DEFUNCIÓN CORRESPONDE A UNA MUJER DE 10 A 54 AÑOS
21.1 Especifique si la muerte ocurrió durante:
El embarazo ○1 El parto ○2 El puerperio ○3
43 días a 11 meses después del parto o aborto ○4
No estuvo embarazada en los últimos 11 meses previos a la muerte ○5

21.2 ¿Las causas anotadas fueron complicaciones propias del embarazo, parto o puerperio?
Sí ○1 No ○2

21.3 ¿Las causas anotadas complicaron el embarazo, parto o puerperio?
Sí ○1 No ○2

Uso exclusivo del personal codificador
20. CAUSA BÁSICA DE DEFUNCIÓN
Código CIE

MUERTES ACCIDENTALES Y VIOLENTAS

22. SI LA MUERTE FUE ACCIDENTAL O VIOLENTA, ESPECIFIQUE
22.1 Fue un presunto
Accidente ○1 Homicidio ○2 Suicidio ○3 Se ignora ○9

22.2 ¿Ocurrió en el desempeño de su trabajo?
Sí ○1 No ○2 Se ignora ○9

22.3 Sitio donde ocurrió la lesión
Vivienda particular ○0 Área deportiva ○3 Área industrial (taller, fábrica u obra) ○6
Vivienda colectiva (asilo, orfanato, etc.) ○1 Calle o carretera (vía pública) ○4 Granja (rancho o parcela) ○7
Escuela u oficina pública ○2 Área comercial o de servicio ○5 Otro ○8
Se ignora ○9

22.4 Anote la relación que tenía el presunto agresor con el(la) fallecido(a)

22.5 La defunción fue registrada en el Ministerio Público con el acta número:

22.6 Describa brevemente la situación, circunstancia o motivos en que se produjo la lesión del presunto accidente, homicidio o suicidio

22.7 Anote el domicilio donde ocurrió la lesión del presunto accidente, homicidio o suicidio
22.7.1 Tipo de vialidad — 22.7.2 Nombre de la vialidad
22.7.3 Núm. Exterior — 22.7.4 Núm. Interior — 22.7.5 Tipo de asentamiento humano — 22.7.6 Nombre del asentamiento humano
22.7.7 Código Postal — 22.7.8 Localidad — 22.7.9 Municipio o delegación — 22.7.10 Entidad federativa

DEL INF.

23. NOMBRE
Nombre(s) — Primer Apellido — Segundo Apellido

24. PARENTESCO CON EL(LA) FALLECIDO(A)

DEL CERTIFICANTE

25. CERTIFICADA POR
Médico tratante ○1 Médico legista ○2 Otro médico* ○3
Persona autorizada por la Secretaría de Salud ○4 Autoridad civil* ○5 Otro* ○8
*Especifique

26. SI EL CERTIFICANTE ES MÉDICO
Número de la cédula profesional

27. NOMBRE
Nombre(s) — Primer Apellido — Segundo Apellido

28. FIRMA

29. DOMICILIO y TELÉFONO
29.1 Tipo de vialidad — 29.2 Nombre de la vialidad — 29.3 Núm. Exterior — 29.4 Núm. Interior — 29.5 Tipo de asentamiento humano
29.6 Nombre del asentamiento humano — 29.7 Código Postal — 29.8 Localidad
29.9 Municipio o delegación — 29.10 Entidad federativa — 29.11 Teléfono

30. FECHA DE CERTIFICACIÓN
Día — Mes — Año

DEL REG. CIVIL

31. LA DEFUNCIÓN FUE INSCRITA EN LA OFICIALÍA O JUZGADO
Núm.____________, Libro Núm.____________
31.1 Acta Núm.____________

32. LUGAR Y FECHA DE REGISTRO
32.1 Localidad
32.2 Municipio o delegación — 32.3 Entidad federativa — 32.4 Día — Mes — Año

ATENCIÓN: EL PERSONAL DEL REGISTRO CIVIL DEBE REMITIR ESTE ORIGINAL A LA SECRETARÍA DE SALUD

ENTREGUE EL ORIGINAL, LA 1ª COPIA (ROSA) Y LA 2ª COPIA (AZUL) AL REGISTRO CIVIL PARA OBTENER EL ACTA DE DEFUNCIÓN.

