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Guidelines for interpreting verbal autopsy data

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Implementing verbal autopsy

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Acronyms

CDR	crude death rate
COD	cause of death
CRVS	civil registration and vital statistics
CSMF	cause-specific mortality fraction
DHS	Demographic and Health Survey
GBD	Global Burden of Disease
HDSS	health and demographic surveillance system
HIV/AIDS	human immunodeficiency virus/acquired immune deficiency syndrome
ICD-10	International Classification of Diseases, 10th revision
LMIC	low and middle-income country
MCCOD	medical certification of cause of death
NCD	non-communicable disease
PCVA	physician-certified verbal autopsy
PHMRC	Population Health Metrics Research Consortium
SDG	Sustainable Development Goal
SDI	Socio-Demographic Index
VA	verbal autopsy
WHO	World Health Organization

FIVE STEPS IN THE INTERPRETATION OF VA RESULTS (EXECUTIVE SUMMARY)

Verbal autopsy (VA) is the only practical alternative to the medical certification of cause of death (MCCOD) by a trained physician, and the subsequent coding of that death certificate by a trained coder. MCCOD represents the very best practice for countries to follow but, in many countries, physicians are not available to certify deaths and capacity for correct International Classification of Diseases coding is limited. In these cases, the information from VA can be of enormous value for informing public health policy by generating relevant and timely cause of death (COD) information for populations where no such information exists.

These guidelines provide five steps for users of VA to follow to help them interpret and present their VA data, and thus improve the VA's utility for public health decision-making.

Step 1: Understand the VA Population

The characteristics of the VA population are important to understand because they influence COD patterns in that population. Characteristics of the VA population include those related to geography, population age distribution, socioeconomic factors, epidemiological profile and proportion of deaths occurring in hospital with MCCOD. These characteristics of the VA population (and how similar they are to the general population) will affect how well the VA data represent this wider population.

Representativeness is important for two reasons. Firstly, it allows us to determine how applicable the cause-specific mortality fractions (CSMFs) from VAs are to the whole population – that is, it helps us understand the generalisability of the data. Secondly, it helps us to assess the plausibility of the CSMFs from VAs against comparator data, which may represent a different population. For example, deaths in populations with lower socioeconomic status are likely to be associated with more deaths from infectious and communicable diseases, higher maternal mortality and more injury deaths. This is partly because physical and financial access to healthcare facilities are limited, and partly because they have not received, or absorbed, health promotion messages. Conversely, wealthier populations are likely to have more deaths from non-communicable diseases (NCDs), typically at older ages, and to have lower levels of injury deaths, skewed towards motor vehicle accidents. A comprehensive understanding of the characteristics of the population from which the VA data have been collected (and of the comparator dataset) is essential to correctly interpret and evaluate the plausibility of the COD data. If the VA data under analysis have been selected using an appropriate sampling method as outlined in CRVS-VA Sample Size Calculator Guidance,[1] the need to assess the relative epidemiological and demographic characteristics of the VA area is less critical, since the sample is designed to represent the whole country.

Step 2: Estimate the completeness of VA death reporting

In addition to understanding the characteristics of the VA population and how well it represents mortality conditions in the country, the actual number of VAs that have been recorded will affect how the results should be interpreted. First, it is important to calculate the expected number of deaths in the VA population (from crude death rate [CDR]), and preferably how many of these will be children,

[1] University of Melbourne. *Sampling strategies for representative national CRVS verbal autopsy planning: A guidance document and sample size calculator tool*. Melbourne, Australia: University of Melbourne, Civil Registration and Vital Statistics Improvement, and Bloomberg Philanthropies Data for Health Initiative; 2018. Found at: https://crvsgateway.info/Implementing-verbal-autopsy~41

young adults and older people (e.g. deaths at ages 0–4 years, 5–64 years, ≥65 years).[2] From this knowledge, the completeness of capturing deaths in the VA population can be ascertained.[3] This serves two very important purposes:

- Comparing expected versus observed numbers of deaths can identify which areas require more intensive support and follow-up to capture all deaths in the target population.
- Informing how the data might be used. Low levels of completeness of VAs are likely to lead to significant bias in the information on CODs, since the unrecorded deaths might have a different COD structure (due to different characteristics of the unrecorded population).

This latter purpose is important to consider when interpreting the VA data.

Step 3: Assess the plausibility of the age–sex distribution of deaths from VA

The risk of death with increasing age varies in a predictable way, being high among infants, often rising in young males, due to injuries, and thereafter rising exponentially with advancing age. Population dynamics, defined by prevailing fertility and mortality rates, imply a larger population alive at younger than older ages. These two factors, namely the age-specific risk of death applied to (typically) decreasing population numbers at older ages, should result in a predictable age distribution of deaths in the population, which is closely related to the overall level of mortality. In populations where child mortality is low, more deaths can be expected at older ages. The converse is also true. Similarly, females typically experience lower risks of death at all ages than males, generally resulting in a more skewed (to the older ages) age distribution of deaths. In addition, since VA is generally only applied to community deaths, the age distribution of these deaths might be expected to be older than for the general population since preference for admission to hospital is often given to infants and younger adults suffering from acute conditions or accidents, with the age distribution of hospital deaths skewed accordingly towards younger ages. However, this may also reflect low completeness of death registration at younger ages for community deaths, which is a problem in many low to middle-income countries.[4,5]

Step 4: Conduct a plausibility analysis on the cause-specific mortality fractions from VA

4.1 Assess the plausibility of cause-specific mortality fractions from verbal autopsy

Epidemiological research has established predictable changes in the leading CODs at different stages of life. Communicable diseases such as diarrhoea, meningitis and pneumonia are most common among infants and young children; accidents, injuries, tuberculosis and HIV are major CODs among young adults. In older adults, major NCDs such as heart disease and stroke, cancer, chronic respiratory diseases and diabetes are the most likely CODs. The age pattern of CSMFs, or the distribution of leading CODs at each age, should reflect this epidemiological reality. The relative importance of CSMFs

[2] Estimates for countries can be found at the Global Burden of Disease Study 2017 results website (ghdx.healthdata.org/gbd-results-tool) and the UN World Population Prospects: The 2017 revision website (population.un.org/wpp/).

[3] Adair T, Lopez AD. Estimating the completeness of death registration: An empirical method. *PLoS ONE*. 2018; 13(5):e0197047.

[4] Vapattanawong P, Prasartkul P. Under-registration of deaths in Thailand in 2005–2006: Results of cross-matching data from two sources. *Bull World Health Organ.* 2011; 89(11):806-812.

[5] Garenne et al. Completeness of birth and death registration in a rural area of South Africa: The Agincourt health and demographic surveillance, 1992–2014. *Global Health Action*. 2016; 9(1):32795.

from various diseases and injuries at different ages should also be consistent with the extent of the epidemiological transition in a population. In countries where mortality is low, most deaths will occur among older people, mostly from NCDs, whereas communicable diseases and injuries will likely be substantially more important in higher mortality populations. The plausibility of the VA COD data can also be assessed by comparing them with other country-level data (e.g. hospital data, health and demographic surveillance system data), considering the known biases in all datasets that are being compared.

4.2 Assess the plausibility of verbal autopsy outputs in the context of risk factors and health determinants

Individual exposures or an individual's exposure to population characteristics that are likely to increase the risk of death are generally known as risk factors. Risk factors may be specific to a disease or injury or cause many disease and injury outcomes. Understanding the risk factors associated with, or present in, a population will help to assess the plausibility of the CSMFs. Example questions to be asked when interpreting CSMFs from VA are:

- Is HIV prevalence known to be high?
- Does the population live in a malaria-endemic zone?
- Is much of the population exposed to rivers, lakes or other large water bodies where drowning is more likely?

In other words, understanding the likely extent of exposure of the population to large, predictable causes of disease and injuries will help assess the plausibility of the disease and injury patterns that the VA data are suggesting for that population. For example, if smoking is prevalent in a population (and has been for the past 20–30 years), the CSMFs should be relatively high for causes for which smoking is a major risk factor, such as lung cancer, heart disease and chronic obstructive pulmonary disease. If more men in the population smoke and drink alcohol than women, then diseases precipitated by these risk factors should be a higher proportion of deaths for men than for women.

4.3 Calculate the extent and pattern of undetermined and residual causes of death

Since VA is a relatively blunt diagnostic procedure, it is reasonable to expect that the probable CODs will be difficult to determine if the reported pattern of symptoms experienced by the deceased is complex, confusing or poorly recalled by the family member responding to the VA interviewer. This is likely to be more common for deaths among older adults, who often experience several morbid conditions preceding death, making it difficult for VA to diagnose the most probable COD. In these cases, an undetermined COD is assigned. In other cases, poorly trained or unmotivated interviewers might not ask questions about symptoms in a manner that reduces ambiguity in responses, leading to the inability of diagnostic algorithms to identify the most probable COD. High fractions of undetermined CODs, typically more than 20 per cent or so, can significantly affect the interpretation of COD patterns from VA. This can suggest the need for improved training and supervision of interviewers, particularly if a significant number of the undetermined cases occur in children, young and middle-aged adults among whom the clinical course of disease or injury is generally less complicated and more obvious to detect.

Large residual causes or 'other' categories of disease are a consequence of the VA method, which can only reliably predict a limited number of causes. Public health action is typically focused on controlling

specific diseases or injuries (e.g. lung cancer, breast cancer, road traffic injuries). For COD data to be useful for monitoring and evaluating policy responses to these diseases or injuries, they need to be able to be separately identified in the COD data system of a country. Leading COD lists where 'other' or residual categories of diseases – such as 'other cancers', 'other CVDs' [cardiovascular diseases], 'other injuries' – are the most common outputs from a VA are likely to be less useful for informing public health action. The presence of such residual categories among VA output can increase uncertainty about the relative importance of specific conditions and, hence, significantly affect the value of the data for public health policy. Although VA cannot disaggregate these causes further, it is possible to estimate the probable composition of these residual categories using information from external sources such as hospital data or the Global Burden of Disease cause-specific estimates.

Step 5: Present the main findings of your VA data for policy action

Data need to be interpreted and communicated in ways that produce knowledge, which can then lead to informed decision and action. VA results need to be presented in a simple, concise and meaningful way for policy-makers to quickly grasp the messages and implement actions. A policy brief, and short PowerPoint presentation using simple graphics to highlight key messages and a short conclusion with recommendations will improve the policy value of the results. A more detailed report for technical audiences should also be produced, with feedback helping to improve methods and analysis for the future. Other stakeholders for VA, such as civil society and the media, might require more innovative approaches and the use of social media for dissemination.

Once data from VA and other mortality sources have been analysed separately, they need to be carefully integrated with other routine COD information to produce national population mortality statistics. If VA data are based on a representative sample (Step 1) and with high-enough levels of completeness (Step 2) to overcome concerns about any systematic biases in the data, VA data can be integrated with MCCOD data to, for example, inform national mortality monitoring strategies or progress towards the Sustainable Development Goals. When used appropriately, these data will assist governments to understand overall population mortality statistics for the country and put policies in place to address the major challenges to further health development in the country.

INTRODUCTION AND OVERVIEW OF VERBAL AUTOPSY IMPLEMENTATION APPROACHES

Reliable and representative mortality and cause of death (COD) statistics are essential to inform public health policy, respond to emerging health needs, and document progress towards nationally and internationally endorsed goals and targets such as the Sustainable Development Goals (SDGs) (Box 1). Yet, an estimated 62 per cent of all deaths are never officially registered and therefore remain invisible to health policy-makers.[6] In 2017, about 13 per cent of 195 countries had no COD data available and about 59 per cent of countries had less than 65 per cent of their CODs properly certified (see Figure 1).[7] This is because, in many low and middle-income countries (LMICs), deaths occur at home without someone present (usually a physician) who has the required training to determine the medical COD according to the World Health Organization's (WHO's) international standards.

The verbal autopsy (VA) method is proposed as an interim solution to fill the gap in COD data for policy-makers, by routinely applying the method to all (or some) community deaths that are registered or otherwise notified to government authorities.

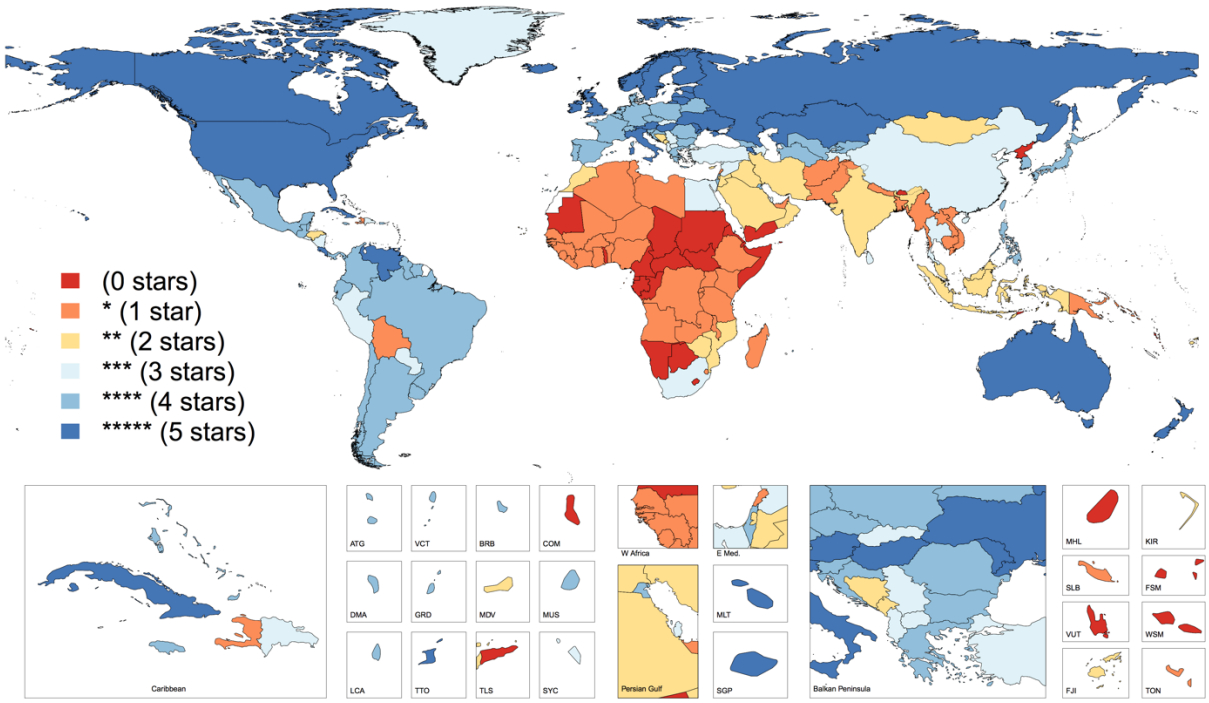
Box 1. Mortality data from verbal autopsy for monitoring the Sustainable Development Goals[8]
The UN Member States agreed to the Sustainable Development Goals (SDGs) as representing the direction of global development efforts between 2015 and 2030, and:

- Of the nine health-related goals, five are directly measured by mortality measures.
- Fourteen indicators specify cause-specific mortality.
- The SDGs require timely and continuing data series to enable comparisons over time.
- The SDGs call for data at national and subnational administrative levels.

The implementation of verbal autopsy methods can provide a unique source of information that governments and policy-makers can use to monitor progress towards achieving the SDGs. Importantly, there are advantages in using these methods, which rely on direct measurement of causes of death and require stakeholder collaboration, which ultimately strengthens country capacity.

[6] GBD 2017 Mortality Collaborators. Global, regional, and national age-sex specific mortality and life expectancy, 1950–2017: A systematic analysis for the Global Burden of Disease Study 2017. *The Lancet*. 2018; 392(10159):1684–1735.
[7] GBD 2017 Causes of Death Collaborators. Global, regional, and national age-sex specific mortality for 282 causes of death, in 195 countries and territories, 1980–2017: A systematic analysis for the Global Burden of Disease Study 2017. *The Lancet*. 2018; 392(10159):1736–1788.
[8] University of Melbourne. *CRVS systems matter for Sustainable Development Goal achievement*. CRVS development series. Melbourne, Australia: University of Melbourne, Civil Registration and Vital Statistics Improvement, and Bloomberg Philanthropies Data for Health Initiative; 2017.

Figure 1 Classification of national time series of vital registration and verbal autopsy data, 1980-2017, on the basis of the fraction of deaths well-certified and assigned a detailed Global Burden of Disease cause



Note: For Global Burden of Disease (GBD) 2017, a simple star-rating system from 0 to 5 was developed to give a picture of the quality of data available in a given country across the full-time series used in GBD estimates. Countries improve in the star rating as they increase availability, completeness and detail of their mortality data, and reduce the percentage of deaths coded to ill-defined garbage codes or highly aggregated causes. See Source for more details.
Source: GBD 2017 Causes of Death Collaborators[9]

VA has been developed so that it is now a practical and cost-effective way of determining CODs occurring outside hospitals or in health facilities with only limited diagnostic capability. VA is designed to generate COD distribution data (cause-specific mortality fractions, or CSMFs) that are meaningful at the population level.

The development of VA tools started in contexts – mostly rural – where available data on patterns of mortality were sparse and most deaths occurred outside health facilities and were not routinely medically certified. It has been widely used over many years in locations where longitudinal surveillance is done, such as health and demographic surveillance systems (HDSS) and has generated a rich source of statistics on emerging patterns of mortality and CODs around the world.[10] Continuous implementation of VA has spread from individual surveillance and research sites to representative sample areas in populous countries, including China, India and Indonesia. Although these VA applications have generated useful data on COD distributions, they were not (except China) generally linked in any way to official registration of deaths by the civil registration and vital statistics (CRVS) system.

The potential for VA to be routinely applied has been facilitated by electronic questionnaires on

[9] GBD 2017 Causes of Death Collaborators. Global, regional, and national age-sex specific mortality for 282 causes of death, in 195 countries and territories, 1980–2017: A systematic analysis for the Global Burden of Disease Study 2017. *The Lancet*. 2018; 392(10159):1736–1788.

[10] Sankoh O, P Byass. Cause-specific mortality at INDEPTH health and demographic surveillance system sites in Africa and Asia: Concluding synthesis. Global Health Action. 2014; 29(7):25590.

mobile devices and the development of computer algorithms to analyse responses and estimate probable COD with increasing accuracy. Several countries are now piloting the implementation of VA as part of efforts to strengthen country CRVS systems. In this scenario, VA is implemented alongside measures to strengthen notification and registration of death. The VA is linked to the notification of community deaths so that they can be officially registered and generate COD distribution data that can be used alongside other sources of mortality data to underpin public health policy and planning. This approach positions VA on a pathway towards the eventual goal of complete registration of deaths and medical certification of cause of death (MCCOD) for all deaths. Guidance is available on how to deal with the system-wide implications of introducing VA into existing health and CRVS systems.[11]

Routine use of VA in national CRVS systems is becoming more widespread, but many countries have not systematically developed the capacity to correctly interpret VA data. Therefore, this guidance document aims to help countries understand and interpret mortality and COD data generated from VA implemented routinely as part of health information, mortality surveillance and CRVS systems. Examples throughout this guidance document are not country-specific but have been developed based on experience with VA implementation in several countries under the Bloomberg Data for Health Initiative (D4H). The guidance describes techniques and approaches that can be used to contextualise and interpret the VA findings, assess their plausibility and present them in ways that are relevant and useful to country health-related policy-makers. The target audience includes data managers and analysts involved in country health information, and CRVS or related statistical systems. In particular, the guidance will be of interest to national mortality technical working groups that may have been established to support CRVS reforms in countries and are likely to be the primary users of the VA findings.[12]

Questionnaires and diagnostic algorithms for verbal autopsy

VA is a process for determining the probable COD based on responses collected, usually by a frontline health or community-based worker, from families and/or caregivers of the deceased.[13] VA comprises three main elements:

- A structured questionnaire to elicit information from the respondents on signs and symptoms experienced by the decedent before death, known as the verbal autopsy instrument (VAI).
- A method to diagnose the most probable COD based on the responses recorded in the VAI. Previously been done by physicians, referred to as physician-certified verbal autopsy (PCVA, automated algorithms are available to generate the probable COD.
- A target COD list, which includes all causes that can realistically be diagnosed from a brief VA interview with reasonable accuracy and that can be mapped to the International Classification of Diseases (currently in its 10th revision [ICD-10]), allowing for the VA-determined cause to be classified according to ICD.

The basic premise of VA is that:

- Each COD can be associated with an established pattern of clinical characteristics defined by

[11] De Savigny D et al. Integrating community-based verbal autopsy into civil registration and vital statistics (CRVS): System-level considerations. *Global Health Action*. 2017; 10(1):1272882.

[12] In countries seeking to strengthen their CRVS system, technical committees focused on different aspects of CRVS and an overall national coordinating committee are recommended to ensure the various elements of CRVS are considered in national CRVS strengthening activities.

[13] World Health Organization. *Verbal autopsy standards: Ascertaining and attributing cause of death*. Geneva: WHO; 2007.

a distinct pattern of signs, symptoms, severity and duration.
- The symptoms can be recognised, remembered and reported on by lay respondents.
- It is possible to correctly diagnose deaths, based on the reported information, for all major diseases and injuries of public health importance.

VA questionnaires have been designed to focus on three age groups – neonates, children and adults (+12 years old), defined by periods in life when the leading CODs are likely to change.[14] VA COD data should be interpreted for these age groups. In addition to the structured portion of the questionnaire, VA questionnaires include an 'open narrative'[15] and/or checklist,[16] which are used to capture extra information spontaneously offered by respondents about the period leading up to death, including any information they were told, or that was recorded, from contact with health services. This open narrative is usually asked at the end of the structured questions. Open narrative information (free-text verbatim narrative typed into the questionnaire) is critical for PCVA but may also be useful in a post-analysis of VAs that return an undetermined or residual COD (See Step 4.3).

There are two VA questionnaire options currently in widespread use to collect information from families (see Appendix 1 and websites for extra information):

- Population Health Metrics Research Consortium (PHMRC) shortened questionnaire or SmartVA questionnaire: www.healthdata.org/verbal-autopsy/tools
- WHO 2016 VA questionnaire: www.who.int/healthinfo/statistics/verbalautopsystandards/en/.

Both questionnaires map to cause lists that are compatible with ICD-10 and to that used in the Global Burden of Disease (GBD) Study.[17] The target cause lists differ in details (see Appendix 2 and 3), but both focus on major CODs of public health relevance, and both are likely to account for 80–90 per cent of CODs that in typically occur in LMICs.[18]

For VA to be used routinely and to generate CSMFs in a timely, standardised and cost-effective way, efficient ways of determining the COD based on the interviews are needed. Automated algorithms are consistent (results for a given VA will always produce the same results), low-cost, fast and reliable, and perform as well as, if not better than, PCVA.[19,20]

Currently, three automated diagnostic methods are available to diagnose the probable COD from a VA interview: Tariff, InterVA and InSilicoVA (see Appendix 4). For those using the WHO 2016 VAI, it is probable that using the three different diagnostic algorithms, will often produce two or even three discrepant results. Countries will then need to choose from among these possible diagnoses using the steps outlined in this guidance document to assess which algorithm is producing the most plausible

[14] The age group for adults in VA is ≥12 years due to the need to capture young maternal deaths.