LOS DATOS PERSONALES ESTÁN PROTEGIDOS CONFORME A LA LEY FEDERAL DE TRANSPARENCIA Y ACCESO A LA INFORMACIÓN PÚBLICA GUBERNAMENTAL, LOS LINEAMIENTOS DE PROTECCIÓN DE DATOS PERSONALES Y LA LEY FEDERAL DE PROTECCIÓN DE DATOS PERSONALES EN POSESIÓN DE LOS PARTICULARES.

170000001

Annex 2: Pan American Health Organization—6/67 list for mortality tabulation

No.	Description	ICD-10
0.00	**Symptoms, signs and ill-defined conditions**	**R00-R99**
1.00	**Communicable diseases**	**A00-B99, G00-G03, J00-J22**
1.1	Intestinal infectious diseases	A00-A09
1.2	Tuberculosis	A15-A19
1.3	Certain vector-borne diseases and rabies	A20, A44, A75-A79, A82-A84, A85.2, A90-A98, B50-B57
1.4	Certain diseases preventable by immunization	A33-A37, A80, B05, B06, B16, B17.0 B18.0-B18.1, B26
1.5	Meningitis	A39, A87, G00-G03
1.6	Septicemia, except neonatal	A40-A41
1.7	HIV disease (AIDS)	B20-B24
1.8	Acute respiratory infections	J00-J22
1.9	Other infectious and parasitic diseases	(remainder of A00-B99 I,.e. A21-A32, A38, A42-A43, A46-A74, A81, A85.0-A85.1, A85.8, A86, A88-A89, A99-B04, B07-B15, B17.1-B17.8, B18.2 B19.9, B25, B27-B49, B58-B99)
2.00	**Neoplasms (Tumors)**	**C00-D48**
2.01	Malignant neoplasm of stomach	C16
2.02	Malignant neoplasm of colon and rectosigmoid junction	C18-C19
2.03	Malignant neoplasm of digestive organs and peritoneum, except stomach and colon	C15, C17, C20-C26, C48
2.04	Malignant neoplasm of trachea, bronchus and lung	C33-C34
2.05	Malignant neoplasm of respiratory and intrathoracic organs, except trachea, bronchus and lung	C30-C32, C37-C39
2.06	Malignant neoplasm of female breast	C50 (in women)
2.07	Malignant neoplasm of cervix uteri	C53

No.	Description	ICD-10
2.08	Malignant neoplasm of corpus uteri	C54
2.09	Malignant neoplasm of uterus, part unspecified	C55
2.10	Malignant neoplasm of prostate	C61
2.11	Malignant neoplasm of other genitourinary organs	C51-C52, C56-C57, C60, C62-C68
2.12	Leukemia	C91-C95
2.13	Malignant neoplasm of lymphoid, other hematopoietic and related tissue	C81-C90, C96
2.14	Malignant neoplasm of other and unspecified sites	(remainder of C00-C97, i.e. C00-C14, C40-C47, C49, C50 en hombres, C58, C69-C80, C97)
2.15	Carcinoma in situ, benign neoplasms and neoplasms of uncertain or unknown behavior	D00-D48
3.00	**Diseases of the circulatory system**	**I00-I99**
3.01	Acute rheumatic fever and chronic rheumatic heart diseases	I00-I09
3.02	Hypertensive diseases	I10-I15
3.03	Ischemic heart disease	I20-I25
3.04	Pulmonary heart disease, diseases of pulmonary circulation and other forms of heart disease	I26-I45, I47-I49, I51
3.05	Cardiac arrest	I46
3.06	Heart failure	I50
3.07	Cerebrovascular diseases	I60-I69
3.08	Atherosclerosis	I70
3.09	All other diseases of the circulatory system	I71-I99