[15] Available with WHO2016 VAI

[16] Available with SmartVA and WHO2016 VAIs

[17] GBD 2017 Causes of Death Collaborators. Global, regional, and national age-sex specific mortality for 282 causes of death, in 195 countries and territories, 1980–2017: A systematic analysis for the Global Burden of Disease Study 2017. *The Lancet*. 2018; 392(10159):1736–1788.

[18] Ibid

[19] Murray C et al. Using verbal autopsy to measure causes of death: The comparative performance of existing methods. *BMC Medicine*. 2014; 12:5.

[20] Byass P et al. Comparing verbal autopsy cause of death findings as determined by physician coding and probabilistic modelling: A public health analysis of 54 000 deaths in Africa and Asia. *J Global Health*. 2015; 5(1):010402.

COD estimates.[21] This is not relevant for SmartVA, which applies a single diagnostic algorithm (Tariff) to assign the most probable COD.

Outputs from verbal autopsy

The most important policy-relevant outputs of VA are the numbers of deaths in the population due to various causes, expressed as a fraction of total deaths, or cause-specific mortality fractions (CSMFs), for a population. CSMFs measure the relative frequency of different CODs in a defined population. CSMFs should be determined separately for each sex and at least for broad age groups (e.g. neonates, under-fives, adolescents, younger adults and elderly) if there are insufficient cases for more detailed age tabulations (e.g. 5-year age groups). It is this information about the leading CODs within each age group that policy-makers need to determine health priorities and programs.

The diagnostic procedures used in VA are substantially different from those applied by physicians in hospitals and have much less clinical information available. As a result, VA can identify far fewer CODs than MCCOD by physicians and are organised into broader groups. Thus, whereas application of the ICD to hospital MCCOD can generate more than 3000 distinct CODs, the main VA tools currently available generate between 46 and 63 causes, although these are likely to be more than enough to determine public health priorities (see Appendixes 2 and 3). In addition, this VA-derived ICD-10 code is used for aggregation and interpretation purposes and represents a range of codes where the probable COD could be any one of these associated conditions. When considering VA data along with other mortality data, such as MCCOD information, it is important to be aware of these inherent statistical limitations that restrict analyses to broader disease categories of public health importance.

Interpreting verbal autopsies

Different applications of verbal autopsy

Originally developed by researchers as an instrument to determine CODs in rural and remote areas settings where most deaths occur in the community, VA has since been used in a variety of different contexts, including:

- For community deaths where the death was not attended by a physician and where no COD can be assigned
- To support improved determination of CODs in hospital settings when a patient is delivered to the hospital after death has occurred – sometimes referred to as dead on arrival (DOA) or brought in dead
- Where death occurs in a hospital and is certified by a physician but there is uncertainty regarding the accuracy of the underlying COD
- As an aid to physicians who need to certify a death for a person they have not seen or treated (see Appendix 5).

In this guidance document, we focus on the most common VA implementation approach – when VA is used to determine CODs in the community where there is little or no contact with health services and where there is generally no physician available to certify the COD. These guidelines are particularly

[21] Nichols EK et al. (2018) The WHO 2016 verbal autopsy instrument: An international standard suitable for automated analysis by InterVA, InSilicoVA, and Tariff 2.0. *PLOS Medicine*. 2018; 15(1):e1002486.

relevant to an emerging scenario in which VA is implemented as part of a broader CRVS strategy that includes:

- Strengthened notification practices, to ensure that all deaths are notified to the civil registrar
- Efforts to ensure that reliable COD information is available for both hospital and community deaths.

This comprehensive approach to CRVS reform is the model currently being introduced in several Bloomberg D4H countries.[22]

Sampling for verbal autopsy

The methods by which VA deaths are selected is critical to the interpretation of the VA COD results.

In some instances, decision-makers will want to determine CODs among specific populations – for instance, those living in remote, hard-to-reach areas where there is little or no information on CODs from hospitals. In these circumstances, the COD pattern found using VA would not be expected to reflect COD patterns in the rest of the country.

More commonly, however, the aim is to generate nationally representative data on COD distributions in the population for health policy and planning purposes. In some settings, it may be feasible to apply VA to all deaths for which there is no MCCOD (most likely in small countries), but it is more usual and efficient to select a representative sample of deaths that will provide decision-makers with nationally relevant information on COD patterns.

A CRVS-VA Sample Size Calculator Guidance Document and Sample Size Calculator Tool is available to help decide on the most cost-effective and efficient method for selecting samples for VA.[23] In brief, sampling principles need to be applied in a pragmatic way to VA. It is logistically and operationally inefficient to do random VA sampling on individual deaths. Therefore, cluster sampling is recommended whereby the minimum cluster sample unit should be the catchment area of deaths that can be reached by a single trained and equipped VA interviewer. Larger cluster design units with larger populations and multiple VA interviewers working across the cluster are also possible. The Sample Size Calculator Guidance Document and Sample Size Calculator Tool covers decisions about the geographic disaggregation of the analysis that need to be made before implementing VA and describes how to draw a random sample of cluster units from an appropriately constructed sample frame.

It is generally recommended to conduct VA only on those deaths that occurred at home and for which no MCCOD is available. A possible exception might be to apply VA to all DOA cases in hospitals for which diagnostic accuracy of a COD could be poor.

It should be noted that the need to capture the *fact of death* for the whole population for notification and registration purposes remains. This information is the single most important aspect of mortality data that needs to be collected for all deaths. Therefore, whilst sampling is appropriate for population level cause of death assignment, it is not generally advised for collection of fact of information about deaths by age, sex and location.

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[22] Bangladesh, China, Ghana, Kenya, Myanmar, Rwanda, Solomon Islands, Sri Lanka and Tanzania

[23] University of Melbourne. *Sampling strategies for representative national CRVS verbal autopsy planning: A guidance document and sample size calculator tool*. Melbourne, Australia: University of Melbourne, Civil Registration and Vital Statistics Improvement, and Bloomberg Philanthropies Data for Health Initiative; 2018. Found at: https://crvsgateway.info/Implementing-verbal-autopsy~41

Stages of implementation

VA implementation is a considerable undertaking, especially if it is to be rolled out nationally. As such, there are several stages (Table 1) that will test different aspects of implementation before a country decides to institutionalise the approach.

Table 1 Pathways to scale: Phases of CRVS VA Implementation[24]

Phase	Purpose	Example	Scale
Pretest	To test technical issues	Adapting and testing technologies, instruments, translations	Local
Pilot	To test process issues	Developing training, supervision, communications, IT processes and investigating integration with CRVS and HMIS, initial costing, and SOPs	District
Demonstration	To test systems integration issues	Developing integration with CRVS and HMIS information systems. Ideally a full costing study and sampling strategy will be employed	Regional, emulating proposed national scenarios
Scaling up	To institutionalise VA	Rolling out to national or sub-national level	National sample

CRVS = civil registration and vital statistics; HMIS = health management information system; SOP = standard operating procedure; VA = verbal autopsy

The **pretest phase** focuses on understanding technical issues – such as if the questionnaire and the logistics of the VA implementation at a smaller scale are working. It is usually based on convenience in terms of the trial locations and would not represent locations outside this area. The **pilot phase** tests whether the VA processes will work in a defined area. It is concerned with logistics around implementation including the training, supervisory structure and IT considerations. This stage can capture obvious errors in the CSMFs arising from poor interview technique or language issues. The **demonstration phase** tests the method across a larger number of sites that – potentially, but not always – better represent the whole country. This stage tests system-level issues at a larger scale. There may several demonstration phases. The **scaling up phase** implies that the country has decided that the previous stages of VA implementation were successful and that there is a real benefit to institutionalising the VA implementation nationally. At this stage, a decision on whether VA will be done on all deaths or a representative sample will be made.

Although it is appropriate to interpret VA information at each stage except for the pretest, the stage of implementation needs to be considered. Since earlier stages reflect deaths that do not necessarily represent the whole country, comparisons with national data should be conducted with caution. In addition, there are degrees of uncertainty in CSMFs depending on the number of VAs available for analysis and this also needs to be considered when interpreting CSMFs at different stages of implementation (See Step 4.1).

[24] University of Melbourne. *Sampling strategies for representative national CRVS verbal autopsy planning: A guidance document and sample size calculator tool*. Melbourne, Australia: University of Melbourne, Civil Registration and Vital Statistics Improvement, and Bloomberg Philanthropies Data for Health Initiative; 2018. Found at: https://crvsgateway.info/Implementing-verbal-autopsy~41

Uncertainty around verbal autopsy data

VA can yield extremely useful information on the probable pattern of CODs in populations where access to health facilities is low or non-existent. However, the method is essentially a proxy for proper clinical diagnosis, and hence likely to be characterised by considerable uncertainty, especially when used to predict an individual's COD. VA data are designed to represent patterns of mortality at the population level, where the aggregation of individual causes will inevitably result in compensating errors. This is because the number of cases is fixed. Hence, each cause will benefit or suffer from diagnostic inflows and outflows that, in aggregate, tend to balance each other out and have far less impact on diagnostic accuracy than individual COD predictions from VA.

Sources of uncertainty for VA include:

- Tool-based uncertainty: All diagnostic algorithms quantify such uncertainty in CSMFs in different ways, either explicitly, through an 'undetermined' category or implicitly through the use of uncertainty intervals (Step 4 and Appendix 4). This is important to remember when interpreting small differences in the relative importance of different CODs.
- Measurement uncertainty: These sources of uncertainty relate to the quality of the VA interview, which will vary according to skills of the interviewer and the context of implementation, including health knowledge of the population and language spoken.
- Sampling uncertainty: Uncertainty also applies to how representative a selected VA sample is of the population it purports to represent. Such sampling uncertainty also contributes to the margin of error around CSMF distributions. The CRVS-VA Sample Size Calculator Guidance Document and Sample Size Calculator Tool can be used to determine the sampling uncertainty around the COD results from a particular sampling strategy. [25]
- Small number (stochastic) uncertainty: Erroneous CSMFs can be the result of small numbers, where unusual COD in a handful of cases will have a disproportionate effect on overall results (see Step 4.1).

These uncertainties do not invalidate the use of VA as a cost-effective way of generating COD information,[26] but must be considered when interpreting VA outputs, particularly when the sample size is small.[27]

Comparison data for the interpretation

To help assess plausibility, comparator datasets are used alongside the VA data. The appropriate comparator dataset will depend on the application of VA or the stage of implementation. For VA implementation using a method that produces a representative sample for the whole country, a national-level comparator dataset is appropriate. Where VA implementation is confined to specific locations, or for specific populations, other datasets (if available) may be more appropriate. The important thing to note when comparing data is how alike the populations are from the different datasets. This will reflect how alike we would expect the cause distribution from the various datasets to be.

[25] University of Melbourne. *Sampling strategies for representative national CRVS verbal autopsy planning: A guidance document and sample size calculator tool*. Melbourne, Australia: University of Melbourne, Civil Registration and Vital Statistics Improvement, and Bloomberg Philanthropies Data for Health Initiative; 2018. Found at: https://crvsgateway.info/Implementing-verbal-autopsy~41

[26] Joshi R et al. How much does a verbal autopsy based mortality surveillance system cost in rural India? *PLoS ONE*. 2015; 10(5):e0126410.

[27] Begg S et al. Design options for sample-based mortality surveillance. *Int J Epidemiol*. 2005; 34(5):1080-1087.

Available comparison data may include:

- Population statistics from the CRVS system
- COD information from MCCOD or health management information systems
- COD distributions from ongoing HDSS sites
- Morbidity data from hospitals that provide information on the diseases presenting at hospitals
- Specific mortality surveillance and program data such as from maternal/perinatal death notifications, and registries for cancers, malaria, HIV/AIDS and tuberculosis
- Periodic household surveys such as Demographic and Health Surveys (DHSs) or maternal mortality surveys.

In addition, the ongoing GBD Study provides country-level estimates and, for several countries, sub-national estimates, of the age distribution and CODs. This information uses all available sources of data in the country, and of the region as a whole, to calculate estimates of the most probable levels and patterns of mortality in more than 195 countries around the world. GBD data can be downloaded from the GHDx website[28] and is an important additional source of comparator information for assessing the plausibility of VA COD data, given the extensive application of demographic and epidemiological relationships applied in the GBD to predict probable COD patterns. As for all other data, a thorough review of the characteristics and provenance of the comparator datasets are needed before comparing or interpreting any information. To facilitate comparing the GBD data with VA outputs, the Annex of the CRVS-VA Sample Size Calculator Guidance Document and Sample Size Calculator Tool[29] includes a method for estimating national CSMFs from GBD data.

Countries should use locally generated comparative data wherever possible, provided there is confidence in their accuracy. Although the GBD estimates provide useful comparators against which to evaluate the plausibility of the VA findings, it is important to remember that they may be uncertain, given the generally poor state of knowledge and data about CODs in many countries. All significant discrepancies with the GBD should be carefully investigated, keeping in mind that local evidence may provide a more accurate and realistic account of current epidemiological patterns than the GBD in cases where the availability of data and information for the GBD estimates are limited.

Using these guidelines to assess the plausibility of verbal autopsy data

Deriving COD from VA as part of routine data collection to generate population-level mortality statistics on a large scale is a relatively new endeavour. As such, the plausibility of the COD results from VA should be systematically reviewed whenever VA is applied. This document outlines logical steps to take and comprehensive and practical guidance to those trying to interpret VA data. It draws on decades of research about the relationship between CSMF and demographic and epidemiological factors and introduces an innovative way to assess the plausibility of VA data. By applying the principles and techniques included in this guidance document, data analysts will gain a clearer understanding of their VA data and their relationship to comparator datasets. This analysis is a precursor to the development of COD statistics for the whole population – hospital and community – that will enable governments at various levels to develop evidence-based policies to benefit the health of their populations.

[28] ghdx.healthdata.org/gbd-2017

[29] University of Melbourne. *Sampling strategies for representative national CRVS verbal autopsy planning: A guidance document and sample size calculator tool*. Melbourne, Australia: University of Melbourne, Civil Registration and Vital Statistics Improvement, and Bloomberg Philanthropies Data for Health Initiative; 2018. Found at: https://crvsgateway.info/Implementing-verbal-autopsy~41

STEP 1: UNDERSTAND THE VERBAL AUTOPSY POPULATION

In most countries, verbal autopsies (VAs) will be collected from a subset of the national population. They will be collected in certain geographic areas of the population, typically small areas of enumeration such as sub-districts. Within these geographic areas, VAs are most likely to be collected for deaths that occur outside of hospitals. VA data should be analysed with a sound understanding of the area where VA is being implemented. It should be noted that this step is less important if a statistically representative cluster sampling strategy has been employed for selection of the VA population, because this population will be very similar to the national population. However, if a sample is used due to its convenience, then it is important to understand the context of the VA population relative to the national level, particularly if a national-level comparator dataset will be used for plausibility assessment of cause of death (COD).

The VA population characteristics[30] are important to understand because they influence the COD pattern in that population. This is imperative for assessing the plausibility of VA data against a comparator dataset, such as national results from routine data sources, the Global Burden of Disease (GBD) Study or a health and demographic surveillance system (HDSS), which would be derived from a population whose characteristics may differ from the VA population. More generally, knowing the VA population characteristics will help to interpret VA results.

Step 1 describes how to understand the key aspects of the VA population relevant for interpreting the VA results, using the characteristics defined in Table 2.

Table 2 Parameters important for assessing representativeness of verbal autopsy population

Parameter	Importance of parameter for interpretation	Potential data sources
Geographic coverage	The geographic areas where VAs are collected, whether a statistically representative sample of the national or sub-national populations, or selected by convenience	Population censuses, national statistical office annual population estimates
Population age distribution	The population age distribution, which influences overall COD patterns (because the CSMFs of most diseases vary with age)	Population censuses, national statistical office annual population estimates, socioeconomic or Demographic and Health Surveys, the UN World Population Prospects,[31] GBD Studies[32]
Socioeconomic characteristics of the population	A population's economic resources, knowledge to prevent and treat diseases, and access to health facilities will all influence COD patterns	Population censuses, socioeconomic or Demographic and Health Surveys, national statistical data, surveillance reports
Epidemiological profile	Geographic areas will vary in the levels and patterns of mortality due to the prevalence of different types of diseases, which will affect the COD distribution	Demographic and Health Surveys, surveillance reports
Hospital deaths	The proportion of hospital deaths, where CODs will vary significantly from those that occur outside a facility	Annual health data, annual statistics reports

[30] It should be noted that there may be one or many VA implementation areas in a country, so this analysis may be conducted for all VA implementation areas combined, or for any level that VA data are aggregated.
[31] UN World Population Prospects: The 2017 revision (population.un.org/wpp/).
[32] Global Burden of Disease Study 2017 results (ghdx.healthdata.org/gbd-results-tool).

COD = cause of death; CSMF = cause-specific mortality fraction; GBD = Global Burden of Disease; VA = verbal autopsy

The characteristics in Table 2 can help explain the plausibility of VA results when compared with a comparator dataset. Although these characteristics will affect COD patterns, this effect will be greater for some causes than others. For example, certain infectious diseases, such as malaria and measles, or deaths from conflict can have a marked geographic variation within a country. Other causes such as major non-communicable diseases, including ischemic heart disease and stroke, are likely to be common CODs in most populations. However, when analysing cause-specific mortality fractions (CSMFs), a decline in deaths from one cause will need to offset deaths from another cause. So, if infectious diseases in one area comprise a lower fraction of deaths than another area, these will need to be offset by higher non-communicable disease or injury deaths, even if the risk of non-communicable disease or injury death is not any higher in the other area.

In addition, it is important to be explicit about which type of deaths VAs will be conducted on, as this may vary by country. For instance:

- Will VAs be conducted for deaths where the deceased was discharged from hospital shortly before death and for which hospital records may be sufficient to record a medical certification cause of death (MCCOD)?
- Will VAs be conducted for dead on arrival cases or do hospitals have alternative methods for assigning COD in these cases?
- Will police cases be included in VA deaths?

Such characteristics of VA deaths should be clear since it will affect the cause distribution of VA deaths.

Geographic coverage of verbal autopsy

The geographic coverage of VA will have a bearing on how representative the VA population is of the national population. Any presentation of VA data should include a description of how the VA population was chosen and its characteristics.

Where the goal of VA is to produce nationally representative COD distribution data, the VA population should be chosen to represent the national (or sub-national) population of interest using a sampling frame and statistical approach. A VA population chosen using a sampling frame aims to select population clusters that will produce results that are approximately representative of the national population and of sufficient number to provide confidence in small cause-specific mortality fraction (CSMF) estimates. The CRVS-VA Sample Size Calculator Tool assists users to define and select population clusters that provide CSMFs with a predetermined level of uncertainty for a given number of clusters and VAs.[33] The sampling design would be used by countries that have completed VA pretest, pilot and demonstration phases and are rolling out to national CRVS VA implementation.

VA may also be applied to particular locations according to political realities, logistical convenience or for specific populations not currently accessible to physician certification. If VA implementation is still at the pretest or pilot phase, then a country may choose to first implement in certain locations because they are accessible and move to more representative areas in later roll-out phases. It is important that

[33] University of Melbourne. *Sampling strategies for representative national CRVS verbal autopsy planning: A guidance document and sample size calculator tool*. Melbourne, Australia: University of Melbourne, Civil Registration and Vital Statistics Improvement, and Bloomberg Philanthropies Data for Health Initiative; 2018. Found at: https://crvsgateway.info/Implementing-verbal-autopsy~41

data from the VA population chosen for convenience are not disregarded, as they can be used to improve data collection later. The CRVS-VA Sample Size Calculator Tool[34] has a mode that permits details of the convenience sample characteristics to be entered to estimate the potential uncertainty around the various levels of CSMFs that will be produced.

Geographic information systems software can be used to explore several geographical characteristics of interest for the VA population. For example, maps can be used to identify urban–rural populations, populations outside hospital catchment areas, remote or difficult to reach areas and disaster-prone areas.

Figure 2 shows the sample frame for VA implementation in Tanzania. A practical criterion applied to the sampling frame was the exclusion of 236 wards (highlighted in yellow) with population density of less than 15 people/km^2, which also accounted for 80 of the 83 biggest wards in terms of area. This makes sense regarding feasibility, as it would be challenging to implement VA in wards with a big area. However, it needs to be noted as a limitation of the sampling strategy, since CODs in these low-density areas may be different to those in other parts of the country.

Figure 2 Map showing sampling frame of VA implementation sites[35]

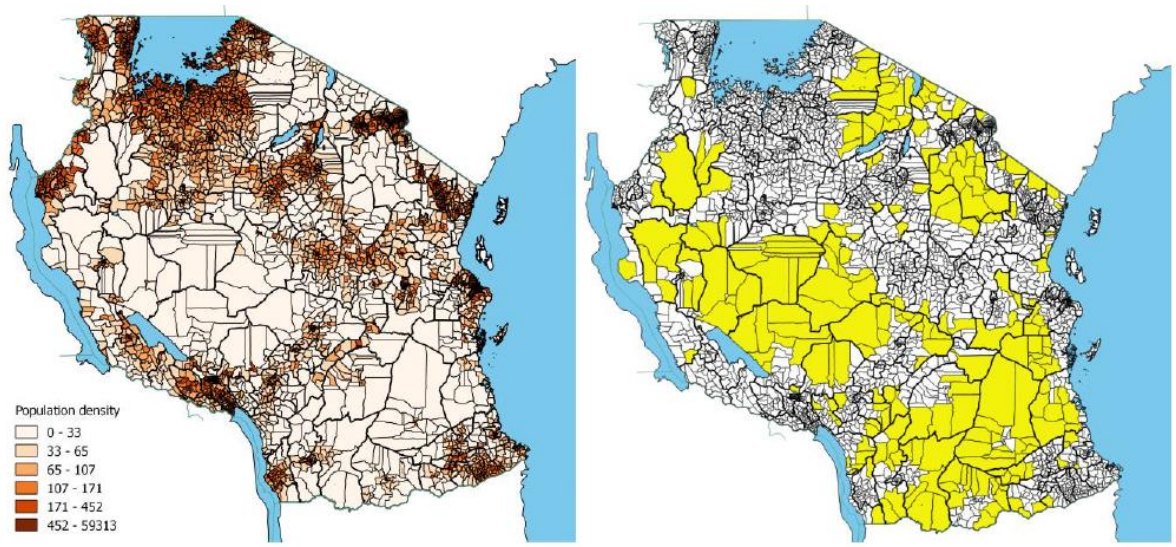


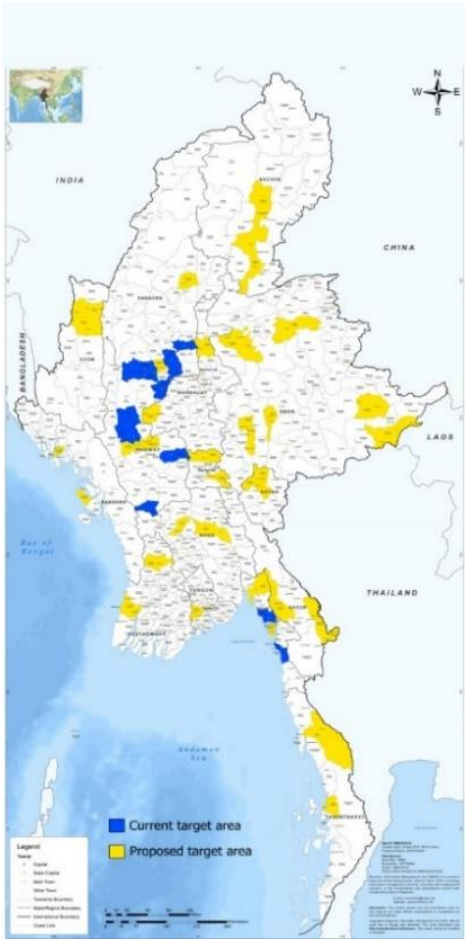
Figure 3 shows the townships targeted for the pilot (blue) and demonstration (yellow) phase in Myanmar. In the pilot phase, the townships were confined to three states chosen from three broad geographical regions of the country (north, central, south). In the demonstration phase, at least two townships from each state and region throughout the country were chosen using a two-level cluster sampling strategy. Although some logistical restrictions determined the final selection of townships in some states and regions, this strategy aims to demonstrate the feasibility of implementing VA activities in all parts of the country. Similar to Tanzania, the COD patterns in excluded townships may

[34] University of Melbourne. *Sampling strategies for representative national CRVS verbal autopsy planning: A guidance document and sample size calculator tool*. Melbourne, Australia: University of Melbourne, Civil Registration and Vital Statistics Improvement, and Bloomberg Philanthropies Data for Health Initiative; 2018. Found at: https://crvsgateway.info/Implementing-verbal-autopsy~41

[35] Ibid

be different to other parts of the country, which needs to be considered when assessing the generalisability of results.