No.	Description	ICD-10
4.00	**Certain conditions originating in the perinatal period**	**P00-P96**
4.01	Fetus and newborn affected by certain maternal conditions	P00, P04
4.02	Fetus and newborn affected by obstetric complications, birth trauma	P01-P03, P10-P15
4.03	Slow fetal growth, fetal malnutrition, short gestation, low birth weight	P05, P07
4.04	Respiratory disorders specific to the perinatal period	P20-P28
4.05	Bacterial sepsis of newborn	P36
4.06	Remainder of certain conditions originating in the perinatal period	(rest of P00-P96, i.e. P08, P29, P35, P37-P96)
5.00	**External causes**	**V01-Y89**
5.01	Land transport accidents	V01-V89
5.02	Other and unspecified transport accidents	V90-V99
5.03	Falls	W00-W19
5.04	Accidents caused by firearm discharge	W32-W34
5.05	Accidental drowning and submersion	W65-W74
5.06	Accidental threats to breathing	W75-W84
5.07	Exposure to electric current	W85-W87
5.08	Exposure to smoke, fire and flames	X00-X09
5.09	Accidental poisoning by and exposure to noxious substances	X40-X49
5.10	All other accidents	W20-W31, W35-W64, W88-W99, X10-X39, X50-X59, Y40-Y84
5.11	Intentional self-harm (suicide)	X60-X84
5.12	Assault (homicide)	X85-Y09

No.	Description	ICD-10
5.13	Event of undetermined intent	Y10-Y34
5.14	All other external causes	Y35-Y36, Y85-Y89
6.00	**All other diseases**	**D50-D89, E00-E90, F00-F99, G04-G98, H00-H59, H60-H95. J30-J98. K00-K93, L00-L99, M00-M99, N00-N99, O00-O99, Q00-Q99)**
6.01	Diabetes mellitus	E10-E14
6.02	Nutritional deficiencies and nutritional anemia	E40-E64, D50-D53
6.03	Mental and behavioral disorders	F00-F99
6.04	Diseases of the nervous system, except meningitis	G04-G99
6.05	Chronic lower respiratory diseases	J40-J47
6.06	Remainder of diseases of the respiratory system	J30-J39, J60-J98
6.07	Apendicitis, hernia of abdominal cavity and intestinal obstruction	K35-K46, K56
6.08	Cirrhosis and certain other chronic diseases of liver	K70, K73, K74, K76
6.09	All other diseases of the digestive system	(rest of K00-K93, i.e. K00-K31, K50-K55, K57-K66, K71, K72, K75, K80-K93)
6.10	Diseases of the urinary system	N00-N39
6.11	Hyplasia of prostate	N40
6.12	Pregnancy, childbirth and the puerperium	O00-O99
6.13	Congenital malformations, deformations and chromosomal abnormalities	Q00-Q99
6.14	Remainder of all other diseases	(rest of A00-Q99, i.e. D55-D89. E00-E07, E15-E34, E65-E90, H00-H59, H60-H95, L00-L99, M00-M99, N41-N99)

Source: Pan American Health Organization. Available at: http://www1.paho.org/English/DD/AIS/EB_v23n4.pdf

Annex 3: Argentina—mortality list by selected causes

Cause	ICD-10 Codes
1. Infectious and parasitic diseases	**A00-B99**
Intestinal infectious diseases	A00-A09
Tuberculosis, including sequelae	A15-A19; B90
Tetanus	Neonatal: A33; Obstetric: A34; Other: A35
Septicemias	A40-A41
Meningococcal infection	A39
Viral meningitis	A87
Measles	B05
Dengue	A90-A91
Rubella	B06
Viral hepatitis	B15-B19
Human immunodeficiency virus (HIV) disease	B20-B24
Trypanosomiasis (Chagas disease)	B57
All other infectious and parasitic diseases	All other categories in A and B
2. Neoplasms	**C00-D48**
Malignant	C00-C97
Esophagus	C15
Stomach	C16
Colon, rectus and rectosigmoid junction and anus	C18-C21
Liver and intrahepatic bile ducts	C22
Gall bladder and other parts of the biliary tract	C23-C24

Cause	ICD-10 Codes
Pancreas	C25
Trachea, bronchus and lung	C33-C34
Breast	C50
Uterus	C53-C55
Ovary	C56
Prostate	C61
Kidney and other urinary organs, except bladder	C64-C66; C68
Bladder	C67
Brain and other parts of the central nervous system	C69-C72
Non-Hodgkin lymphoma	C82-C85
Leukemia	C91-C95
Malignant neoplasms of unspecified sites	C80
All other malignant neoplasms	All other categories in C
Carcinoma in situ, benign neoplasms and neoplasms of uncertain or unknown behavior	D00-D48
3. Diabetes mellitus	**E10-E14**
4. Nutritional deficiencies and nutritional anemia	**E40-E64; D50-D53**
5. Metabolic disorders	**E70-E90**
6. Meningitis	**G00,G03**
7. Alzheimer disease	**G30**
8. Mental and behavioral disorders	**F00-F99**
Alcohol dependence syndrome	F10
9. Diseases of the circulatory system	**I00-I99**

Cause	ICD-10 Codes
Hypertensive diseases	I10 -I14
Ischemic heart diseases	I20-I25
Heart failure	I50
Complications and ill-defined descriptions of heart disease	I51
All other heart diseases	All other categories in I00-I52
Cerebrovascular diseases	I60-I69
Atherosclerosis	I70
All other diseases of the circulatory system	All other categories in I
10. Diseases of the respiratory system	**J00-J99**
Pneumonia and influenza	J09-J18
Acute bronchitis and bronchiolitis	J20-J21
All other acute respiratory infections	All other categories in J00-J22
Chronic lower respiratory diseases	J40-J47
Pneumonitis due to solids and liquids	J69
Respiratory failure, not elsewhere classified	J96
All other diseases of the respiratory system	All other categories in J
11. Appendicitis, hernia of the abdominal cavity and intestinal obstruction	**K35-K46; K56**
12. Diseases of liver	**K70-K77**
Certain chronic diseases of liver and cirrhosis	K70; K73-K74; K76
13. Diseases of the urinary system	**N00-N39**
Nephritis and nephrosis	N00-N07; N17-N19; N25-N27;

Cause	ICD-10 Codes
All other diseases of the urinary system	All other categories in N00-N39
14. Pregnancy, childbirth and the puerperium	**O00-O99**
15. Certain conditions originating in the perinatal period	**P00-P96**
16. Congenital malformations, deformations and chromosomal abnormalities	**Q00-Q99**
17. External causes	**V01-Y98**
Motor vehicle traffic accidents	V02-V04 with 1 or 9 as the fourth digit; V051; V092 and V093; V12-V15 and V20-V28 with 4, 5 or 9 as the fourth digit; V30-V38, V40-V48, V50-V58, V60-V68, V70-V78 with 5, 6, 7 or 9 as the fourth digit; V19, V29, V39, V49, V59, V69 and V79 with 4, 5, 6 or 9 as the fourth digit; V803 - V805; V811; V821; V830-V833; V840-V843 ; V850-V853; V860 - V863; V870 - V878; V892 and V899
Other transport accidents, including sequelae	All other categories in V01-V99, Y85
Accidental drowning and submersion	W65-W74
Unspecified accidents	X59
Other external causes of accidental injury, including sequelae	W00-W64, W75-X58, Y86
Suicide, including sequelae	X60-X84, Y870
Assault, including sequelae	X85-Y09, Y871
Events of undetermined intent, including sequelae	Y10-Y34; Y872
Complications of medical and surgical care	Y40-Y84
All other external causes	All other categories in V01-Y98
18. All other defined causes	**Remainder of categories, except R00-R99**
ILL-DEFINED AND UNKNOWN CAUSES	**R00-R99**