Figure 3 Pilot and demonstration verbal autopsy implementation sites, Myanmar[36]



blue = pilot phase; yellow = demonstration phase

Age–sex distribution of the verbal autopsy population

The age–sex distribution of the population refers to the percentage of the population at each age and sex. This is important to understand for a VA population when comparing it with comparator data because population age distribution will influence the COD distribution in two ways. Firstly, the population age distribution heavily influences the distribution of death by age and sex (see Step 3), because the risk of dying is strongly associated with age. The age–sex distribution of deaths will then influence the leading CODs within a population because the likelihood of dying from a specific COD varies by age and sex of the decedent. For example, in an older population, we expect that a higher proportion of the population would die at old ages than in a younger population. A higher proportion of deaths at older age will imply more deaths from non-communicable diseases than in a population with a younger age distribution of deaths. An understanding of the population age distribution is therefore imperative in interpreting COD data.

[36] D4H Evaluation meeting, Myanmar, July 2017

Secondly, and more indirectly, a population with an older age distribution typically has a higher overall socioeconomic status than a younger population. An older age distribution is caused by lower fertility and mortality resulting from factors such as improved child survival, urbanisation and increased female education, which in turn are generally associated with a wealthier population. Thus, a population's COD distribution is related to socioeconomic status. The move from a younger to an older population is described as the Demographic transition (Box 2).

Box 2 Demographic transition

The **demographic transition** describes the process of declining birth and mortality rates that has occurred in most countries over a long period of time, and which has led to progressively older age distribution of the population. More traditional societies have a younger population because of high birth rates and high child mortality rates. Over time, declining birth rates gradually reduce the proportionate size of each successively younger generation to older generations, and declining mortality rates cause people to live longer, resulting in an older population age distribution. The demographic transition is not only useful for assessing population change in a particular country or sub-national area over time, but also for comparing different populations in the present day that are at different stages of the transition.

A population pyramid visually represents the age–sex distribution of a population. A population pyramid presents the percentage of all deaths for each five-year age group and sex. Population data for five-year age groups and each sex should be available for a VA population from a national statistics office from the latest population census. Some national statistics offices will also estimate the population (either total numbers or by age and sex) every year, based on assumptions of fertility, mortality and migration rates using demographic models. The UN World Population Prospects[37] and the GBD Study[38] also estimate the population of each country by age and sex each year. Appendix 6 describes a simple approach to estimate population data by age and sex if they are not available for a VA implementation area for a particular year.

The **percentage of the population aged 65 years and over** is a summary measure of population age distribution. This is useful to quantify the relative age distribution of each population.

Figures 4-6 are examples of the population pyramid for a VA population and the national population. They show that the population age–sex distribution of VA population 1 (Figure 5) is broadly similar to the national population (Figure 4). Although the VA population age groups 0–14 years has a different proportion of the population than the national population, this is not a common pattern. Such differences in individual age groups can occur in a VA population with a relatively small population. It is more important to compare the overall age pattern of the two populations, which is similar. For VA population 1 (Figure 5), there is no reason to suggest that the population age distribution is sufficiently different from the national population to influence COD patterns, especially as the percentage of the population aged 65 years and over is very similar. However, VA population 2 (Figure 6) has a much older population than the national level. Ten per cent of its population is aged 65 years and over compared with just 4 per cent at the national level. VA implementation area 2 would have an older

[37] UN World Population Prospects: The 2017 revision (population.un.org/wpp/).

[38] GBD 2017 Mortality Collaborators. Global, regional, and national age-sex specific mortality and life expectancy, 1950–2017: A systematic analysis for the Global Burden of Disease Study 2017. *The Lancet*. 2018; 392(10159):1684–1735.

age distribution of deaths than the national population and, very likely, a higher level of socioeconomic status, and therefore have a higher proportion of deaths from non-communicable diseases.

Figure 4 Example population pyramid for a national population (4% population aged 65+)

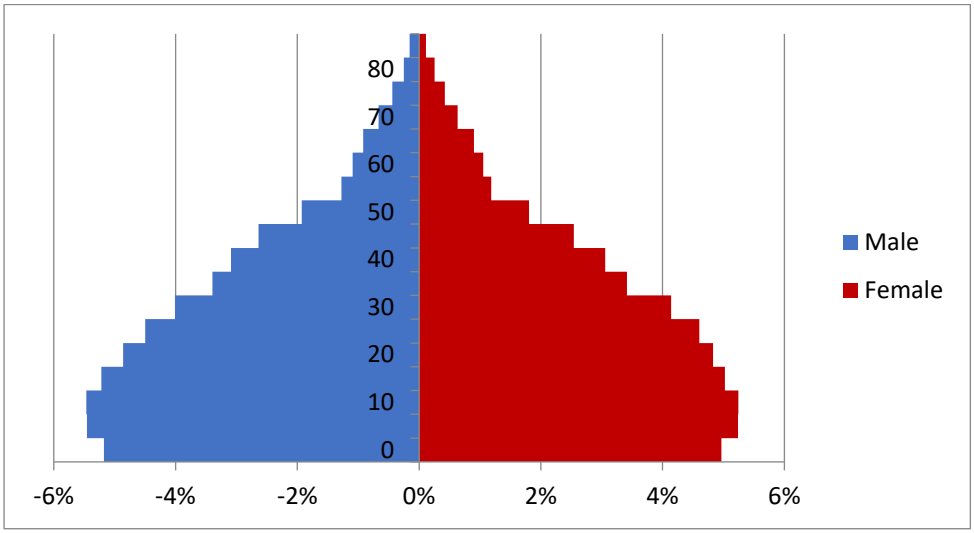


Figure 5 Example population pyramid for verbal autopsy population 1 (5% population aged 65+)

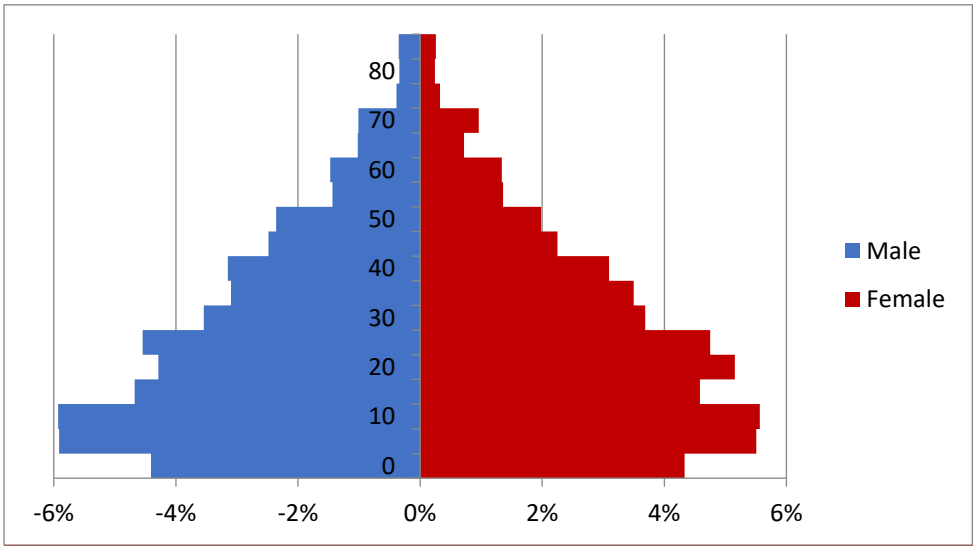
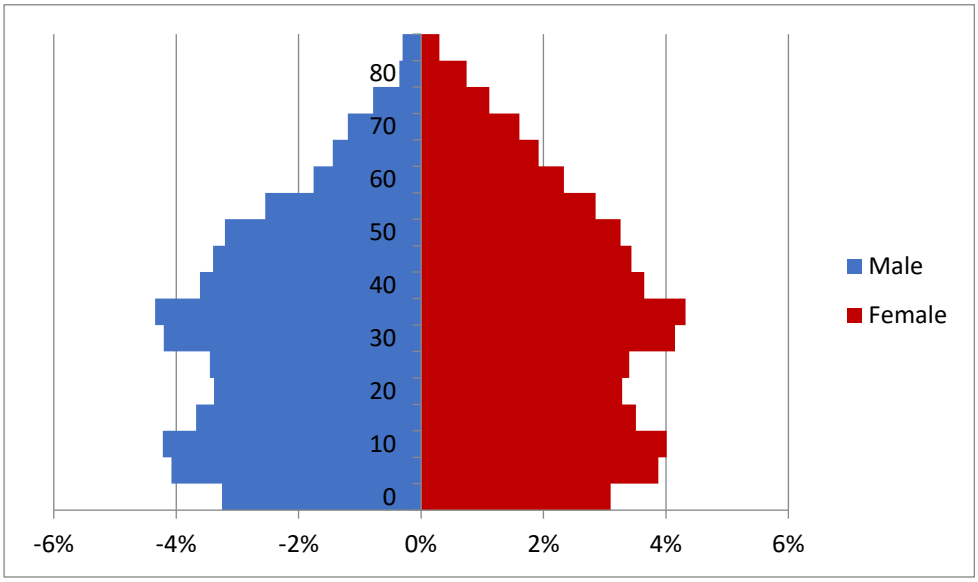


Figure 6 Example population pyramid for verbal autopsy population 2 (10% population aged 65+)



It is worth noting that, at sub-national areas, the population age distribution can be strongly influenced by internal migration, for example, a sub-national area with a high number of younger male migrants where mining is a prominent industry of employment. In such cases, the age distribution of the population may not have a strong relationship with the COD pattern in that population because of an unusually high proportion of people at ages where death rates are low.

Socioeconomic status of the VA population

Differences in socioeconomic factors are related to the health of populations. Socioeconomic characteristics of the population reflect the population's economic resources and knowledge to prevent and treat diseases, as well as their access to health facilities. If the VA population has different socioeconomic characteristics to other parts of the country, you would expect patterns of disease to be different.

There are some key differences in the patterns of CODs according to socioeconomic status of a population. Some examples are presented for countries at different levels of the Socio-Demographic Index (SDI). GBD researchers developed this index to measure a country based on its average income per person, educational attainment and total fertility rate.[39] Each country is classified into one of five levels: high, high–middle, middle, low–middle and low. These examples are presented as CSMFs, which show the proportion of deaths for each cause group. These reflect progress along the epidemiologic transition[40] – that is, high SDI countries are furthest along this transition.

Figures 7-9 show typical relationships between the CSMFs at each age and SDI level for broad disease groups I, II and III.[41] Perhaps the most important cause to assess is Group I (communicable disease), which is inversely related to the SDI level. In many age groups, the CSMF for Group I of low SDI countries is five times higher than high SDI countries. This relationship would be most apparent when

[39] Global Burden of Disease Study 2015. *Global Burden of Disease Study 2015 (GBD 2015) Socio-Demographic Index (SDI) 1980–2015*. Seattle: Institute for Health Metrics and Evaluation; 2016.

[40] The epidemiologic transition refers to a transition from high mortality due to infectious, maternal, neonatal and nutritional conditions, to those due to non-communicable diseases (associated with older age).

[41] The Global Burden of Disease Study provides a broad classification of cause of death according to three groups: Group I – Communicable, maternal, neonatal and nutritional; Group II – Non-communicable; Group III – Injury.

comparing VA data from populations with a much lower socioeconomic status than the national level. The higher Group I CSMFs in low SDI countries are offset by lower Group II and Group III CSMFs compared with high SDI countries. HIV/AIDS is a notable exception, which commonly has a greater impact on people in urban areas and of higher socioeconomic status than the rest of the population. Noticeably, injury CSMFs are particularly high in high SDI countries in young adulthood because there are fewer competing CODs, such as HIV/AIDS and other Group I causes. The CSMFs for Groups I, II and III (for each SDI category) should always total 100 per cent.

The United Nations Human Development Index is another composite index of development and measures average achievement in three basic dimensions of human development – a long and healthy life, knowledge and a decent standard of living. This measure is available at the national and sub-national level. [42]

[42] UN Human Development Index (hdr.undp.org/en/content/human-development-index-hdi)

Figure 7 Cause-specific mortality fractions, by Group I and level of Socio-Demographic Index (SDI)

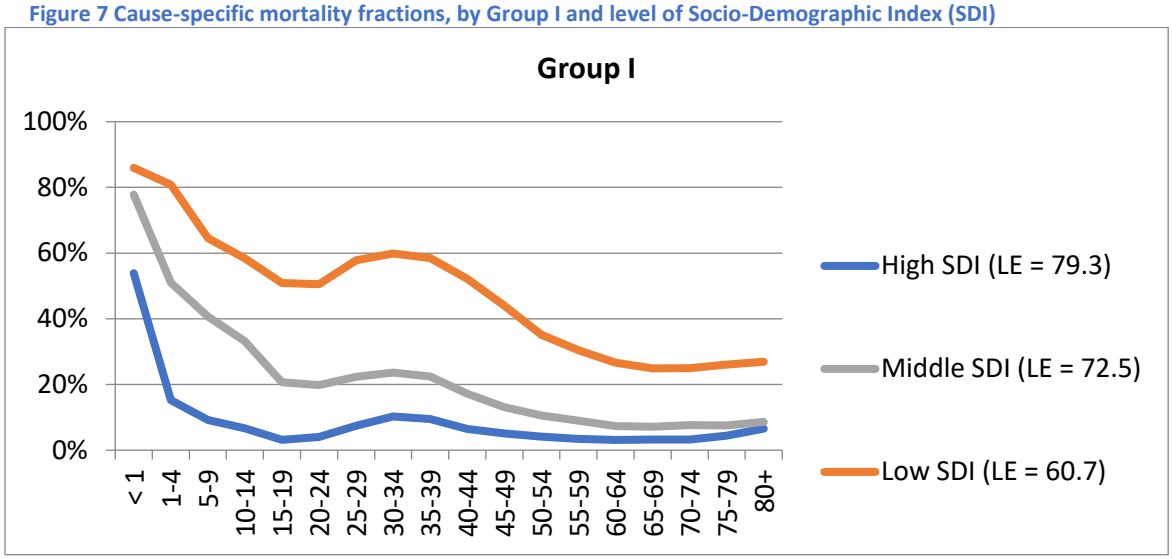


Figure 8 Cause-specific mortality fractions, by Group II and level of Socio-Demographic Index (SDI)

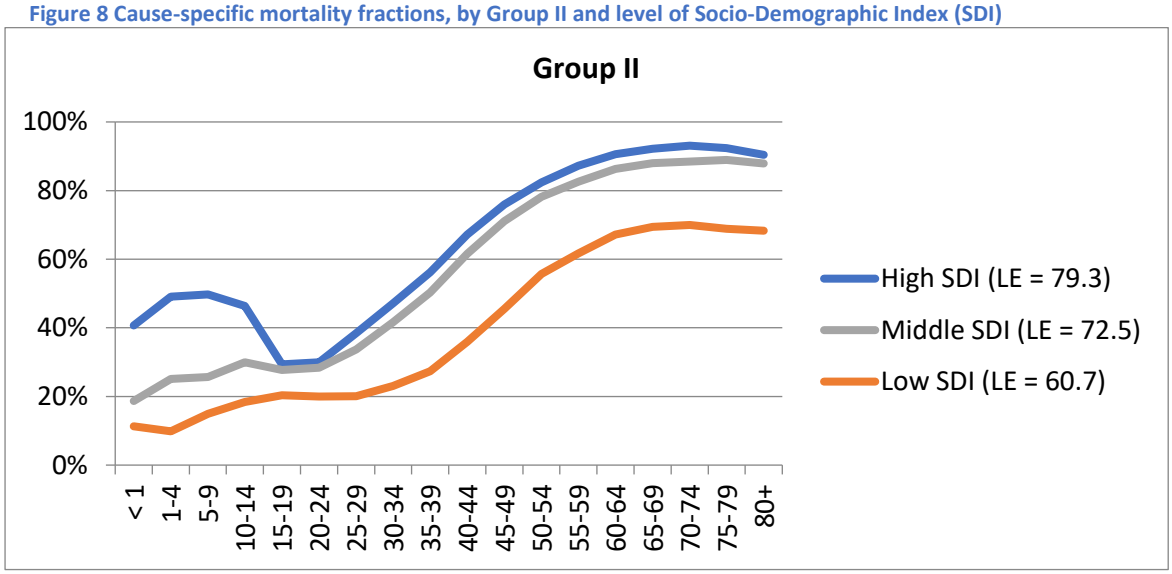
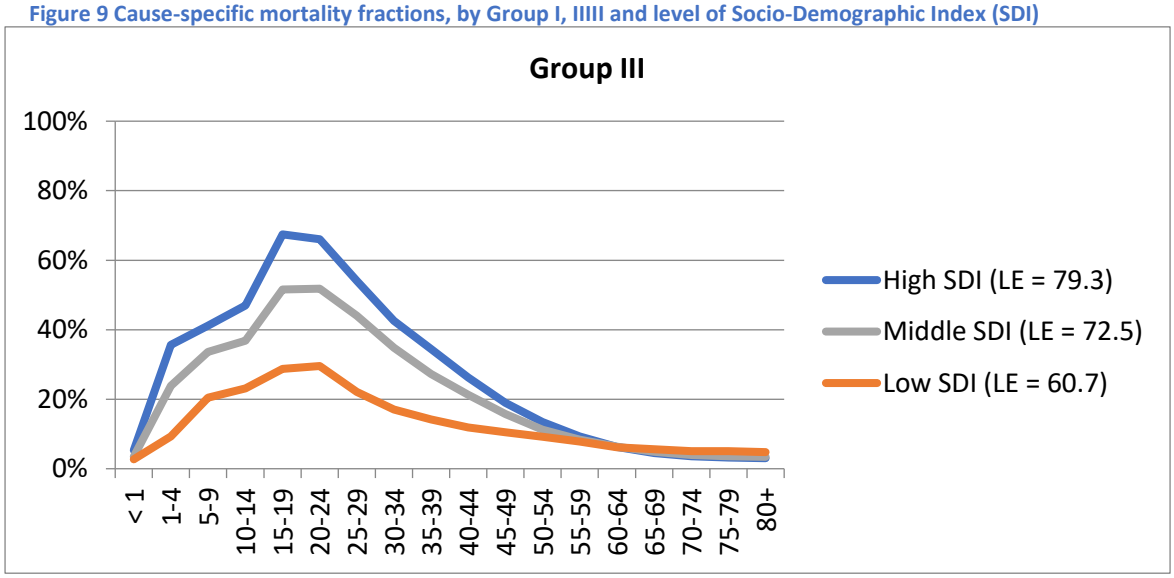


Figure 9 Cause-specific mortality fractions, by Group I, IIIII and level of Socio-Demographic Index (SDI)



LE = life expectancy
Source: Global Burden of Disease Study 2017 results website (ghdx.healthdata.org/gbd-results-tool).

There are many ways to measure the socioeconomic characteristics of a population. Measures need to be readily available at lower administrative levels and also be easy to compare across different populations. Two useful socioeconomic characteristics that can be used to compare the VA population to the national level of a comparator population are:

- **Percentage of the population living in urban areas.** Typically, CODs are related to urbanisation (e.g. more urbanised areas have a higher percentage of deaths from non-communicable diseases than rural areas). An urban population is more likely to have access to health services than rural areas. All population censuses should have these data available at lower administrative levels. This indicator may be susceptible to rapid change in areas on the fringes of large cities, so recent data should be used in such populations, if possible.
- **Percentage of the population that have finished secondary school for a specific age group.** CODs are commonly related to the level of education of a population (e.g. the percentage of deaths from non-communicable diseases typically increases with level of education). The percentage of the population who have completed secondary school should only be measured for a specific age group above age 20 years (e.g. 20–24 years, 30–34 years) because increasing education levels can bias results if a broader age group is used. This indicator should be readily available from the most recent census or a Demographic and Health Survey (DHS).[43] This indicator typically does not change rapidly unless a population has high levels of migration, so it can accurately describe the education status of the population even if the most recent census was 5–10 years ago. An alternative education indicator would be to use the percentage of the adult population who are literate; however, this should not be used for a country with at least 90 per cent literacy, as this indicator would not sufficiently distinguish populations by education level.

Table 3 is an example of demographic and socioeconomic indicators in a VA population and at the national level. Although the VA population has an older population age structure than the national level, it has a less urbanised and less educated population. The VA population can be described as having a somewhat lower socioeconomic status than the national level. This is useful background information when interpreting VA data from this area and may contribute to any differences in COD patterns compared with the national level, as well as to other characteristics of the VA population.

Table 3 Example demographic and socioeconomic indicators, verbal autopsy population and national

Indicator	Verbal autopsy population	National level
Population in urban areas	12.0%	30.0%
Population aged 25–29 that have finished secondary education	28.0%	38.0%
Population aged 65+	7.6%	5.8%

[43] DHSs are generally not reliable below the province or region level. It may be necessary to use information for the whole region as a proxy for lower administrative levels such as districts.

Countries may wish to use other indicators of socioeconomic status that may be particularly relevant to the country or for which reliable data are available. Some countries' national statistical offices may have a socioeconomic index for each sub-national area that has been developed from a range of indicators, such as education, employment, income, wealth and poverty. Other data such as household wealth may be reliably measured, and thus be a useful socioeconomic indicator.

Epidemiological profile of the verbal autopsy population

The use of COD results in a VA population needs to be undertaken with an understanding of its epidemiological profile. The level of mortality, the prevalence of different diseases and risk factors associated with certain diseases will affect COD patterns in a population.