Source: Dirección de Estadísticas e Información de Salud – Ministerio de Salud

Annex 4: Colombia—list 105 for mortality tabulation

List No.	Cause	ICD-10 Codes	ICD-9 Codes
01	Intestinal infectious diseases	A00-A09	001-009, 136.5
02	Tuberculosis and sequelae	A15-A19, B90	010-018, 137
03	Certain vector-borne diseases and rabies	A20, A44, A75-A79, A82-A84, A85.2, A90-A98, B50-B57	020, 060-066, 071, 078.6-078.8, 080-088
04	Certain diseases preventable by immunization	A33-A37, A80, B05-B06, B26, B91	032-033, 037, 045, 055-056, 072, 138, 771,3
05	Septicemia, except neonatal	A40-A41	038
06	All other bacterial diseases	A21-A32, A38-A39, A42-A43, A46-A49	021-031, 034.1-036, 039-040.1, 040.3-041, 100
07	Syphilis and other venereal diseases	A50-A64	054.1, 090-099.2, 099.4-099.9, 131.0
08	Viral hepatitis viral and sequelae	B15-B19, B94.2	070
09	HIV disease (AIDS)	B20-B24	089
10	All other infectious and parasitic diseases	A65-A74, A81, A85.0-A85.1, A85.8-A89, A99-B04, B07-B09, B25, B27-B49, B58-B89, B92-B94.1, B94.8-B99	046-054.0, 0.54.2-054.9, 057, 073-078.5, 079, 101-104, 110-130, 131.8-134, 136.2-136.4, 136.8-136.9, 139
11	Malignant neoplasms of the lip, oral cavity and pharynx	C00-C14	140-149
12	Malignant neoplasm of esophagus	C15	150
13	Malignant neoplasm of stomach	C16	151
14	Malignant neoplasm of colon, rectosigmoid junction, rectum and anus	C18-C21	153-154
15	Malignant neoplasm of liver	C22	155

List No.	Cause	ICD-10 Codes	ICD-9 Codes
16	Malignant neoplasm of the gallbladder and biliary tract	C23-C24	156
17	Malignant neoplasm of pancreas	C25	157
18	All other malignant neoplasms of the digestive organs and peritoneum	C17, C26, C48	152, 158-159
19	Malignant neoplasm of larynx	C32	161
20	Malignant neoplasm of trachea, bronchus and lung	C33-C34	162
21	All other malignant neoplasms of the respiratory and intrathoracic organs, except trachea, bronchus and lung	C30-C31, C37-C39	160, 163-165
22	Malignant neoplasm of bones and articular cartilage	C40-C41	170
23	Melanoma and other malignant neoplasms of skin	C43-C44	172-173
24	Malignant neoplasm of female breast	C50, in women	174
25	Malignant neoplasm of cervix uteri	C53	180
26	Malignant neoplasm of other parts of the uterus	C54-C55	182, 179
27	Malignant neoplasm of ovary	C56	183.0
28	Malignant neoplasm of prostate	C61	185
29	Malignant neoplasm of bladder	C67	188
30	All other malignant neoplasms of the urinary organs	C64-C66, C68	189
31	Malignant neoplasm of the brain, eye and other parts of the central nervous system	C69-C72	190-192
32	Malignant neoplasm of thyroid and other endocrine glands	C73-C75	193-194
33	Malignant neoplasm of ill-defined and secondary sites	C76-C79	195-198

List No.	Cause	ICD-10 Codes	ICD-9 Codes
34	Malignant neoplasm of unspecified sites	C80	199
35	Leukemia	C91-C95	204-208
36	All other malignant neoplasms of lymphoid, hematopoietic and related tissue	C81-C85, C88-C90, C96	200-203, 273.3
37	Neoplasms: in situ, benign and of uncertain or unknown behavior	D00-D48	210-239, 273.1
38	All other malignant neoplasms of other sites	C45-C47, C49, C50 in men, C51-C52, C57-C58, C60, C62-C63, C97	171, 175, 181, 183.2-184, 186-187
39	Anemias: nutritional, hemolytic, aplastic and others	D50-D53, D55-D62, D64	280-285
40	Coagulation defects, purpura and other hemorrhagic conditions and disorders that affect immunity	D65-D76, D80-D89	273.0, 273.2, 279, 286-289.0, 289.4-289.9, 135
41	Diabetes mellitus	E10-E14	250
42	Nutritional deficiencies	E40-E64	260-268.1, 268.9-269
43	All other endocrine and nutritional disorders	E00-E07, E15-E34, E65-E89	240-246, 251-259, 270-272, 273.8-273.9, 275-278, 330.0-330.1
44	Mental and behavioral disorders	F01, F03-F99	290-319
45	Meningitis and other inflammatory diseases of the central nervous system	G00, G03-G04, G06, G08-G09	320-326
46	Epilepsy and other episodic and paroxysmal disorders	G40-G45, G47	345-347, 435, 780.5

List No.	Cause	ICD-10 Codes	ICD-9 Codes
47	All other diseases of the central nervous system	G10-G12, G20-G21, G23-G25, G30-G31, G35-G37, G50-G52, G54, G56-G58, G60-G62, G64, G70-G72, G80-G83, G90-G93, G95-G96, G98	330.8-337, 340-344, 348-359
48	Diseases of the eye and adnexa, of the ear and mastoid	H00-H02, H04-H05, H10-H11, H15-H18, H20-H21, H25-H27, H30-H31, H33-H35, H40, H43-H44, H46-H47, H49-H57, H59-H61, H65-H66, H68-H74, H80-H81, H83-H93, H95	360-389
49	Acute rheumatic fever and chronic rheumatic heart disease	I00-I09	390-398
50	Hypertensive diseases	I10-I15	401-405
51	Ischemic heart diseases	I20-I25	410-414
52	Pulmonary heart disease and diseases of pulmonary circulation	I26-I28	415-417
53	All other forms of heart disease	I30-I31, I33-I38, I40, I42, I44-I46.1, I47-I49, I51	420-427.4, 427.6-427.9, 429
54	Heart failure	I50	428
55	Cerebrovascular diseases	I60-I67, I69	430-434, 436-438
56	Atherosclerosis	I70	440
57	Aortic aneurysm	I71	441

List No.	Cause	ICD-10 Codes	ICD-9 Codes
58	Vascular diseases and other diseases of the circulatory system	I72-I78, I80-I95, I99	289.1-289.3, 442-444, 447-448, 451-459
59	Pneumonia	J12-J16, J18	480-486, 514
60	Chronic lower respiratory diseases	J40-J47	490-494, 496
61	Lung diseases due to external agents	J60-J70	495, 500-508
62	All other diseases of the respiratory system	J00-J11, J20-J22, J30-J39, J80-J86, J90, J92-J94, J96-J98	034.0, 460-466, 470-478, 487, 510-513, 515-519
63	Ulcer	K25-K28	531-534
64	Diseases of esophagus and other diseases of stomach and duodenum	K20–K22, K29–K31	530, 535-537
65	Diseases of appendix, hernia and intestinal obstruction	K35-K38, K40-K46, K56	540-543, 550-553, 560
66	Diseases of liver	K70-K76	570-573
67	Disorders of gallbladder, biliary tract and pancreas	K80-K86	574-575, 576.1-577
68	Noninfective enteritis and colitis and other intestinal diseases	K50-K52, K55, K57-K63	555-558, 562-566, 569
69	Diseases of the peritoneum and other diseases of the digestive system	K00-K14, K65-K66, K90, K92.8-K92.9	520-529, 567-568, 579, 040.2
70	Gastrointestinal hemorrhage	K92.0-K92.2	578
71	Diseases of the skin and subcutaneous tissue	L00-L08, L10-L13, L20-L44, L50-L53, L55-L60, L63-L85, L87-L98	680-686, 690-709, 136.0