The following information can be used to understand a VA population's epidemiological profile and to compare with the national level of other comparator population:

- **Under-five mortality or 5q0 (probability of dying from live birth to five years of age).** This is a valuable summary measure of a population's mortality level that is commonly available at the sub-national level. Sources of data include DHS and population censuses. DHS 5q0 estimates are derived from detailed retrospective birth histories; however, they may only be available at relatively high administrative levels, reference the 10-year period prior to the survey[44] and be subject to sampling uncertainty because the DHS is a sample survey. Where more than one DHS is available in a country, it is advisable to average the 5q0 in multiple DHSs and compare them with the average national 5q0. Under-five mortality estimates from a census are based on less detailed birth histories than a DHS but are more reliable for lower levels of administration. Census publications should include 5q0 estimates at lower levels of enumeration.
- **Evidence on disease prevalence.** National or provincial government health offices may have data on disease prevalence for a particular area – for example, if an area has a high rate of malaria or other infectious disease. These data will help to understand the COD profile of a population and how it may differ from the national level. Diseases most likely to differ by geographic area include infectious diseases such as HIV/AIDS, malaria, tuberculosis and measles, as well as causes influenced by the local environment, such as drowning.
- **Evidence on risk factor prevalence.** Data on risk factor prevalence are commonly available from the DHS or other national health surveys. Intra-country variation in risk factor prevalence can provide insight into the likely COD distribution in a population. Risk factors may include smoking prevalence (which can influence, with a lag, lung cancer and chronic respiratory disease mortality), nutrition status and measures of antenatal and delivery care. Other risk factors include exposure to conflict or violence, which can be concentrated within specific areas (see Step 4.2).

[44] For national level 5q0, estimates will reference the 5 years before the survey.

Hospital deaths within the verbal autopsy population

One of the challenges when analysing VA data is that it is mostly conducted for deaths that occur outside of hospitals (i.e. community deaths). The rationale is that deaths in hospital will be certified by a physician and there is no need to perform a VA.[45] It is nonetheless important to understand the characteristics of hospital deaths within the VA population. The number of deaths that occur in hospitals is important to know, because it helps measure the completeness of VA deaths as a percentage of non-hospital deaths[46] (see Step 2). Additionally, knowledge of the COD profile of hospital deaths allows hospital and VA CODs to be integrated, which can inform CODs at the population level (see Step 5).

Understanding what constitutes a hospital death can be complicated. The definition usually includes all deaths that occur in a facility that can perform a MCCOD. It usually excludes deaths for which patients have received hospital care and are discharged shortly before death. In some cases, it may also exclude deaths that occur shortly before arrival at hospital (DOA) where a physician has not treated the patient and has not been able to give a preliminary diagnosis.

Hospital deaths are likely to differ significantly in both age distribution and CODs compared with VA deaths.[47] Hospital deaths tend to be more common among children (especially neonates) and younger adults of working age, and so typically have a younger age distribution (see Figure 10). Non-hospital deaths typically have an older age distribution, partly due to poor reporting of deaths at young ages and also because older people with terminal illnesses often prefer to die at home. As a result, CODs in hospitals tend to be more likely to be those at younger ages (e.g. neonatal causes, pneumonia) and those requiring more intensive care. Although injury deaths are common in hospitals, the immediate cause (e.g. head injury) rather than the underlying cause (road traffic accident) is often coded. VA may provide a more reliable source of deaths due to accidents.[48] VA deaths will also be more likely to capture non-communicable diseases.

The percentage of deaths in a population that occur in hospitals will vary by region. This will be important in determining how close VA data can be expected to concord with national CODs. If a VA population has a higher proportion of non-hospital deaths (or hospital deaths) to the general population of the country, then we might expect a different cause-specific death distribution (see also Step 3).

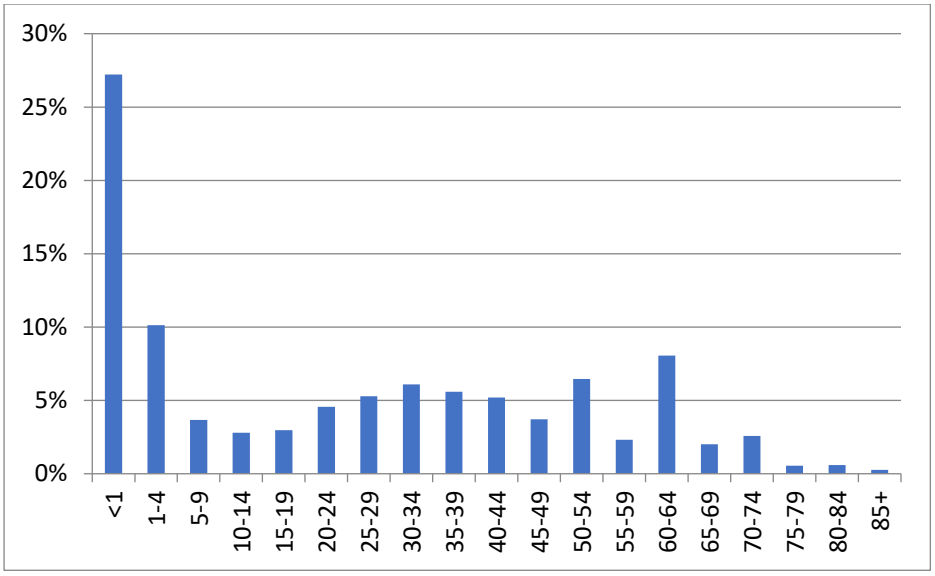
[45] Sometimes non-hospital deaths will be medially certified, especially for medico-legal cases.

[46] This may not be complete if data are only available for public facilities.

[47] Murray CJL et al. Estimating population cause-specific mortality fractions from in-hospital mortality: Validation of a new method. *PLoS Med*. 2007; 4(11):e326.

[48] Subject to the laws of the country. Since external causes are often classed as 'police cases', it may not be possible to use VA to collect COD information on these cases.

Figure 10 Typical age distribution of hospital deaths



Additionally, where hospital death data are available, these should only represent residents in the VA population. In locations with a large hospital that serves residents from a broad area, it is likely that some deaths in that hospital will be of non-residents. This may be difficult to do in practice, but, ideally, non-resident deaths should be excluded if comparing VA deaths with hospital deaths.

STEP 2: ESTIMATE THE COMPLETENESS OF DEATH REPORTING FOR VERBAL AUTOPSY DATA

Verbal autopsy (VA) data collection attempts to capture all deaths in the VA target population (either all deaths or all non-hospital deaths). However, this will probably not be the case, particularly in the early stages of VA collection, due to the lack of skills, training and procedures to ensure that all deaths are notified to the agency responsible for conducting VAs.

It is important to estimate the completeness of VA death reporting to improve confidence in the usefulness of the data for planning. Completeness of VA death reporting can be measured as the percentage of:

- **Total deaths** in a population that are captured by VA
- **Non-hospital deaths**[49] in a population that are captured by VA. If VAs are only collected on non-hospital deaths, then this indicator will be more relevant and useful.

There are two main reasons it is important to understand the completeness of VA death reporting. Firstly, it informs monitoring of the performance of the VA death reporting (notification) collection system. Low completeness of death reporting for VA indicates that the system is not capturing all deaths in the target population. The completeness of death reporting has been found to be the most important component of a mortality reporting system when determining the accuracy of cause-specific mortality fractions (CSMFs). [50] Where completeness is low, a concerted effort is needed to improve practices to capture these deaths.

Secondly, among the VA target population, the deaths without a VA are likely to have a different cause of death (COD) profile than those with a VA. Those deaths not captured by VA are likely to be in more remote areas and of more marginalised populations – characteristics associated with a higher proportion of deaths from infectious diseases. They may also be in more urbanised areas, where it can be difficult to find respondents at home during working hours and refusal rates can be high. Again, CODs in these areas may be different to those where completeness of VA death reporting is high.

Therefore, the less complete death reporting for VA is, the less likely the VA data will accurately represent the CODs among the VA target population. Although completeness of death reporting of VA between 90 and 95 per cent is unlikely to result in significant bias – and hence not cause for concern – completeness of death reporting of VA below about 60–70 per cent should be interpreted with caution.

Methods to estimate completeness

Conventional estimates to calculate completeness include death-distribution methods (e.g. Brass Growth Balance or Generalised Growth Balance methods) or capture–recapture (direct) methods. Such methods have several limitations, including inaccuracy, lack of timeliness, cost (direct methods) and significant data requirements. A relatively simple method to estimate the completeness of death reporting as a percentage of **all deaths** in a population has recently been developed.[51] This new

[49] This can be extended to include other deaths for which VA would not expect to be collected – for example, police cases. Definition of hospital deaths also need to be clarified (eg if dead on arrival cases are included).
[50] Phillips D et al. A composite metric for assessing data on mortality and causes of death: The vital statistics performance index. *Population Health Metrics*. 2014; 12:14.
[51] Adair T, Lopez AD. Estimating the completeness of death registration: An empirical method. *PLoS ONE*. 2018; 13(5):e0197047.

method, developed using empirical data from 110 countries in the Global Burden of Disease (GBD) Study, enables estimation of completeness of death reporting using only the following data:

- Number of VAs. For the completeness calculation, if VA are not from a 12-month period, they will need to be annualised. For example, if 1000 VAs were collected over 3 months (i.e. 3/12 months or 1/4), the number of VAs will need to be multiplied by the inverse of the fraction (i.e. 4) to get the annualised number of VAs (4000)
- Total population in the VA population, which should be the mid-year population
- Percentage of the population aged 65+ years
- An estimate of the under-five mortality rate for the VA population (number of deaths under five years of age per 1000 live births). National-level estimates can be obtained from the UN Inter-agency Group for Mortality Estimation (IGME)[52] or GBD.[53] Sub-national-level mortality rates can be obtained from DHS data or censuses; this should be scaled to the IGME or GBD estimate.[54] Some VA populations will have no under-five mortality estimate. In this case, an estimate from the next administrative level should be used (e.g. the state-level estimate used for the district).

The method can estimate completeness for males, females or both sexes combined. A worked example of estimating completeness of reporting of all deaths is in Appendix 7.

Knowledge about the level of completeness of death reporting is used to estimate the total number of **all deaths** in the VA population: the number of VAs divided by VA completeness (as a fraction).

To estimate the completeness of VAs as a percentage of non-hospital deaths, a few additional calculations are needed (see below and Box 3). This relies on the availability of the number of hospital deaths of residents of the VA population (see Step 1).

$$\frac{\text{VA deaths}}{\text{completeness (all deaths)}} = \text{estimated total deaths (1)}$$

$$\text{estimated total deaths} - \text{hospital deaths} = \text{non} - \text{hospital deaths (2)}$$

$$\frac{\text{VA deaths}}{\text{non}-\text{hospital deaths}} = \text{completeness (non} - \text{hospital) (3)}$$

Note: these calculations also provide the percentage of all deaths that occur in or out of hospitals.

[52] United Nations Inter-Agency for Group for Child Mortality Estimates (UNIGME). Child mortality estimates 2018. Retrieved from, http://www.childmortality.org

[53] Global Burden of Disease Study 2017 (GBD 2017) Results [Internet]. 2018. Available from: http://ghdx.healthdata.org/gbd-results-tool.

[54] The ratio of the sub-national to national under-five mortality rate would be multiplied by the IGME or GBD under-five mortality rate.

Box 3. Example of estimating the completeness of VAs as a percentage of non-hospital deaths

A province reports 300 VA deaths in 2017. The empirical completeness method calculates the completeness of death reporting for VA to be 65 per cent. That is, the deaths captured by VA comprise an estimated 65 per cent of all deaths in the province. Hospital data reveal that there were 70 deaths of residents of this province in 2017 that occurred in facilities. The following shows how the completeness of VAs as a percentage of non-hospital deaths is calculated:

$\frac{300}{0.65} = 461.5$ (1) (ie estimated total deaths in the province)

$461.5 - 70 = 391.5$ (2) (ie non-hospital deaths)

$\frac{300}{391.5} = 76.6\%$ (3) (ie completeness of non-hospital deaths)

Therefore, deaths captured by VA comprise an estimated 76.6 per cent of non-hospital deaths in this province. Also, hospital deaths comprise 15.2 per cent (70/461.5) of all deaths in the province.

This completeness method has some limitations. Firstly, as a measure of completeness of non-hospital deaths, all hospital deaths are assumed to be reported and the number of hospital deaths is assumed to be accurate. This is not always the case, and the degree to which hospital deaths are incomplete will affect the validity of this measure of non-hospital completeness of VA.[55] Secondly, the method does not perform well in populations with high mortality at adult ages relative to the level of child mortality, such as countries with high HIV/AIDS deaths. Finally, this method will not work well where the calculated crude death rate (CDR) for VA is <1 per 1000. In this case, comparing the VA CDR with the national-level CDR (described below) may be more informative of VA under-reporting.

If total deaths in your VA population is already known because death registration completeness is 100 per cent, then completeness of death reporting for VA can be calculated by dividing VA deaths by the registered deaths in the population. Completeness of non-hospital deaths can then be calculated with the denominator as total registered deaths minus hospital deaths.

An alternative to using the empirical completeness method is to calculate completeness as the VA CDR (number of VAs divided by population multiplied by 1000) divided by a national estimate of the CDR. The relevance of the national CDR to the VA population will depend on the level of mortality and population age distribution in the population (a higher level of mortality compared with the national level would result in a higher CDR, as would an older population age structure). This method would provide a very rough estimate and should be used with caution. If VAs are only collected for non-hospital deaths, then this estimate of completeness will need to estimate the percentage of all deaths that occur in facilities (e.g. if an estimated 20 per cent of deaths occur in facilities, then the national CDR should be multiplied by 0.8). An alternative is to compare the VA CDR with the CDR from a health and demographic surveillance system (HDSS). Such a comparison should consider the level of mortality and population age distribution in the HDSS site compared with the VA population.

[55] A method to calculate the completeness of hospital deaths is under development as of 2019.

STEP 3: ASSESS THE PLAUSIBILITY OF THE AGE–SEX DISTRIBUTION OF DEATH FROM VERBAL AUTOPSY

Steps 1 and 2 describe how verbal autopsy (VA) results may differ from national-level data due to characteristics of the VA population and completeness of VA data. We can now compare VA results to either a national-level dataset (including Global Burden of Disease [GBD] estimates) or another comparator to assess their plausibility and generalisability. This step introduces approaches to assess the plausibility and generalisability of the age–sex distribution of deaths from VAs. Step 4 deals with how to use these data and information to assess the plausibility and generalisability of the cause of death (COD) distribution from VA.

Plausibility refers to whether the age and sex distribution of VA deaths follow a pattern that we would expect based what is known about the socioeconomic and epidemiological situation of a country and typical mortality patterns from data worldwide. **Generalisability** refers to the extent that VA findings can be used as evidence to inform national-level (or other comparator) cause of death (COD) patterns. The rationale for looking at all-cause mortality is that the leading CODs differ across age groups and between males and females. For example, birth asphyxia is a leading cause of neonatal death, road traffic accidents are a leading COD of males aged in their 20s and ischemic heart disease is a leading COD among people aged in their 70s. Also, 'total deaths' is the denominator for cause-specific mortality fractions (CSMFs) that VA generates as an output and on which we will judge plausibility of CODs (see Step 4.1). Hence, it is important to understand the age distribution of deaths to more reliably interpret these CSMFs.

Mortality patterns of verbal autopsy data

The age–sex distribution of deaths is the percentage of total VA deaths that occur at each age–sex group. The distribution is expected to vary considerably depending on the proportion of the population at each age, as described in Step 1, and the overall level of mortality, which determines the risk of dying at each age. In this step, we:

- Assess the age–sex distribution of VA deaths
- Compare the age–sex distribution of VA deaths with a (usually national) comparator
- Compare age–sex distribution of VA deaths with hospital deaths.

A histogram can be used to represent the age–sex distribution of deaths (Figure 11). We would expect that, for each sex, the percentage of deaths will increase with age, except for a likely higher percentage of death among infants than other young child ages. Men should have a younger age distribution of deaths than women because, on average, they do not live as long and there are more women who live to the oldest ages. In fact, at 80+ it is not uncommon for there to be twice as many female than male deaths, simply because twice as many women as men survive to these ages.

It is a good idea to assess your COD distribution alongside your population pyramid (described in Step 1). Since the population age structure influences CODs, this can help us to assess the plausibility of our death distribution from VA. For example, a population pyramid that show an older population should have an older distribution of deaths.

Figure 11 Typical age–sex distribution of verbal autopsy deaths

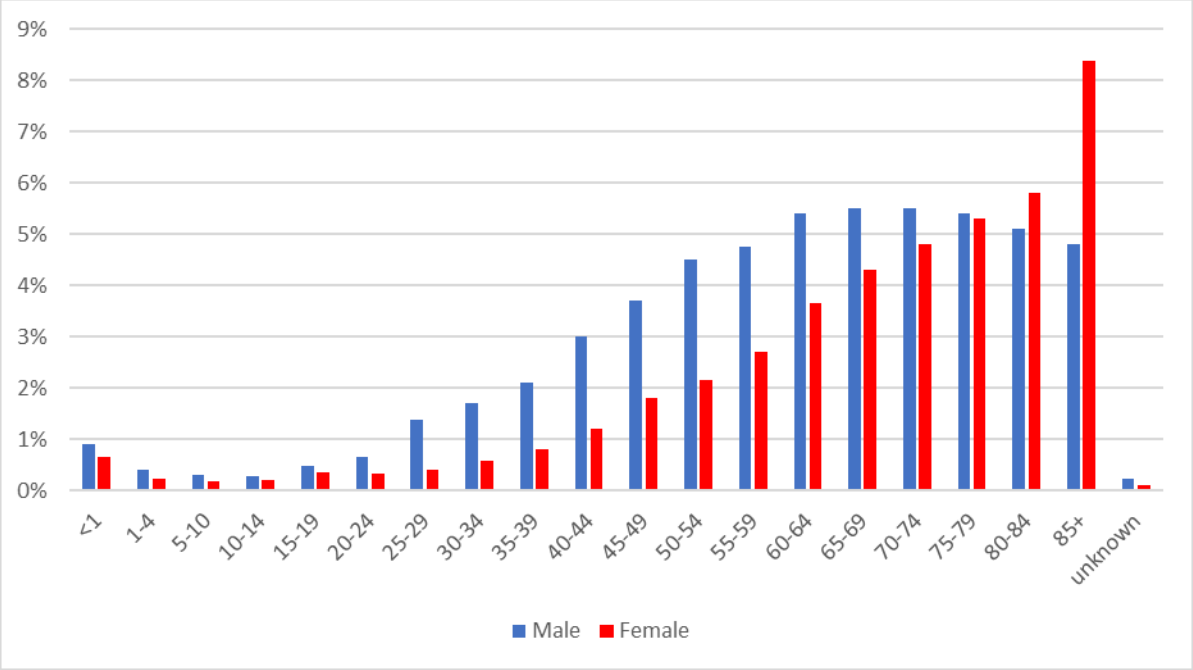


Figure 12 compares a typical age–sex distribution of VA deaths (in this case, limited to community deaths in a country) with GBD estimates (representing all deaths, including those in hospitals) for a country. We would expect that community deaths have an older age distribution than hospital deaths, and therefore all deaths, because acute cases of infection and injury tend to dominate hospital deaths, rather than non-communicable diseases. Younger children and adults incur these infectious diseases and injuries more than older people, who often go home to die once they are told the hospital can no longer help them. In this example, as expected, deaths at younger ages are under-represented in the VA data and those at older ages are over-represented compared with GBD estimates. Such information should be considered whenever CODs of these two datasets are compared, since older people die from different causes than younger people. GBD data are also estimates and are a guide for national-level patterns. If other good-quality, national-level data on age at death are available, they should also be used as the comparator, provided their quality (completeness, diagnostic accuracy) is known. For instance, it is often assumed that data from hospitals is of good quality. Even though, in principle, causes of hospital deaths should be reliably certified by a resident medical practitioner, this frequently is not the case.[56] Consider the results from steps 1 and 2 when comparing VA and hospital data, which may also explain differences between VA and GBD national-level results.

[56] Rampatige et al. Systematic review of statistics on causes of deaths in hospitals: Strengthening the evidence for policy-makers. *Bull WHO*. 2014; 92:807-816.

Figure 12 Typical age distribution of deaths, verbal autopsy (VA) vs Global Burden of Disease (GBD)

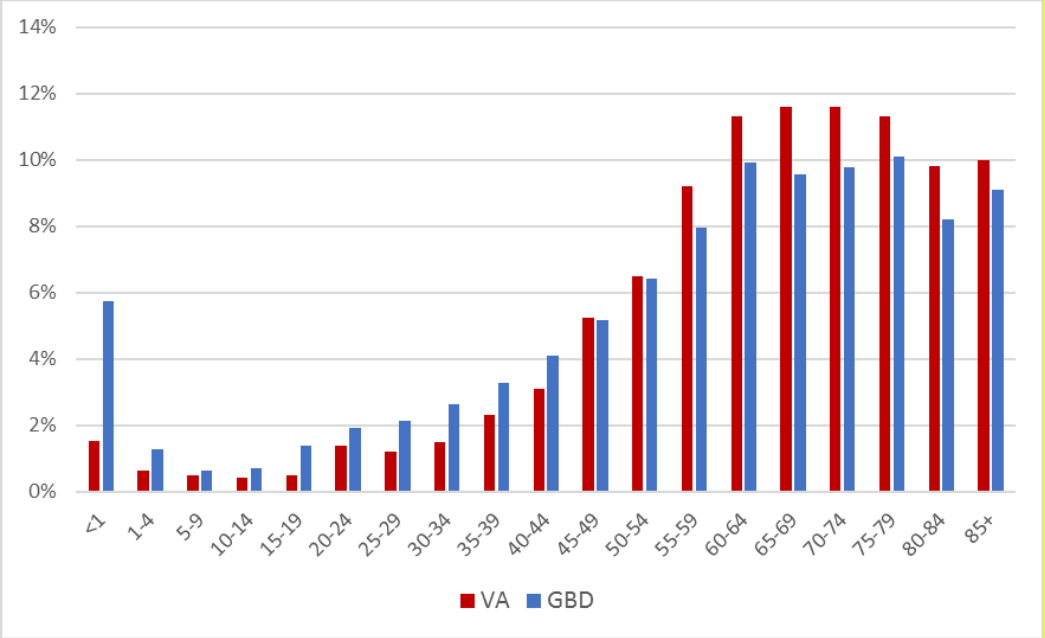
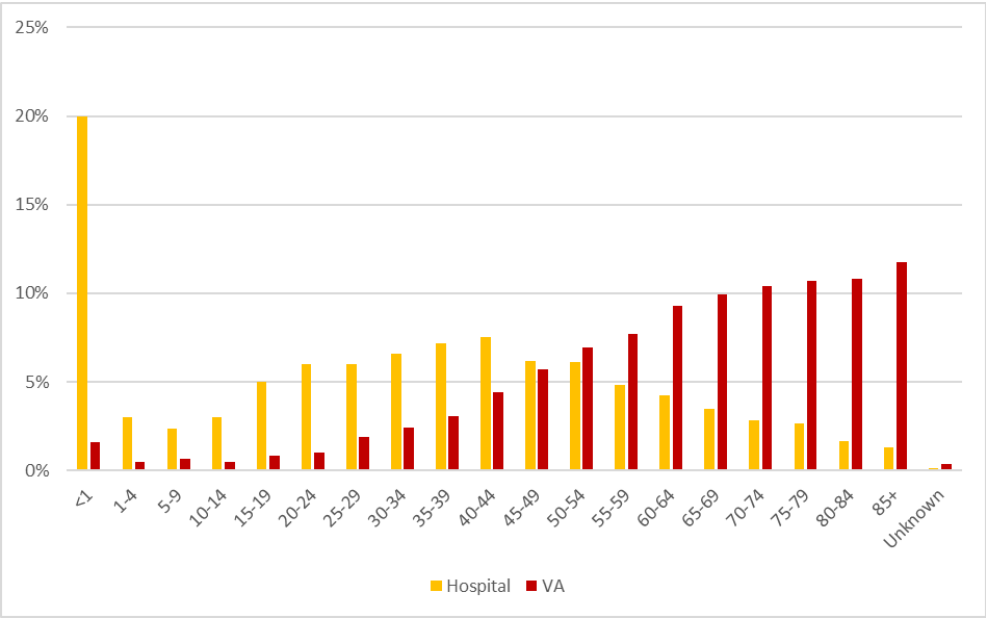


Figure 13 compares the age distribution of VA and hospital deaths. Here, the differences in age distribution between hospital and community deaths are more pronounced, with a much younger distribution in hospital than in the VA results. As mentioned in Step 1, you are likely to see fewer neonatal deaths in the community. This is due, in part, to the high proportion of facility-based delivery in many countries[57] and therefore neonates are more likely to die in hospital, and because community neonatal deaths are often not reported.

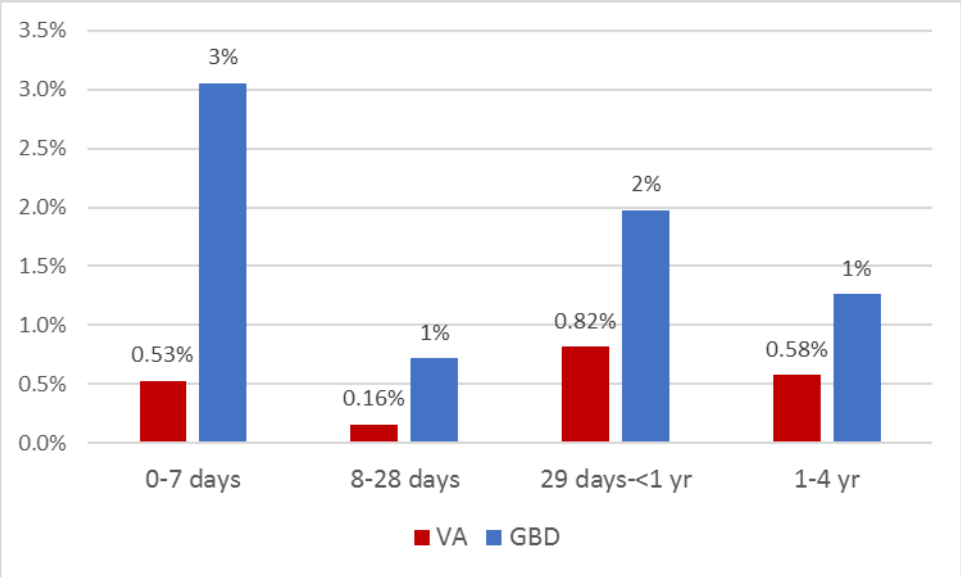
Figure 13 Typical age distribution of deaths, verbal autopsy (VA) vs hospital



[57] The proportion of neonatal deaths in hospital will be associated with the proportion of births that occur in hospital. In areas where facility delivery is low, differences in age distribution between hospital and community are likely to be due to underreporting of neonatal deaths in the community.

When judging the plausibility of VA data, it can be useful to disaggregate the age distribution of deaths of children under 5 years of age. Figure 14 is an example of comparing the distribution of VA under-five deaths with a national estimate from the GBD, which synthesises several existing sources of representative data on child mortality, including censuses and surveys. The national estimate has much higher proportion of under-five deaths in the first week of life, whereas the highest percentage of VA under-five deaths happen in the 29 days to <1 year age group. This likely reflects the greater under-reporting of child deaths in the very youngest age group compared with deaths of children who survive past their first birthday. It could also reflect the difference between community deaths versus all deaths (including hospital deaths).

Figure 14 Distribution of under-five deaths, verbal autopsy (VA) vs Global Burden of Disease (GBD)

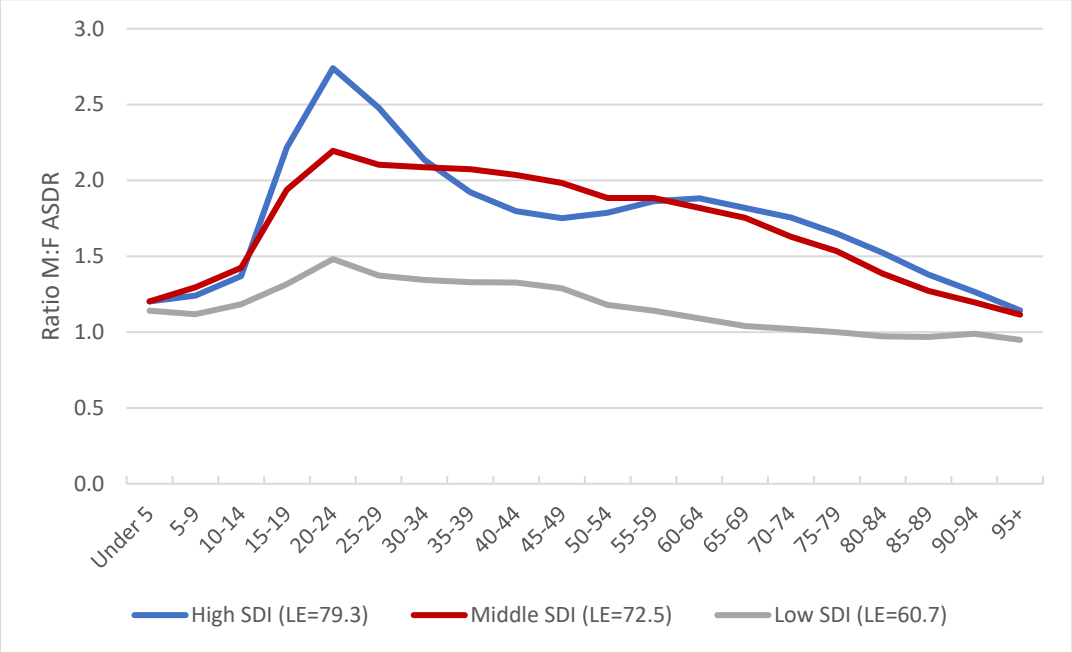


Ratio of male to female deaths at different ages

Epidemiological evidence from around the world consistently shows that men have higher death rates than women at almost all ages. The only exceptions are populations with high prevalence of HIV infection or high maternal mortality, where female mortality may exceed male mortality in some of the reproductive age groups, and populations where the low status of women and girls in society negatively affect their chances of survival. Higher death rates of males than females imply that the ratio of the male and female age-specific death rate (i.e., the male rate divided by the female rate at a certain age) exceeds 1 (see Box 4).

Typically, this ratio of death rates will peak somewhere in the 15–34 age groups because of higher male than female mortality associated with accidents, suicides and violence. A secondary, lower peak in the ratio is often seen around 55–64 years because more males than females tend to die from chronic diseases at those ages. This is particularly pronounced in societies where males have a much higher consumption of tobacco and alcohol than females. At older ages, the sex ratio of mortality approaches 1, but the risk of death generally continues to be higher for older men than older women. Figure 15 shows the typical pattern for the sex ratio of age-specific mortality rates by high, medium and low Socio-Demographic Index.

Figure 15 Sex ratio of age-specific mortality rates by age, and high, middle and low Socio-Demographic Index (SDI) countries



LE= life expectancy

Source: Global Burden of Disease Study 2017 results (ghdx.healthdata.org/gbd-results-tool).

Deviations from this typical age pattern of excess male mortality are possible but should be investigated for plausibility. In particular, a higher than expected male to female mortality ratio at any age is likely indicative of differential underreporting of female deaths. Since VA is generally conducted on community deaths rather than all deaths, the sex ratio may be lower than usual because some of the CODs that account for higher mortality in men, such as injuries, may not be well represented in the VA data.

Box 4. Calculating the sex ratio of age-specific mortality rates

To calculate the sex ratio of age-specific mortality rates (ASMRs), first divide the number of VA deaths in that age group by the population in that age group in the VA population separately for males and females to generate the ASMR. Then divide the ASMR for males by the ASMR for females to produce a ratio for each age group. Comparing your result with a graph such as the one in Figure 15 can help to identify unusual patterns.

STEP 4: CONDUCT A PLAUSIBILITY ANALYSIS ON THE CAUSE-SPECIFIC MORTALITY FRACTIONS FROM VERBAL AUTOPSY DATA

Step 4 helps to interpret the cause of death (COD) analysis from verbal autopsies (VAs). Firstly, the step shows you how to analyse the plausibility of the cause-specific mortality fraction (CSMF), using the information from steps 1–3 and comparator data to assess the COD distribution generated from VA. This step includes examples of how to break down the analysis to investigate improbable results as well as how to judge plausibility against available comparator data. Secondly, the step explores the relationship between CODs and risk factors, or co-variates, as a way of assessing the plausibility of the CSMF from VA. Finally, the inherent limitations of VA are investigated, namely the uncertainty in the results and the need for residual, or 'other' categories due to the limited COD lists that are available for VA.

The fundamental aim of VA is to generate population-level cause-specific mortality data on the leading CODs in populations where physicians are not readily available to certify CODs. Therefore, this step is critical for countries to follow if VA data are to be used confidently for policy and population health monitoring, and VA data systems and procedures are to be improved so that they are fit for purpose.

4.1 Assessing the plausibility of cause-specific mortality fractions from verbal autopsy

The plausibility of the CSMF relates to whether the results conform to what is expected for that population. An assessment of plausibility can be conducted by assessing whether the CSMFs are expected based on the characteristics of the VA population, such as population age structure, socioeconomic status and prevalent risk factors; the completeness of VA reporting; and whether the CSMFs disaggregated by age and sex follow expected patterns (steps 1–3). Another approach is to directly compare CSMFs with other sources of data (i.e. comparator data).

Comparator data sources for plausibility analysis may include:

- COD information from medically certified CODs or health management information systems. Medically certified deaths using international standards and appropriate coding to International Classification of Diseases (ICD), revision 10. These are commonly, but not always, deaths in hospitals.[58] CODs not using such standards should not be considered.
- Mortality data from health and demographic surveillance system (HDSS). This information can be useful but represents a specific sub-national geographic area and has limited generalisability to other populations.
- Morbidity data from hospitals on the most common life-threatening diseases presenting at hospital. These can provide information on the prevalence of disease in the population who can access health services.
- Specific program data such as registries for cancer, malaria, HIV/AIDS and tuberculosis can provide information on prevalence and deaths due to specific diseases.
- Periodic household surveys such as Demographic and Health Surveys (DHSs) or a maternal mortality survey. These typically contain high-quality data and information on specific aspects of mortality, in specific age groups, particularly children and women of reproductive age.

[58] Rampatige R et al. Systematic review of statistics on causes of deaths in hospitals: Strengthening the evidence for policy-makers. *Bull WHO*. 2014; 92:807-816.

- Global Burden of Disease (GBD) data. These are modelled estimates based on a careful evaluation of all available data from the country and region, applying scientific methods to estimate probable COD patterns given information on key epidemiological, sociodemographic, economic and other determinants of mortality in a population.

It is critically important for sound interpretation of VA data that there is an appropriate mapping between VA causes and the causes from the comparator data, to ensure that cause categories being compared are the same. For example, a mapping of GBD Level 3 causes to VA causes (WHO2016 and SmartVA) can be found in Appendix 8. This mapping is essential if the comparator data (in this case the GBD) are to be used to assess the plausibility of the VA data. The same principle needs to be applied for all comparator data.

Similarly, the comparator data used to judge the plausibility of VA data must be subject to the analysis in steps 1–3 to look for similarities or differences in geographical spread, age–sex distribution of the population, socioeconomic status and epidemiological characteristics. Rigorously applying steps 1–3 will uncover the likely representativeness of the data, or the likely similarities or differences between the VA and a comparator. This is critical to understand whether any significant differences in CSMFs illustrate a problem in the data (i.e. implausible results) or whether they reflect real differences in in the populations of the data sources being compared.

A plausibility analysis of VA CSMF should first examine broad patterns of disease, and then progress to a more detailed analysis within age groups or by location. The extent of analyses that are possible depends on the number of VAs available. It is therefore good practice to always indicate the number of VAs analysed when reporting CSMF results. At each stage, other datasets can be used as a comparator to help assess the plausibility.

Number of verbal autopsies to provide reliable cause-specific mortality fractions

VA results can be subject to considerable uncertainty when they are based on small numbers of deaths (stochastic uncertainty), which can potentially result in erroneous CSMFs and cause rankings. Such uncertainty is particularly important for analysing CODs, as most causes will have CSMFs of less than 5 per cent (e.g. if the total sample is only 200 deaths, then most CSMFs will be based on less than 10 deaths). Small numbers of deaths are common for the pretest and pilot phases of VA, or where analysis of VA sub-populations (location or age groups) is required. CSMFs calculated from these data need to be interpreted carefully.

This section will guide you about the appropriate number of VAs that are required to provide reliable CSMFs from the analysis of VAs from a local population. It does not measure uncertainty from large-scale (e.g. national roll-out VA) or national cluster sampling designs, for which a sampling tool provides uncertainty ranges at different levels of CSMFs given many factors, including the number of clusters, the heterogeneity of their populations and the number of deaths. [59] Such uncertainty will typically be wider than what is presented here for specific VA sites because of the greater heterogeneity of populations from which VAs are collected.[60] This section also does not consider other sources of

[59] University of Melbourne. Sampling strategies for representative national CRVS verbal autopsy planning: A guidance document and sample size calculator tool. Melbourne, Australia: University of Melbourne, Civil Registration and Vital Statistics Improvement, and Bloomberg Philanthropies Data for Health Initiative; 2018. Found at: https://crvsgateway.info/Implementing-verbal-autopsy~41

[60] Brown LD et al. Interval estimation for a binomial proportion. *Statistical Science*. 2001; 16:101-133.

uncertainty such as uncertainty in the algorithm used (tool-based uncertainty), or the quality of interviewers or of information provided by the respondent (measurement uncertainty).

The certainty in CSMF results varies with different numbers of VAs and increases with more VAs. Note that the number of VAs refers to the number of cases collected for each population you wish to analyse the deaths for – for example, all males or all females aged 65 and above. VA analyses often combine all ages, so if age or sex-specific analysis is needed, as will generally be the case, this will require more deaths to be collected than what is indicated here, since these guidelines refer to the estimation of cases for the total population only.

To know how many VAs are required to be sure that the results are accurate within a specified range depends on how much certainty policy-makers need. Policy-makers are typically interested in knowing how much confidence they can have in the ranking of causes or how certain they can be about the size of each CSMF. This section provides guidance on the number of VAs required depending on which of these two policy frameworks are of more importance to users.

If it is more important to be certain about the relative ranking of causes identified by VA, note that CSMFs across different populations are quite similar to each other at various cause rankings, especially at ranks five and above. Table 4 shows typical CSMF values at different rank orders based on empirical VA studies in several countries.[61] If your population's CSMFs at different ranks are much closer than those shown in the table, there would be less certainty than is outlined in Box 5.

Appendix 9 has more detail about the calculations in this section.

Table 4 Typical cause-specific mortality fractions (CSMF) at different rank orders

Cause rank	Typical CSMF range (%)
1	20–25%
2	12–15%
3	10–12%
4	8–10%
5	6–8%
10	3–5%
15	1–2%

[61] These CSMFs are based on VA results from several countries using the SmartVA cause list for adults.

Box 5. Summary guidance for choosing verbal autopsy numbers to reduce uncertainty in cause-specific morality fractions

If the number of verbal autopsies (VAs) collected is:

500 deaths, then:

- There is high likelihood that causes ranked 1 and 2 are actually 1 and 2.
- There is high likelihood that causes ranked 3, 4 and 5 are actually all within the top 5 causes.
- Causes with a cause-specific mortality fraction (CSMF) of 4–7 per cent have moderate uncertainty.
- Causes with CSMF of less than 4 per cent have high uncertainty.
- There is high uncertainty about the actual ranking of causes ranked 6 and higher.

700 deaths, then:

- There is high likelihood that causes ranked 1 and 2 are actually 1 and 2.
- There is high likelihood that causes ranked 3, 4 and 5 are actually all within the top 5 causes.
- Causes with a CSMF of 3–7 per cent have moderate uncertainty.
- Causes with a CSMF of less than 3 per cent have high uncertainty.
- There is high uncertainty about the actual ranking of causes ranked 6 and higher.

1000 deaths, then:

- There is high likelihood that causes ranked 1, 2, 3, 4 and 5 are actually in that order.
- Causes with a CSMF of 2–7 per cent have moderate uncertainty.
- Causes with a CSMF of less than 2 per cent have high uncertainty.
- There is high uncertainty about the actual ranking of causes ranked 6 and higher.

1500 deaths, then:

- There is high likelihood that causes ranked 1, 2, 3, 4 and 5 are actually in that order.
- Causes with a CSMF of 4–7 per cent have low uncertainty.
- Causes with a CSMF of 1–3 per cent have moderate uncertainty.
- Causes with CSMF of less than 1 per cent have high uncertainty.
- Moderate uncertainty about the actual ranking of causes ranked 6 to 10.
- High uncertainty about the actual ranking of causes ranked 10 and higher.

Worked example

In your VA site, you want to know the exact rank of each of the top 5 causes for males and females separately. You are prepared to tolerate moderate uncertainty in the ranking of causes with a CSMF of between 2 and 7 per cent (these would be causes that are ranked approximately 6th to 13th). You could achieve this level of confidence in your results by selecting a sample size of 1000 male deaths and 1000 female deaths.

Broad categories of causes of death

The first step in analysing COD distribution in VA data is to assess the broad categories of COD. One way to assess the plausibility of broad categories of disease is to compare them with expected COD distributions based on life expectancy (Table 5). Generally, countries with low life expectancy are characterised by high levels of mortality due to infectious and parasitic diseases, especially in childhood, along with high maternal mortality (Group I causes). As life expectancy rises, the pattern of mortality changes, with more deaths occurring in older age groups due to non-communicable diseases such as cardiovascular diseases and cancers (Group II causes). The proportion of deaths due to injuries (Group III causes) typically remains constant as life expectancy increases.

Table 5 Expected distribution of cause of death according to life expectancy, by broad disease groups[62]

Disease category	Life expectancy (years)				
	55	60	65	70	75
Group I (%)	22%	16%	13%	11%	8%
Group II (%)	66%	70%	74%	78%	83%
Group III (%)	13%	14%	13%	11%	9%

A country's VA data does not need to match these percentages exactly. However, any large deviations might warrant further investigation into whether the different results could be due to the characteristics of the VA population or the fact that VA is performed only on community deaths.

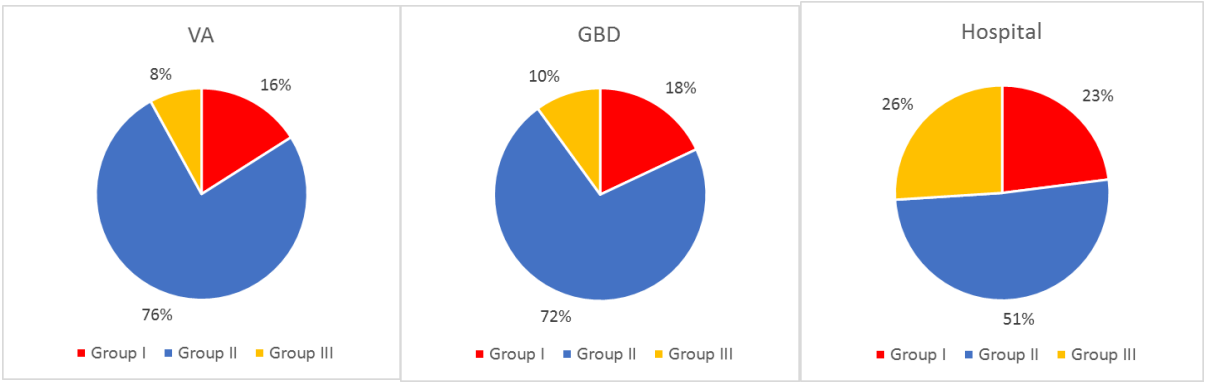
To look at broad COD categories, VA data need to be aggregated into three GBD disease groupings:

- Group I. Infectious and parasitic diseases (e.g. tuberculosis, pneumonia, diarrhoea, malaria, measles); maternal and neonatal causes (e.g., maternal haemorrhage, birth trauma); malnutrition.
- Group II. Non-communicable diseases (e.g. cancer, diabetes, heart disease, stroke); mental health conditions (e.g. schizophrenia).
- Group III. Injuries (e.g. accidents, homicide, suicide).

In addition, the broad COD categories from VA data can be compared with other available data sources, similarly aggregated to Groups I, II and III. Figure 16 illustrates the broad cause distribution across three datasets: VA, GBD and hospital deaths. It shows a high correlation between the broad cause distribution between VA and GBD estimates. These results may be plausible if VA is being conducted on all deaths, or the proportion of hospital deaths in the VA population is very low (i.e. less than 10 per cent). In this example, hospital deaths show a much larger proportion of injuries, a lower proportion of Group II (non-communicable diseases) and slightly higher proportion of Group I deaths. This is consistent with the age distribution of deaths in hospitals, which commonly see more children and younger adults presenting due to acute conditions (infectious diseases and injuries) and fewer deaths at older ages.

[62] AbouZahr C et al. *Mortality statistics: A tool to improve understanding and quality*. Working Paper no. 13. Brisbane: University of Queensland School of Population Health, Health Information Systems Knowledge Hub; 2010.