List No.	Cause	ICD-10 Codes	ICD-9 Codes
72	Diseases of the musculoskeletal system and connective tissue	M00, M02, M05-M06, M08, M10-M13, M15-M25, M30-M35, M40-M48, M50-M62, M65-M67, M70-M72, M75-M81, M83-M89, M91-M99	710-739, 136.1, 274, 446, 099.3, 268.2
73	Glomerular and renal tubulo-interstitial diseases	N00-N07, N10-N15	580-583, 590.0-590.2, 590.8-590.9
74	Renal failure	N17-N19	584-586
75	All other diseases of the urinary system	N20-N21, N23, N25-N28, N30-N32, N34-N36, N39, N99.1	587-589, 590.3, 591-599, 788.0
76	Hyperplasia of prostate	N40	600
77	Disorders of genital organs	N41-N50, N60-N73, N75-N76, N80-N99.0, N99.2-N99.9	601-608, 610-629
78	Pregnancy, childbirth and the puerperium	O00-O99	630-676
79	Fetus and newborn affected by certain maternal conditions	P00, P04	760, 763.5
80	Fetus and newborn affected by obstetric complications and birth trauma	P01-P03, P10-P15	761-763.4, 763.6-763.9, 767
81	Slow fetal growth, fetal malnutrition, short gestation and birth weight	P05, P07	764-765
82	Respiratory disorders specific to the perinatal period	P20-P28	768-770
83	Hemorrhagic and hematological disorders of fetus and newborn	P50-P61	772-774, 776

List No.	Cause	ICD-10 Codes	ICD-9 Codes
84	Infections specific to the perinatal period	P35-P39	771.0-771.2, 771.4-771.8
85	Necrotizing enterocolitis of fetus and newborn	P77	777,5
86	All other conditions originating in the perinatal period	P08, P29, P70-P74, P76, P78-P96	766, 775, 777.1-777.4, 777.6-779
87	Congenital malformations of the circulatory system	Q20-Q28	745-747
88	All other congenital malformations, deformations and abnormalities	Q00-Q18, Q30-Q99	740-744, 748-759
89	Ill-defined signs, symptoms and conditions	R00-R99	780.0-780.4, 780.6-787, 788.1-799, 427.5
90	Motor transport accidents and sequelae	V02-V04, V09.0, V09.2-V09.9, V12-V14, V19.0-19.2, V19.4-V19.6, V19.9, V20-V79, V80.3-V80.5, V81.0-V81.1, V82.0-V82.1, V83-V86, V87.0-V87.8, V88.0-V88.8, V89.0, V89.2, V89.9, Y85.0	E810-E825, E929.0
91	Other land transport accidents	V01, V05-V06, V09.1, V10-11, V15-V18, V19.3, V19.8, V80.0-V80.2, V80.6-V80.9, V81.2-V81.9, V82.2-V82.9, V87.9, V88.9, V89.1, V89.3	E800-E807, E826-E829
92	All other transport and unspecified accidents and sequelae	V90-V99, Y85.9	E830-E848, E929.1
93	Falls	W00-W19	E880-E888

List No.	Cause	ICD-10 Codes	ICD-9 Codes
94	Accidents caused by firearm discharge	W32-W34	E922
95	Accidental drowning and submersion	W65-W74	E910
96	Other accidents that obstruct breathing	W75-W84	E911-E913
97	Exposure to electric current, radiation and extreme ambient air temperature and pressure	W85-W99	E925-E926
98	Exposure to smoke, fire and flames	X00-X09	E890-E899
99	Accidental poisoning by and exposure to noxious substances	X40-X49	E850-E869, E924.1
100	Intentional self-harm (suicide) and sequelae	X60-X84, Y87.0	E950-E959
101	Assault (homicide) and sequelae	X85-Y09, Y87.1	E960-E969
102	Events of undetermined intent and sequelae	Y10-Y34, Y87.2	E980-E989
103	Legal intervention and operations of war and sequelae	Y35-Y36, Y89.0-Y89.1	E970-E978, E990-E999
104	Complications of medical and surgical care and sequelae	Y40-Y84, Y88	E870-E879, E930-E949
105	Other accidents and sequelae	W20-W31, W35-W64, X10-X39, X50-X59, Y86, Y89.9	E900-E909, E914-E921, E923-E924.0, E924.8-E924.9, E927-E928, E929.2-E929.9

Source: DANE. Dirección de Censos y Demografía. Estadísticas vitales.

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