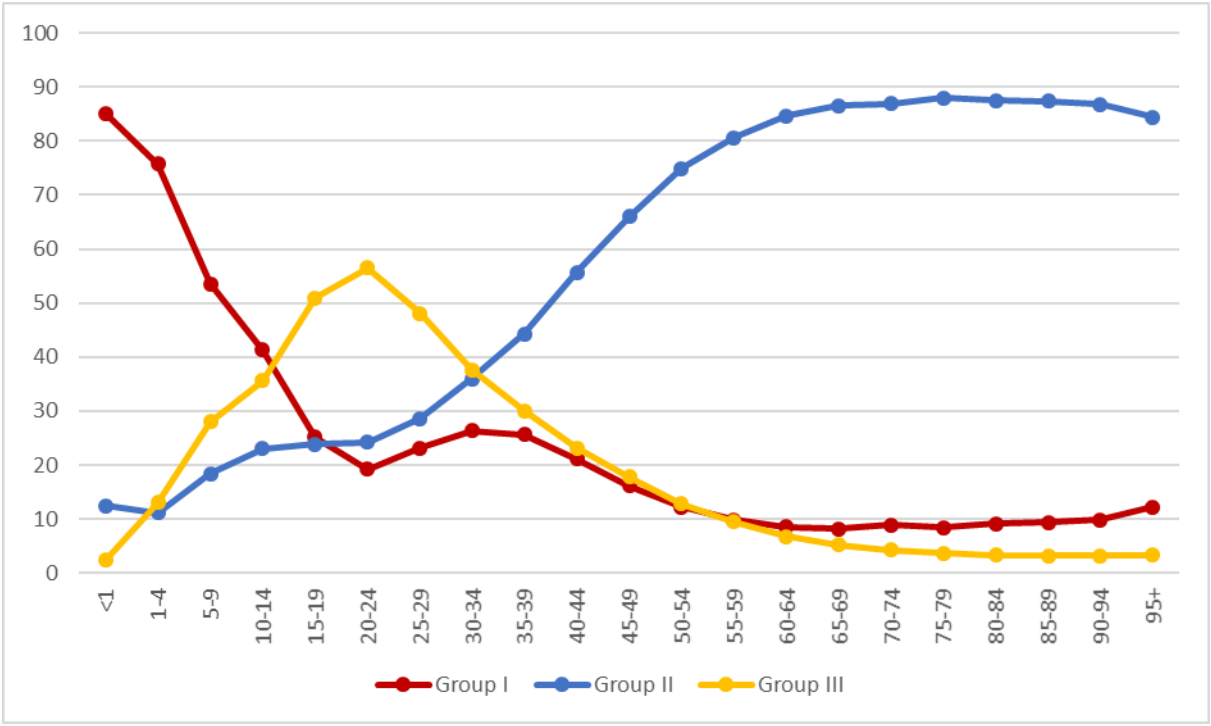
Figure 16 Comparison of causes of death from different sources, by broad disease group



Age pattern of broad causes

Another way to look at broad CODs is according to age. The risk of dying from the different diseases and injuries covered in each group varies with age. For example, a higher proportion of deaths in young children are from diarrhoea and malaria (Group I) than in older ages. Although Group II causes (non-communicable diseases [NCDs]) also contribute to some mortality in children, particularly due to congenital malformations, a higher proportion of deaths at older ages, typically 50+, can be expected to occur from these diseases. For Group III (injuries), the proportion of deaths is generally highest in young adulthood, particularly for male deaths due to traffic accidents and violence (See Figure 17).

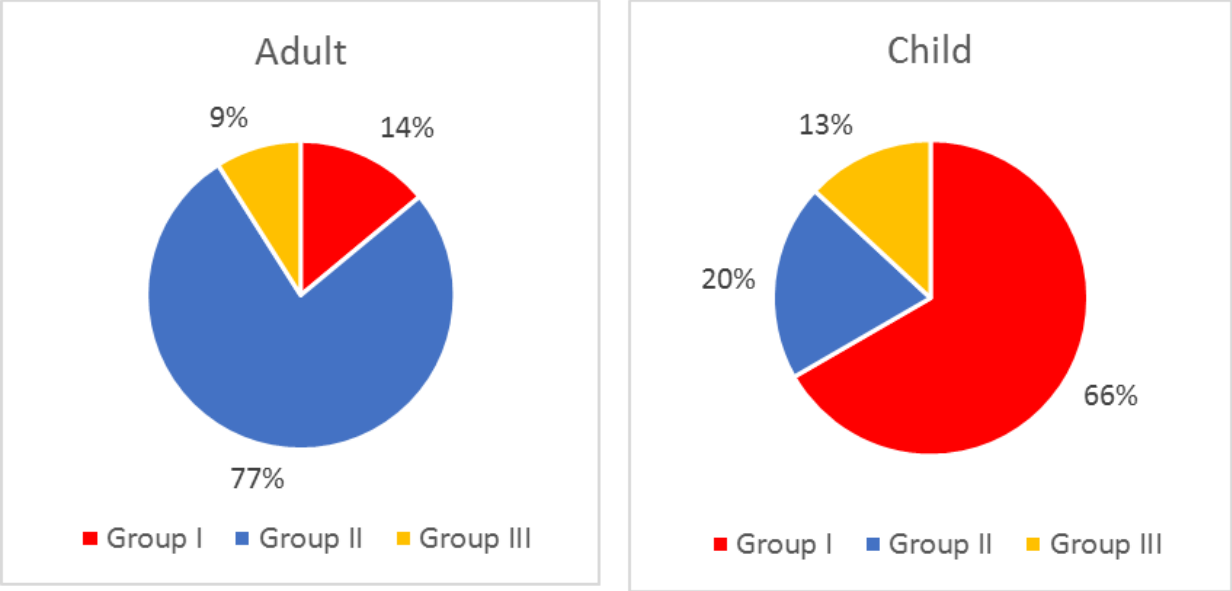
Figure 17 Typical age distribution of broad causes of death, males



Source: Global Burden of Disease Study 2017 results website (ghdx.healthdata.org/gbd-results-tool).

Figure 18 shows a simple way of looking at the pattern of disease from VA data across the three broad categories for children and adults. It is assumed that the data are sufficient (at least 100 VAs) to make this comparison. Particularly during the early stages of VA implementation, there tend to be very few deaths for children.

Figure 18 Example of broad causes of disease for adults (12+ years) and children (29 days to 11 years)



As well as aggregating deaths to three broad causes, aggregated categories can provide meaningful information for health programming (see Table 6). This is particularly useful if there are not enough VAs to analyse CODs in detail. Countries can choose their own aggregation based on their priorities. These data can be aggregated to these categories and then compared with other data sources.

Table 6 Example of verbal autopsy (VA) cause distribution by aggregated cause categories vs comparator

Cause category	VA (%)	National comparator (%)
Tuberculosis and pneumonia	8%	11%
Other communicable, reproductive and nutritional diseases and disorders	25%	22%
All cardiovascular diseases	23%	15%
All cancers	10%	10%
Other non-communicable diseases	25%	30%
All injuries	9%	12%

Leading causes of death

Another step in the plausibility analysis for VA CSMF is to look at the leading CODs. At a minimum, analyse by broad age category following the VA modules (neonatal, child, and adult & adolescent). Since men and women tend to have different CODs, analyse the data by sex, particularly for adults.

At the population level, CSMFs are usually distributed so that the:

- First two ranked causes account for 10–25 per cent of all deaths each
- Next four causes have CSMFs of 3–12 per cent
- Next five include causes with CSMFs of approximately 2–3 per cent.

Figures 19 and 20 shows a typical pattern of top ranked causes, where the top 20 causes account for around 75 per cent of all deaths.[63]

Figure 19 Example pattern of top ranked causes of death, Tanzania, 2016

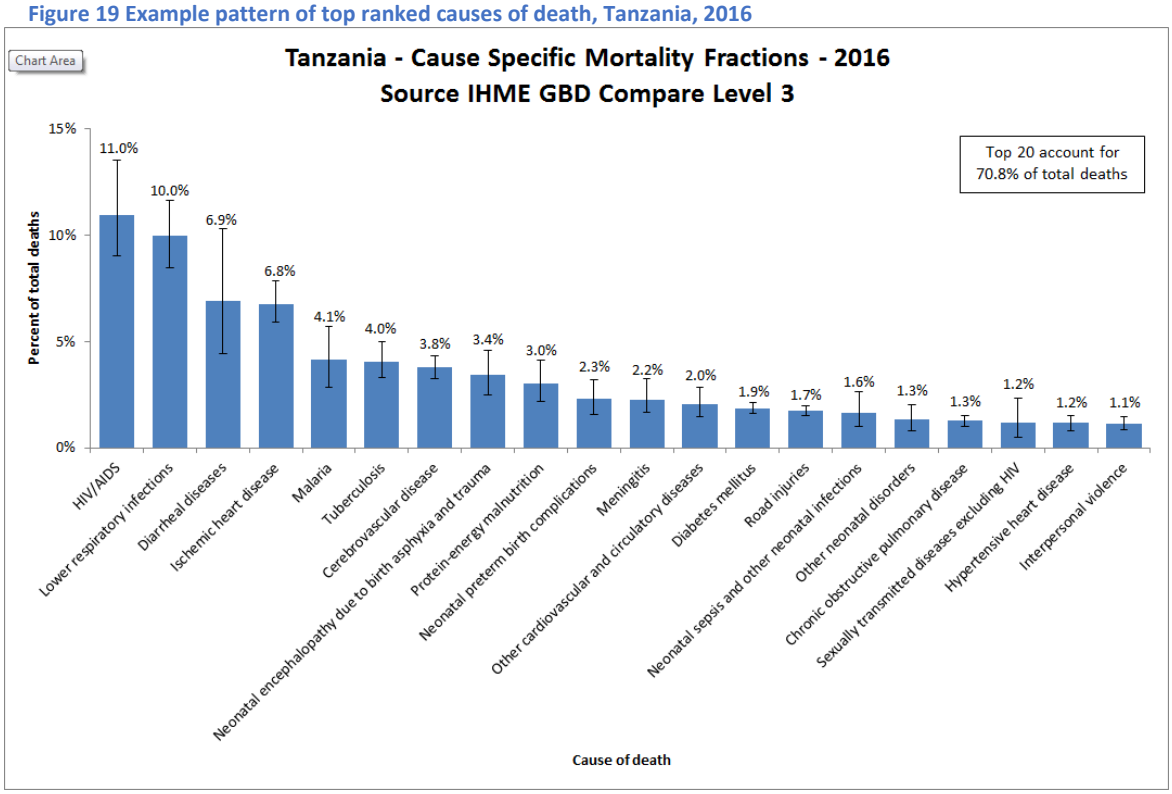
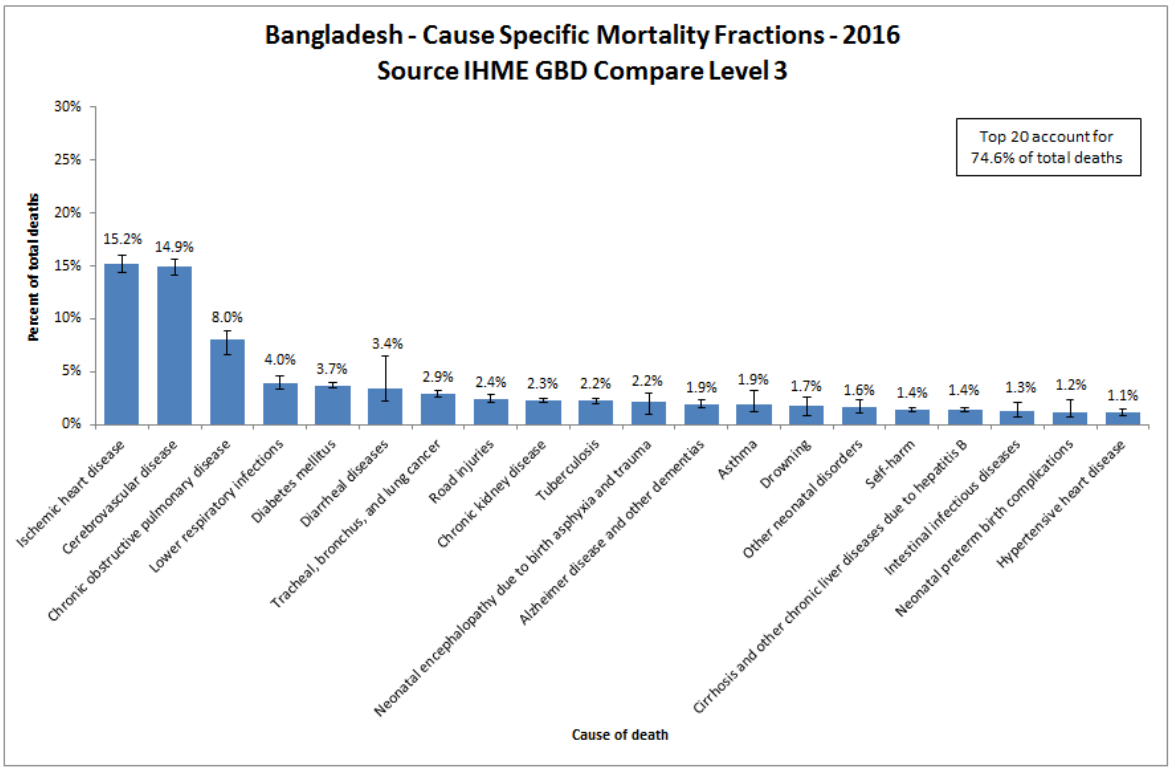


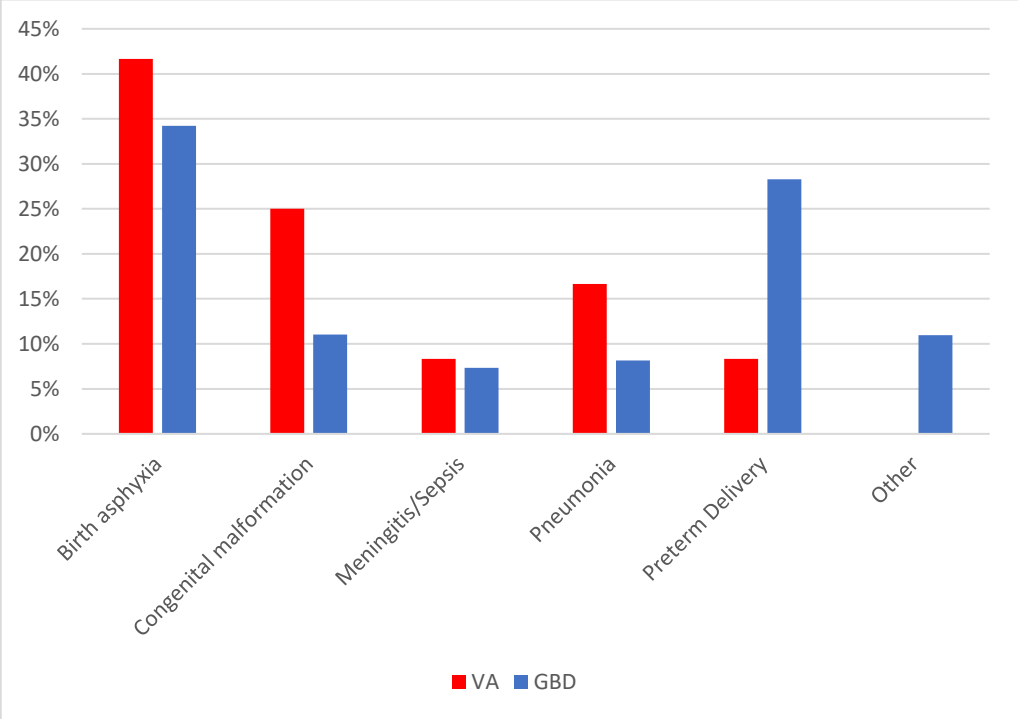
Figure 20 Example pattern of top ranked causes of death, Bangladesh, 2016



[63] University of Melbourne. *Sampling strategies for representative national CRVS verbal autopsy planning: A guidance document and sample size calculator tool*. Melbourne, Australia: University of Melbourne, Civil Registration and Vital Statistics Improvement, and Bloomberg Philanthropies Data for Health Initiative; 2018. Found at: https://crvsgateway.info/Implementing-verbal-autopsy~41

The stage of VA implementation and the number of VAs available for the analysis will dictate the causes that can be reliably predicted using this method. For instance, with few VAs (<100) that may be part of a pretest phase, only basic analysis to pick up obvious anomalies is possible. It is not possible to interpret these data in any meaningful way because the sample is too small to represent a cause distribution in the VA area. This is often the case for child and neonatal deaths, which are often under-represented in VA data. For example, Figure 21shows how small numbers can bias the CSMF compared with GBD data. With such small numbers, the VA data are unlikely to represent the usual COD pattern in this age group.

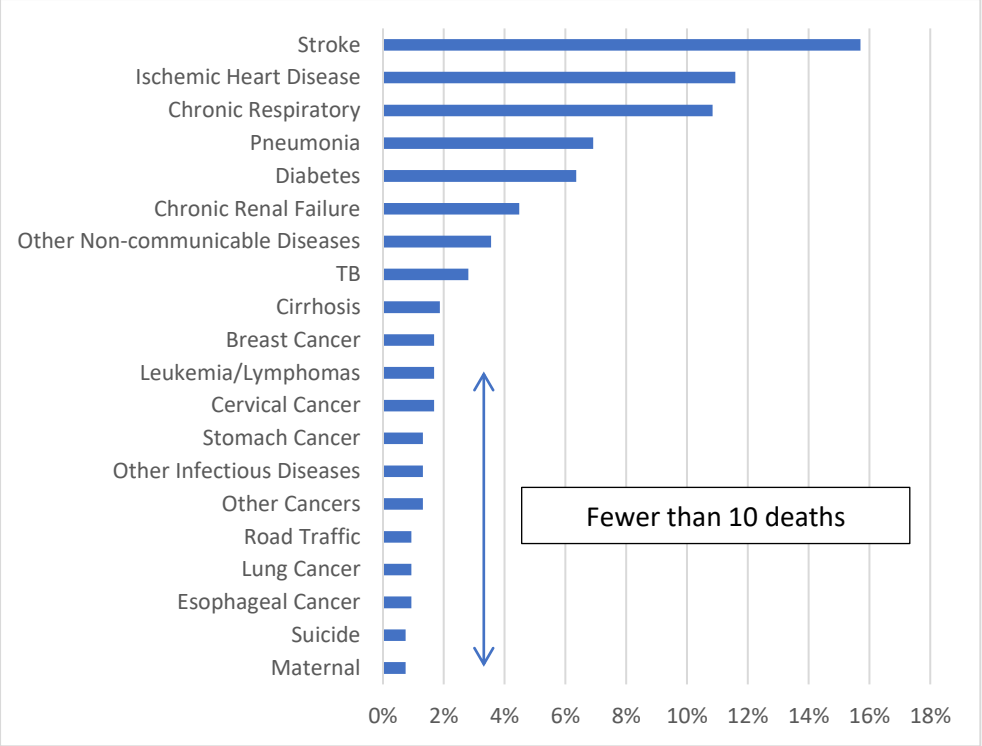
Figure 21 Example of neonatal cause of death from VA (n=12) vs GBD



Note: In this case, 42% of deaths due to birth asphyxia represents only five deaths. Preterm delivery and meningitis/sepsis are represented by only one death each.

With more VAs (~500), data may be reliably analysed for the top 4–6 causes. For causes beyond the top 4–6, the uncertainty around the estimates with these small numbers will not provide an accurate population cause distribution (Figure 22).

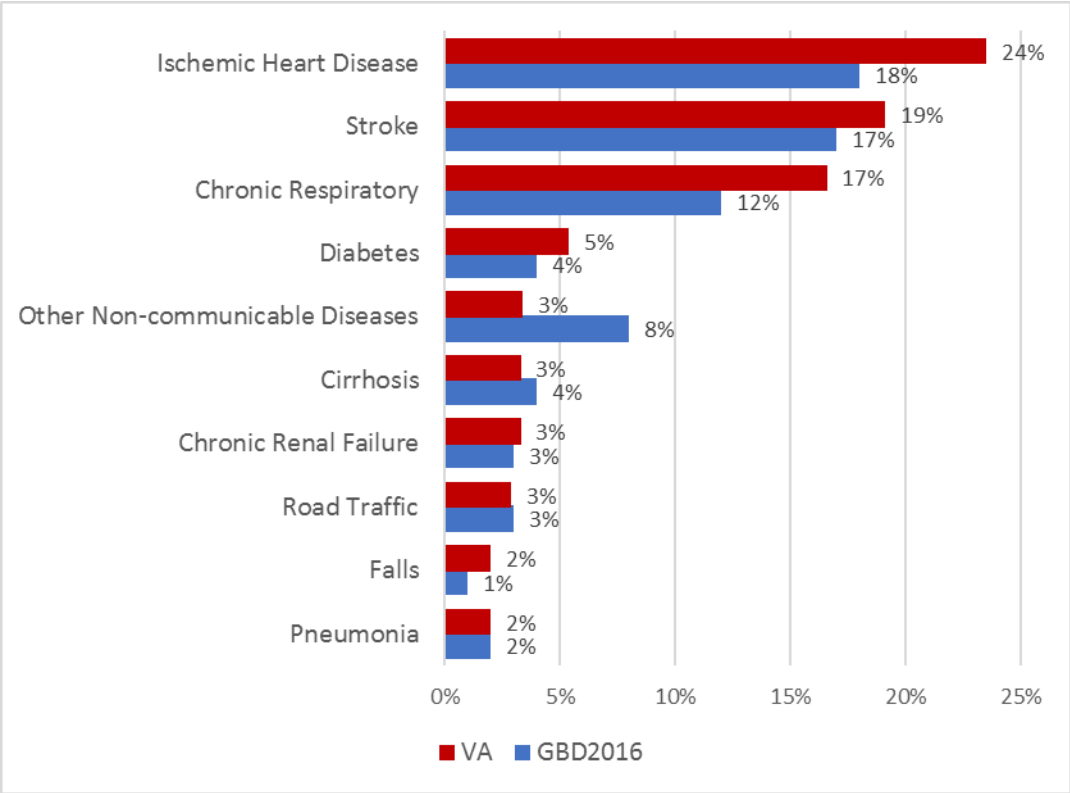
Figure 22 Example of causes of death for adult female (n = ~500)



With around 1500 deaths, the top 10 CODs can be identified, although there will be moderate uncertainty for deaths ranked 6 and below. Comparing this with other data sources can help identify potential problems with the VA COD data. However, as previously mentioned, it is not necessarily expected that the COD distribution from VA will be the same as the comparison dataset, depending on the characteristics of the populations that they come from (Steps 1-3).

It is worthwhile to assess the differences with the comparator data according to the ranking (see Figure 23) and then assess differences in the CSMFs. This approach is suggested because even with several hundred deaths, the CSMFs can be subject to some uncertainty although the ranking is less affected. Additionally, policy-makers are usually interested in the ranking of deaths. In Figure 23, the VA and GBD data correspond, which makes us reasonably confident in the VA data. The order of the top three causes are identical and the main difference is 'other non-communicable diseases', which is 8 per cent in the GBD and only 3 per cent in the VA. However, the difference in ranking (4th in GBD and 5th in VA) is minimal. The specific causes within the 'other non-communicable diseases' group in the GBD can be explored, as shown in Step 4.3.

Figure 23 Example cause-specific mortality fractions for adults, from verbal autopsy (VA) and Global Burden of Disease (GBD) data



With several thousand VAs, a more complex analysis can be performed. For instance, it is possible to break down CODs into more discrete age groups. This can help to understand whether the pattern of disease across the age groups is plausible. For example, in many countries, CODs for which alcohol and smoking are strong risk factors have a higher proportion of men dying from these conditions. Figures 24 and 25 illustrate the typical differences in leading CODs between males and females.

Figure 24 Example leading causes of death in adult males 12+ years (n = 5540)

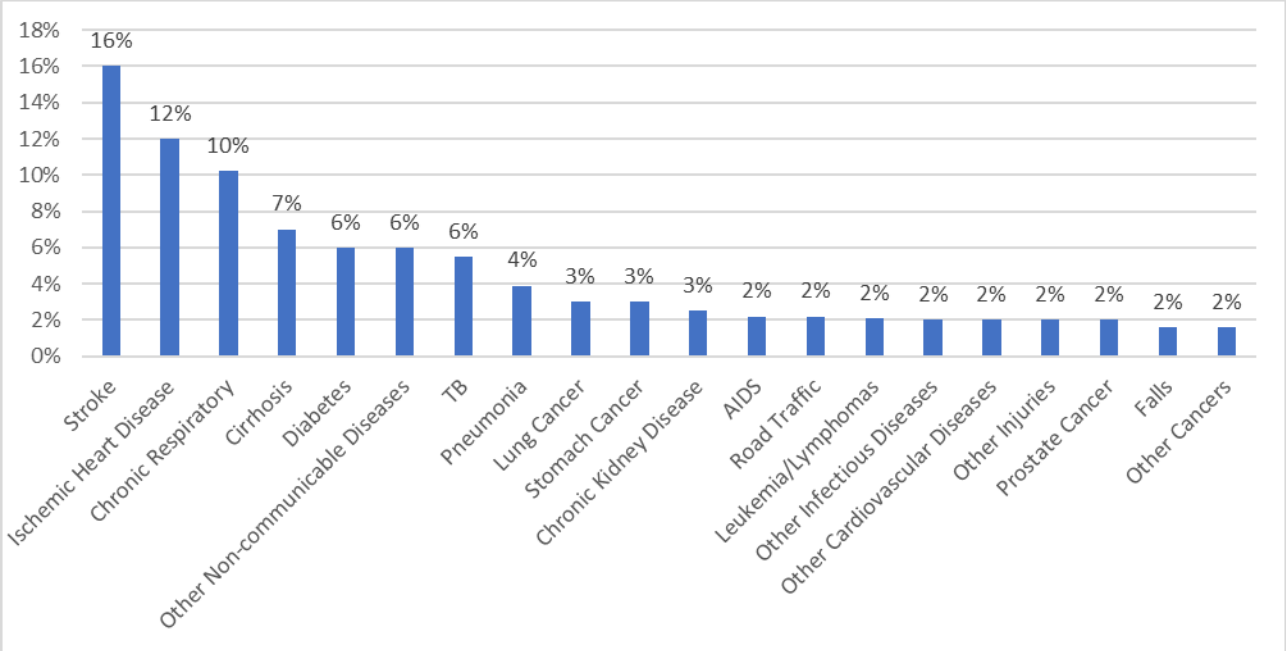
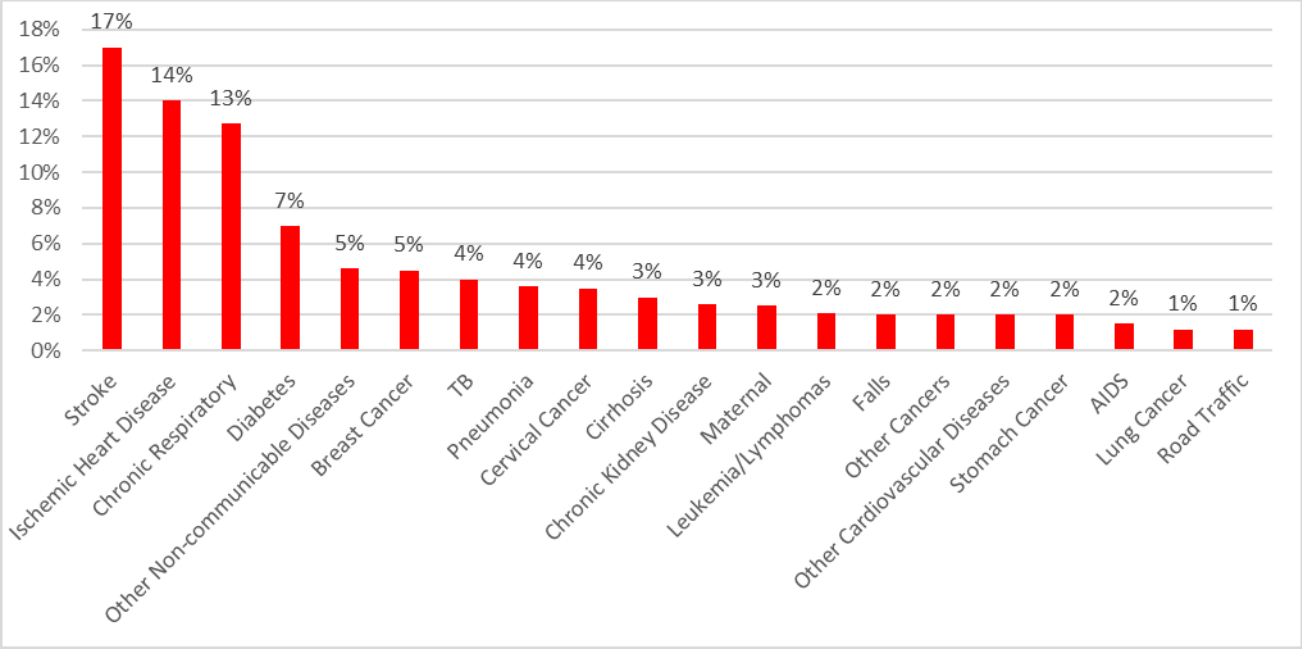


Figure 25 Example leading causes of death in adult females 12+ years (n = 3750)



Figures 26 and Figure 27 show the differences in causes among younger males (12–39 years) versus older males (+60 years), respectively. It is noticeable that cirrhosis, road traffic accidents and AIDS are higher in younger males, whereas stroke, ischemic heart disease and chronic respiratory disease are higher in older males.

Figure 26 Example causes of death, males, 12–39 years (n = 1225)

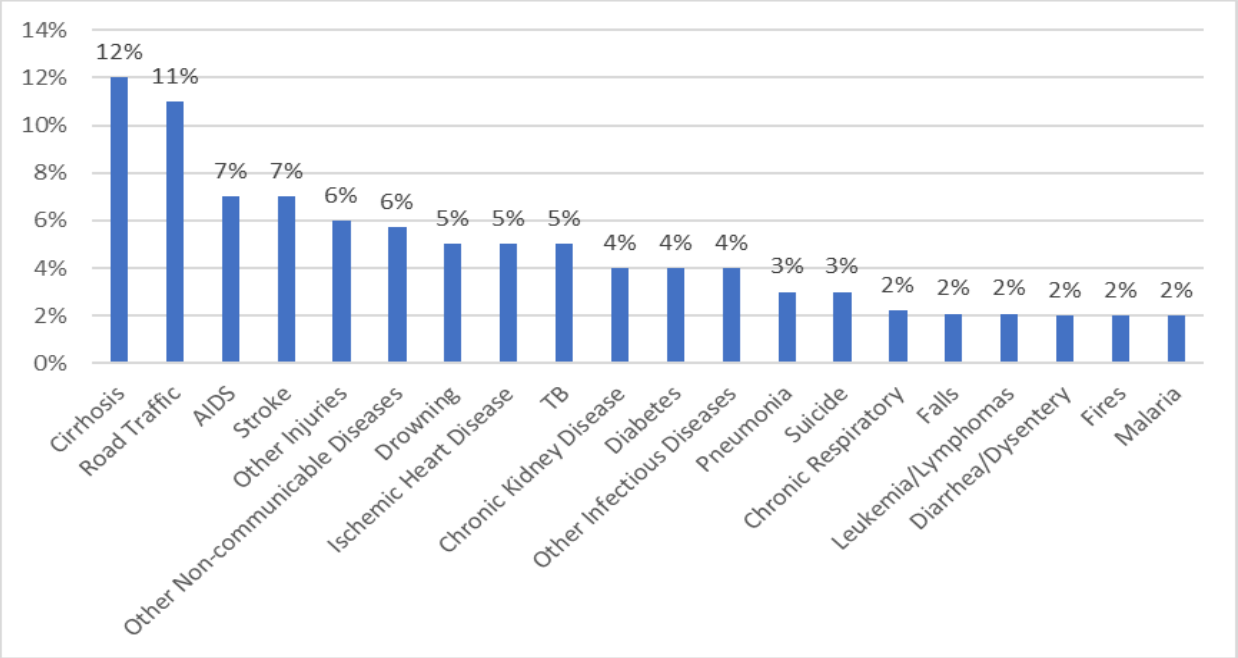
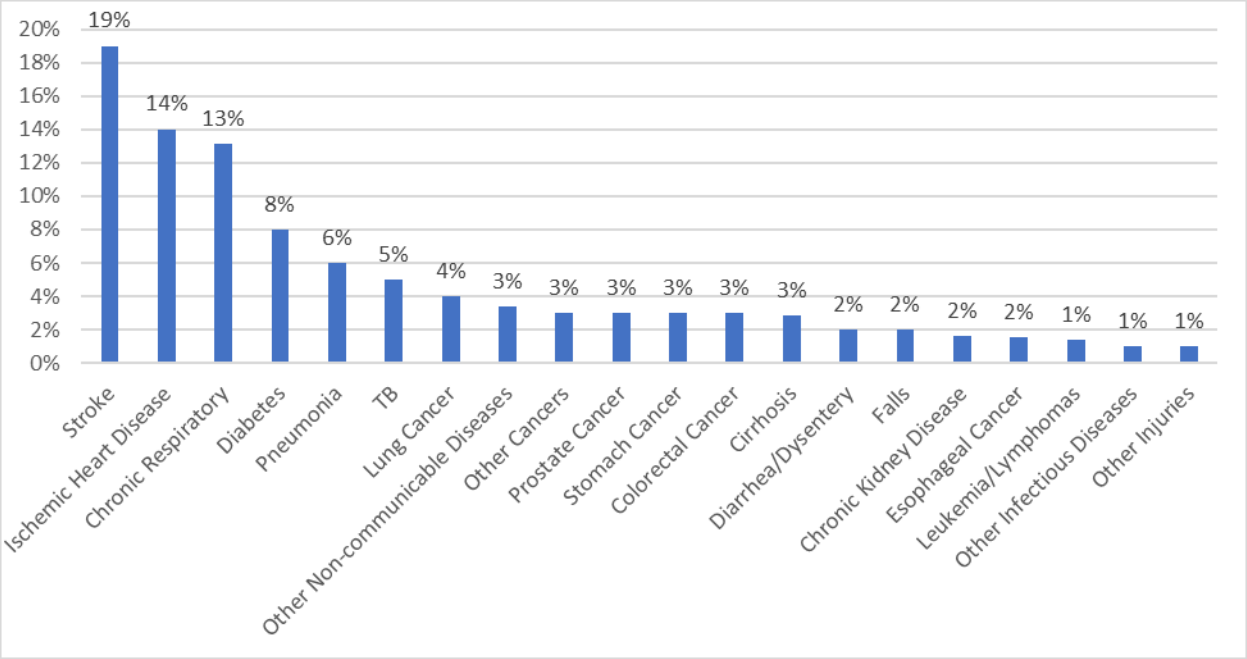


Figure 27 Example causes of death, males, 60+ years (n= 4950)



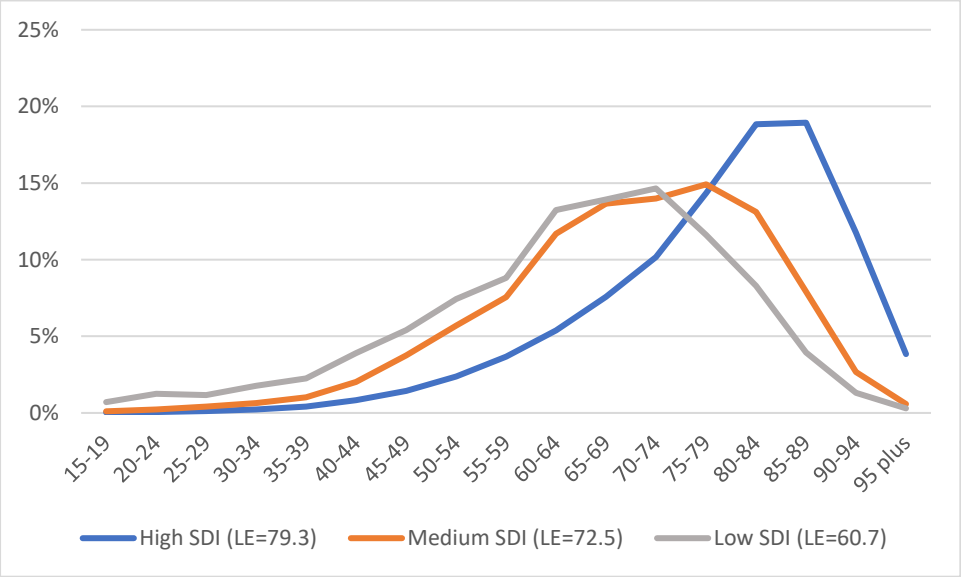
Investigating the CSMF of leading causes by age can also help to understand whether patterns are plausible (see Table 7) by highlighting where there is an unexpectedly high or low proportion of deaths due to a disease in a particular age group. Even if these percentages are higher in younger age groups, the actual number of deaths due to these causes is likely to be higher in the older ages, when most deaths occur. For example, in Table 7, a larger proportion of women die from diabetes in the 50–59 year age group (7 per cent) than the 70–79 year age group (6 per cent). However, due to the higher number of total deaths in the 70–79 year age group, there are more deaths due to diabetes in that age group (178) than the 50–59 year age group (94).

Table 7 Cause-specific mortality fractions of selected causes of death by age group

Cause	12–39 years		30–49 years		50–59 years (%)		60–69 years		70–79 years		80+ years	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
AIDS	2%	2%	8%	6%	2%	1%	1%	0%	0%	0%	0%	0%
Chronic kidney disease	2%	1%	7%	3%	5%	2%	4%	1%	1%	1%	1%	1%
Chronic respiratory	3%	1%	4%	2%	8%	5%	8%	9%	13%	11%	12%	12%
Cirrhosis	3%	1%	9%	3%	8%	4%	5%	1%	2%	1%	1%	0%
Diabetes	2%	3%	3%	5%	3%	7%	4%	6%	3%	6%	3%	3%
Drowning	16%	10%	6%	1%	1%	0%	0%	0%	0%	0%	0%	0%
Ischaemic heart disease	2%	3%	9%	7%	15%	13%	17%	19%	18%	20%	20%	22%
Lung cancer	1%	0%	3%	1%	6%	2%	7%	4%	4%	2%	2%	0%
Pneumonia	2%	2%	2%	3%	4%	3%	5%	3%	6%	4%	7%	5%
Road traffic accident	22%	10%	12%	6%	3%	1%	0%	0%	0%	0%	0%	0%
Stroke	4%	3%	9%	7%	12%	15%	17%	19%	21%	23%	18%	20%
Suicide	4%	1%	3%	2%	1%	0%	0%	1%	0%	0%	0%	0%
Tb	4%	2%	5%	2%	7%	3%	4%	2%	2%	1%	1%	1%
Other causes	32%	61%	20%	52%	26%	44%	28%	35%	30%	31%	35%	36%
Total deaths in age-group	**660**	**390**	**2175**	**1243**	**3453**	**1343**	**3467**	**2517**	**2958**	**2966**	**1680**	**2550**

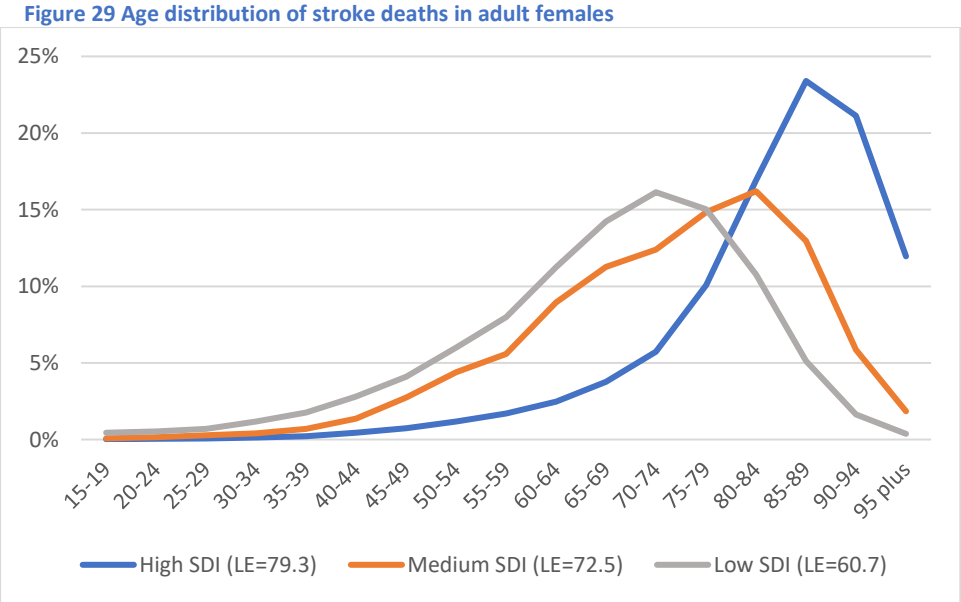
Deaths due to particular diseases tend to follow a predictable age distribution pattern. For instance, Figure 28 and 29 show the age distribution of stroke by low, middle and high Socio-Demographic Index (SDI). Similar figures for other leading causes can be found in Appendix 10. Some diseases, such as ischemic heart disease and other NCDs, show a COD age distribution that is skewed to older ages. For some causes, such as road traffic accidents, the age distribution is skewed to younger ages. Other diseases, such as cirrhosis and diabetes, may peak in the middle age groups. If your VA reveals age distribution of deaths for leading causes that vary significantly from the patterns relevant to your country's SDI, it might be important to investigate to determine whether these are due to real differences in your VA area or country, or whether they are implausible results.

Figure 28 Age distribution of stroke deaths in adult males



LE = life expectancy
Source: Global Burden of Disease Study 2017 results website (ghdx.healthdata.org/gbd-results-tool).

Figure 29 Age distribution of stroke deaths in adult females



LE = life expectancy
Source: Global Burden of Disease Study 2017 results website (ghdx.healthdata.org/gbd-results-tool).

You could also analyse the top CODs by location, to track and compare different areas where VA is being implemented (e.g. Table 8). This can highlight major differences in the COD pattern, which could reflect real differences due to location. It can also highlight problems with the application of VA in these locations. It is a good idea to include the numbers of VA in each site so you can identify anomalies that may be due to small numbers.

Table 8 Top causes of death in adults, by site

Cause of death	Site 1 (n=1032)	Site 2 (n=358)	Site 3 (n=2630)	Site 4 (n=1131)
Stroke	15%	10%	19%	17%
Chronic respiratory	11%	14%	10%	12%
Ischemic heart disease	13%	11%	12%	11%
Diabetes	6%	7%	5%	5%
Cirrhosis	5%	4%	6%	3%
Pneumonia	3%	2%	4%	5%
Tuberculosis	3%	2%	2%	2%
Other non-communicable diseases	5%	3%	3%	3%
Chronic kidney disease	2%	2%	3%	2%
Leukemia/lymphomas	1%	2%	2%	2%

Analysing CSMFs from VAs should follow a standard format (see Step 5), and the amount of detail depends on the number of VAs available. Key stakeholders need to carefully examine VA results to identify potential issues and investigate whether further action is necessary, before these results are used for health policy and planning purposes.

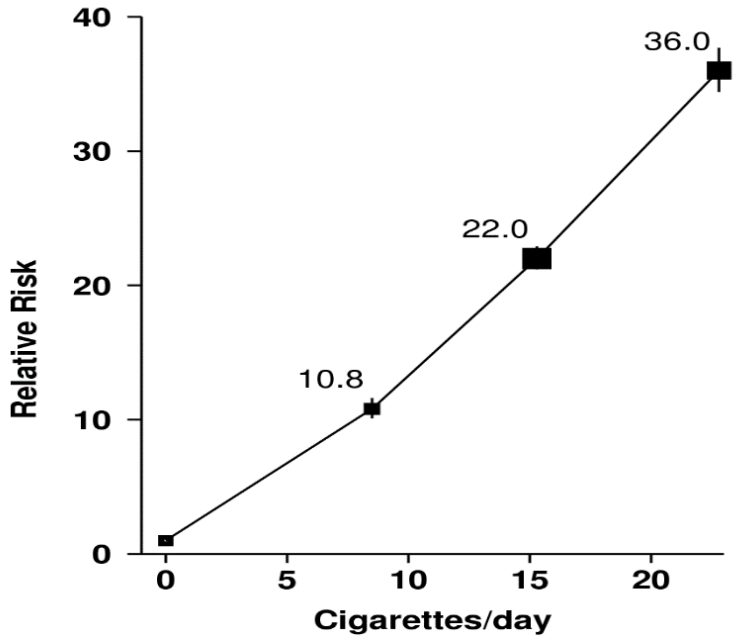
As previously noted, if VA results are thoroughly scrutinised and the results are found to be implausible, the reasons for these implausible results need to be investigated. A qualitative analysis of VA implementation sites and the experiences of VA interviewers and supervisors may be necessary to uncover potential issues such as the translation of the questionnaire. This is especially important if the language spoken in a particular VA site is different to the language in the VA questionnaire. Systematic issues picked up at earlier stages of implementation (pilot and demonstration phases) can improve on quality at later stages. However, implementing VA at scale will bring new challenges and require careful monitoring of results, and refresher training should be an ongoing activity. In addition, algorithms to assign CODs will continue to be improved and updated. If erroneous results cannot be explained by field methods, it may be worth contacting the developers to check if this is a common issue that needs their attention.

4.2 Assessing plausibility of verbal autopsy outputs in the context of risk factors and health determinants

CODs may be understood in terms of the underlying disease or injury that initiated the train of morbid events leading to death (as defined and classified in ICD), or in terms of the individual exposure or population-level characteristics that an individual experiences and have been shown to increase the risk of death. These exposures or population characteristics are generally known as risk factors, and may be related to a disease or injury.

A good example is cigarette smoking. Decades of epidemiological research on health outcomes of smokers versus nonsmokers have definitively established that smokers experience a much higher risk of death from several diseases, including cancers of the lungs, mouth, esophagus, pharynx, larynx and numerous other sites; heart diseases and stroke; and chronic obstructive pulmonary disease.[64, 65, 66] Figure 30 shows the excess mortality risk for smokers from lung cancer in a population which has been smoking for several years.

Figure 30 12-year relative risk, current smoker versus never-smoker, by amount smoked[67]



If the current and past (20–30 years) prevalence of smoking in the VA population is known, we can use this knowledge to assess the plausibility of the VA COD data. In other words, if a large proportion (i.e. 40–60 per cent) of men are smokers, and that this prevalence rate has not changed significantly over the past 20–30 years, then we might reasonably expect that the CSMF for lung cancer in that population would be comparatively high, perhaps 4–6 per cent. Conversely, since women in low to middle-income countries (where VA might be typically applied) have not smoked in large numbers, the expected fraction of deaths

[64] Doll R et al. Mortality in relation to smoking: 50 years' observations on male British doctors. *BMJ*. 2004; 328(7455):1519.
[65]. Thun MJ et al. 50-year trends in smoking-related mortality in the United States. *N Engl J Med*. 2013; 368:351-364.
[66] Pirie K et al. The 21st century hazards of smoking and benefits of stopping: A prospective study of one million women in the UK. *Lancet*. 2013 381(9861):133-141
[67] Ibid

due to lung cancer would be much lower. An exception is if women were exposed to other significant risk factors for lung cancer, such as indoor air pollution.

Knowledge about the prevalence of risk factors or, more broadly, significant co-variates that are known to affect mortality risks from certain diseases and injuries[68] is thus an important contextual factor to consider when assessing the plausibility of VA data. In the case of drowning, for example, we would not expect very many deaths to occur in populations where rivers, lakes or coastlines were not nearby.

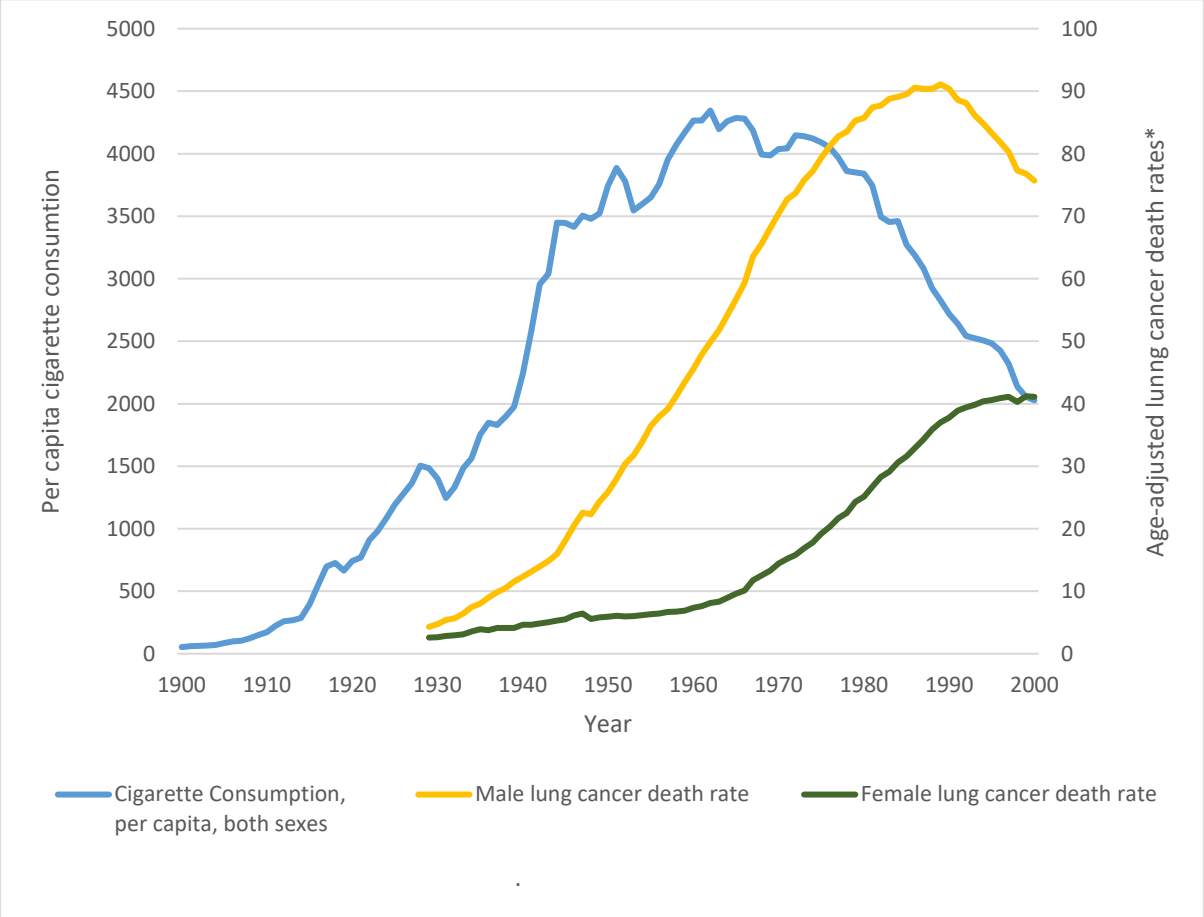
It is not necessary to try to measure the exact impact of risk factors in your VA population on CSMFs; rather, all VA data should be carefully considered in the context of the likely presence (or absence) of major risk factors for the various CODs calculated from the VAs. This applies to the leading CODs (would you expect the CSMFs to be so high given what is known about risk factors and co-variates in the population?) and to causes for which VA suggests a low CSMF and for which prevailing risk factors might suggest that mortality should be higher.

Since levels and patterns of risk factor exposure (e.g. smoking, alcohol use, occupational exposures, diet) generally vary significantly between males and females, CSMFs from VA should be evaluated for males and females in light of what is known about the differential exposure of males and females in the population to the major risk factors being evaluated. Secondly, the assessment of CSMFs from VA in the context of risk factor exposure needs to allow for the time delay between exposure and outcomes. For example, it often takes several years for smoking to cause lung cancer, so merely looking at current smoking prevalence might be misleading; in this case, we would need to consider information on smoking prevalence 20 or 30 years earlier. For some diseases and injuries, the time between exposure to a risk factor and disease or injury outcome can vary. Thus, the effects of alcohol may be acute (e.g. road traffic injuries) or develop after a much longer period of time (e.g. hepatic cirrhosis).

Figure 31 shows the importance of allowing for an appropriate time lag between prevalence of exposure and disease/injury outcome. In this example, the rise in lung cancer mortality during the 20th century in the United States – first in males, and then two to three decades later in females – can be clearly linked to the rapid rise in cigarette consumption several decades earlier (most of which was in men, with women only beginning to smoke in large numbers after World War II). The point is that using risk factor knowledge to judge the plausibility of VA CSMFs should be done carefully, separately for males and females, and be consistent with the known time lags between exposure and mortality that years of epidemiological research has identified.

[68] Co-variates include education, income, access to health services, or even proximity of the population to rivers or lakes (likely to increase the risk of drowning).

Figure 31 Example of tobacco control in the United States: lung cancer rates mirror cigarette consumption for males and females



*Per 100 000, age adjusted to the 2000 US standard population.
Source: US Department of Agriculture[69]

To assist users of VA to use information on the prevalence (or absence) of risk factors to assess the plausibility of their CSMFs from VA, Appendix 11 shows the major risk factors for several of the leading communicable, non-communicable and injury conditions that VA can be expected to identify, based on the GBD Study.[70] Using this information to try and understand how important these various risk factors are in the VA population will help to avoid gross errors in interpreting the CSMFs from VA.

[69] US Department of Agriculture. Cigarette consumption: Tobacco situation and outlook report yearbook. Washington DC: Death Rates: US Mortality Volumes 1930 to 1959 and US Mortality Data 1960 to 2010, National Center for Health Statistics, Centers for Disease Control and Prevention; 2007.

[70] GBD 2017 Risk Factors Collaborators. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Global Health Metrics*. 2018; 392 (10159):1923-1994.

4.3 Understanding undetermined causes of death and residual categories

Undetermined causes of death

VA relies on the responses of family members to a series of questions about the deceased before death. The quality of the information gathered from an interview depends on the selection of informants with detailed knowledge of the terminal illness and the skill of the VA interviewer. There will be cases in which the information gathered is not sufficient to assign a COD. About 10–20 per cent of VA interviews will result in an undetermined cause. Although this may seem high, note that a similar proportion of 'unusable' causes is often observed in medically certified cause of death (MCCOD) data, since physicians are often unaware, or poorly trained in the principles, of correct medical certification of deaths.[71]

When interpreting VA data, it is important to analyse the number and characteristics of the undetermined CODs to see how they vary according to age or location. For instance, a threshold of 10–20 per cent of undetermined CODs might be a reasonable expectation for established VA areas where VA interviewers have had enough time to develop their interview skills and where the population is accustomed to the VA methods. Higher levels of undetermined causes should signal potential problems with the interviewer methods or skills, and indicate the need for reappraisal and, potentially, refresher training.

Countries should investigate the following from the VA dataset:

- **Do the numbers of undetermined CODs increase with age?** It is expected that most of these deaths will be in older ages where symptoms may be vague or more ambiguous due to much greater likelihood of comorbidities before death. Figure 32 shows that undetermined CODs are mainly at older ages. If a significant fraction (>30 per cent) of all undetermined CODs occur in the younger age groups (<70–75 for women, <60 or 65 for men), data collection procedures should be reviewed.

- **Is the number of undetermined CODs reasonably standard across different sites?** If undetermined levels are unacceptably high across all sites, this could indicate a problem with translation of the questionnaire, with the training curriculum in general or with the choice of cadre of worker to conduct the VA interview. These are higher order issues that need to be addressed.

- **Are there differences between regions implementing VA?** This may point to a problem with the quality of some VA interviewers, or the training and supervision offered in those places. For instance, Figure 33 shows a problem in location 4. It is possible that the intervention has not been well implemented in this site, perhaps due to poor training, inadequate community sensitisation or language issues (if the language in this region is different to the questionnaire), but the acceptable levels of undetermined CODs in other sites indicate there is not a general problem with the application of VA in the country.

[71] Mahapatra et al. Civil registration systems and vital statistics: Successes and missed opportunities. *Lancet*. 2007; 370(9599):1653-1663.

Figure 32 Example, age distribution of undetermined causes of death

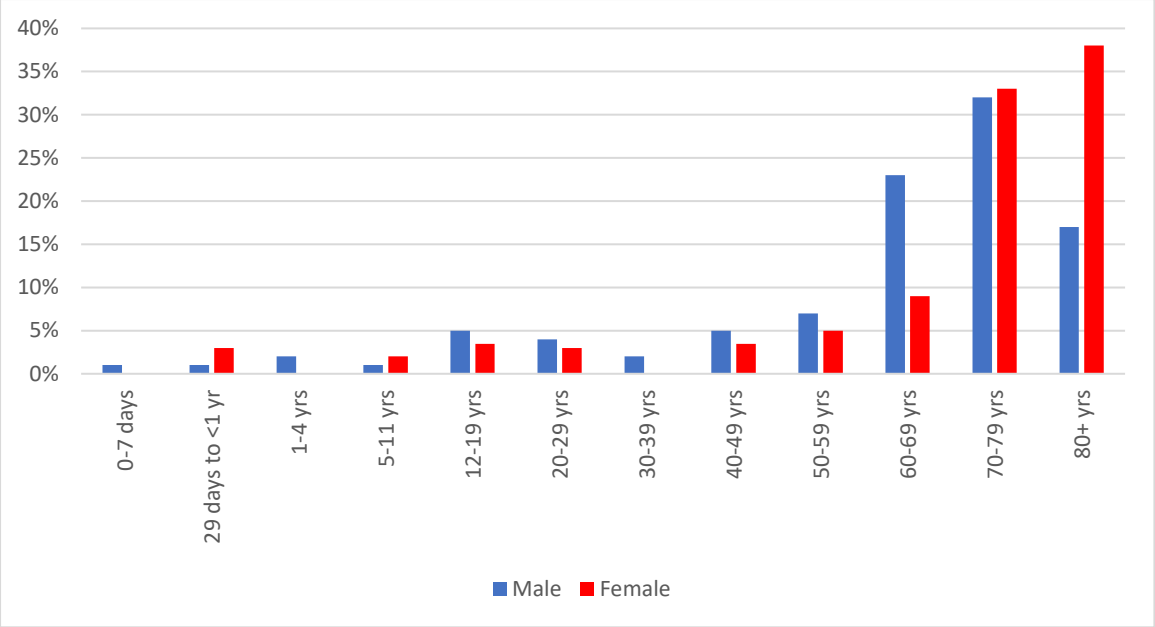
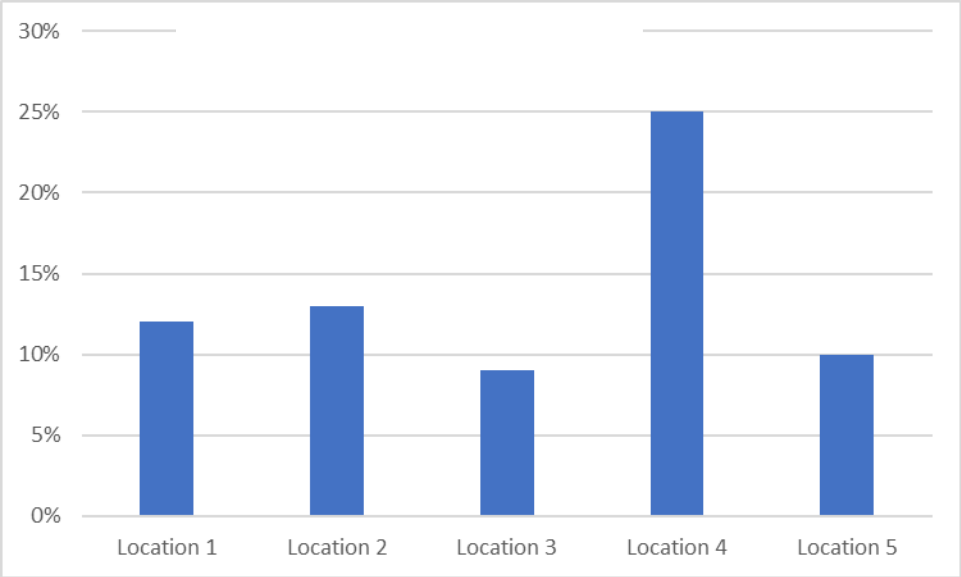


Figure 33 Example, undetermined causes of death, by location of verbal autopsy implementation sites



An unacceptably high number of undetermined CODs will not help identify potential VA implementation issues. However, the pattern of undetermined CODs will help direct a qualitative investigation to understand the root cause of the problem and put actions in place to address them.

The 10–20 per cent undetermined threshold is a guideline because disease distributions will vary between regions. Symptoms such as cough and fever are widely distributed among causes. This will affect CSMF accuracy for diseases such as pneumonia and malaria. Regions with a high proportion of deaths from these causes may have a higher proportion of undetermined CODs. As noted, regions with an older population will likely have a higher proportion of undetermined CODs due to the vagueness and number of comorbidities that present in these age groups. Finally, slightly higher thresholds (up to 20 per cent) can be expected in areas where VA is being newly implemented. It can take some time for VA interviewers

to become familiar with the questionnaire and skilled in the VA methods, and for the community to accept the VA interview as a routine data collection method.

Based on up to two years of VA application in 12 Bloomberg Data for Health Initiative countries, the lowest observed fraction of undetermined CODs was about 9 per cent (for adults). Although a few small research studies and studies using VA data from HDSS (where VA interviewer selection and monitoring is done under optimal conditions) have achieved lower undetermined fractions,[72, 73] routine application of VA at a large scale using existing health staff is unlikely to produce such results. Therefore, around 9 per cent might be acceptable as the lowest level of undetermined CODs attainable using VA.

The proportion of undetermined CODs should always be considered when interpreting CSMFs. Ignoring undetermined CODs can lead to biased CSMFs because certain causes and ages are more likely to be assigned to undetermined.

Dealing with undetermined causes of death

The different diagnostic algorithms used to assign COD to a VA handle uncertainty in the VA results differently (see Appendix 4). The algorithms aim to maximise the usefulness of the VA data while balancing statistical and epidemiological properties. Tariff and InterVA use predetermined thresholds to assign a COD, with undetermined assigned where a threshold for a particular cause has not been reached. Since the threshold chosen is algorithm-specific, the proportion of undetermined CODs produced by these two methods are not comparable. In addition to producing individual CODs, the Tariff method also applies an algorithm to produce likely CSMFs with undetermined COD redistributed to the existing SmartVA cause list.[74] Insilico does not assign undetermined CODs, but uses confidence intervals to indicate the relative uncertainty of particular CODs from VA. For more information on how the different algorithms deal with uncertainty, see Appendix 4.

Because of the potential for undetermined CODs to bias the true COD pattern in a population, tools have been developed to reallocate cases in which the algorithm assigned an undetermined COD. The VA Manager Dashboard[75] can provide physicians with human-readable VA questionnaires that they can use to assign a COD by group consensus. This tool is being piloted and will undergo further development.

Updates in algorithms to redistribute undetermined CODs and incorporate uncertainty in cause predictions are planned statistical improvements. However, countries should focus on operational improvements such as quality VA training and supervision to reduce their levels of undetermined CODs. Questionnaire developers should be notified about systematic issues such as questionnaire translation and cognitive testing. Importantly, the 10–20 per cent threshold is a guideline for the proportion of undetermined CODs and is likely to vary based on the variability in cause and age distribution between regions. Ongoing monitoring of levels and patterns of undetermined CODs should be an integral part of monitoring the VA process so that support can be directed towards problem areas, including the upskilling of staff and community education as needed.

[72] Ndila C et al. Causes of death among persons of all ages within the Kilifi Health and Demographic Surveillance System, Kenya, determined from verbal autopsies interpreted using the InterVA-4 model. *Global Health Action.* 2014; 7(1):25593.
[73] Noriah Maraba et al. Verbal autopsy-assigned causes of death among adults being investigated for TB in South Africa. *Trans R Soc Trop Med Hyg*. 2016; 110:510-516.
[74] Serina P et al. Improving performance of the Tariff method for assigning causes of death to verbal autopsies. *BMC Medicine*. 2015; 13:291.
[75] https://github.com/SwissTPH/VA-Dashboard

Residual categories

Occasionally, the information gathered from a VA interview with a carer or family member cannot provide enough detail for definitive diagnosis, in which case the cause is listed as undetermined. In addition, sometimes the information gathered from a VA interview is not sufficient to assign a specific COD, but is sufficient to assign a broad COD, such as cancer. For these broad COD groups, VA uses a residual cause category called 'other'. Residual categories differ slightly between the VA instrument in use (See Appendixes 2 and 3), but both cause lists include 'other NCDs', 'other cancers', 'other infectious diseases' and 'other cardiovascular diseases'. In addition, SmartVA includes a residual category for injuries, labelled as 'other injuries'. As a result, the various CODs listed collectively account for, and are mutually exclusive and exhaustive of, all ICD codes. Simple mappings with the GBD cause list, thus allow users to classify their VA deaths into the fundamental broad cause classification (Groups I, II and III) used by the GBD to summarise the epidemiological transition in countries.

Since it is important that the output from VA covers all CODs, and yet only a specific set of causes can be reasonably identified from the VA questionnaire, the VA cause lists will therefore contain a number of residual or 'other' categories referring to all other causes that VA cannot identify separately. These aggregated or 'residual' COD groupings from VA can make up a relatively high proportion of deaths in some cases and may even appear among the top CODs in a population. Broad cause categories have some utility in identifying the overall epidemiological profile of a country but are less helpful for informing health policy decisions about priority actions to prevent deaths, which generally require specific diagnostic information.

Disaggregating residual causes

You should expect some residual CODs due to the practical limitations of applying VA – to limit the time of the interview, only causes with readily identifiable symptoms can be included. VA algorithms themselves cannot further "unpack" residual categories, but various external data sources are available and can be used to provide insight into what might be the leading specific causes that make up the residual categories in a particular VA site. This is important for deriving maximum policy benefit from the application of VA: if other NCDs, for example, appear among the leading CODs based on VA, then users will naturally want to know what these other NCDs are and, in particular, are there one or more of them that are likely to be particularly prevalent in the VA population but could not be identified from the VA.

Data on deaths in hospitals could be used to assess whether there are likely to be important and unrecognised CODs among these residual categories. Hospital death data generally provide a high level of COD detail and can provide important insights into what the leading CODs in the residual categories from the VAs might be. For example, after excluding the hospital deaths due to cancer that are identifiable through VA, hospital data on other cancers could be used to disaggregate the likely distribution of 'other cancers' in the VA data. In countries lacking advanced therapy, patients with cancer may be sent home to die. Under such circumstances, hospital morbidity data for cancers, or data from a local cancer registry, may be even more informative of the likely distribution of cancer deaths by site than mortality data. These data have the advantage of being local data on CODs for some sub-populations of the country. They have the disadvantage that they are likely to be biased towards COD patterns typically seen in hospital data and thus are not fully applicable for estimating CODs among the residual categories for VA (i.e. community) deaths.

Other external data sources can be used to disaggregate VA residual categories that have these biases. The GBD Study provides a readily accessible, comprehensive compilation of COD data for all countries. The GBD collaboration is the largest study to determine COD and is empirically based in available mortality and demographic statistics.[76] Because of the principle applied in the GBD to reallocate all 'garbage codes' including unknown CODs using established epidemiological methods,[77] the GBD provides a robust dataset to disaggregate residual CODs. Appendix 8 maps the World Health Organization (WHO) 2016 and SmartVA cause list to the GBD level 3 cause list. GBD level 3 provides a further breakdown of the three broad cause groups (GBD level 1) and the 21 cause categories in GBD level 2. The Institute for Health Metrics and Evaluation (IHME) provides useful visualisations and data downloads that explore the top GBD level 3 specific causes in SmartVA or WHO 2016 residual categories, by country, age and sex.[78,79]

Using IHME's tools, it is recommended that countries identify the top GBD level 3 causes within each of the VA residual categories (e.g. other cancers, other NCDs) in any VA COD list. Countries can use Appendix 8 to map the GBD level 3 causes to VA residual categories. For example, Table 9 shows the top five GBD level 3 causes within the SmartVA residual categories for low and middle-income countries. As shown in the Table, the most important specific conditions included under the residual category 'other cardiovascular diseases' are likely to be hypertensive heart disease, rheumatic heart disease, cardiomyopathies and aortic aneurysm (based on the GBD findings). Since this composition is likely to vary by location, the data should be analysed at the region or country level when using the GBD data to inform the further disaggregation of residual categories.

[76] GBD 2017 Causes of Death Collaborators. Global, regional, and national age-sex specific mortality for 282 causes of death, in 195 countries and territories, 1980–2017: A systematic analysis for the Global Burden of Disease Study 2017. The Lancet. 2018; 392(10159):1736–1788..
[77] Nagavi M. Algorithms for enhancing public health utility of national causes-of-death data. *Pop Health Met*. 2010; 8:9.
[78] vizhub.healthdata.org/gbd-compare/
[79] www.healthdata.org/

Table 9 Top five Global Burden of Disease (GBD) level 3 causes among SmartVA residual categories in low–middle countries, adults >15 years

Data source	SmartVA residual cause				
	Other cancers	**Other cardiovascular diseases**	**Other infectious diseases**	**Other injuries**	**Other non-communicable diseases**
GBD level 3 cause	Liver cancer	Hypertensive heart disease	Acute hepatitis	Conflict and terrorism	Alzheimer disease and other dementias
	Other neoplasms	Rheumatic heart disease	Meningitis	Adverse effects of medical treatment	Urinary diseases and male infertility
	Lip and oral cavity cancer	Other cardiovascular and circulatory diseases	Intestinal infectious diseases	Other unintentional injuries	Epilepsy
	Other pharynx cancer	Cardiomyopathy and myocarditis	Encephalitis	Other transport injuries	Alcohol use disorders
	Pancreatic cancer	Aortic aneurysm	Appendicitis	Exposure to mechanical forces	Haemoglobinopathies and haemolytic anaemias

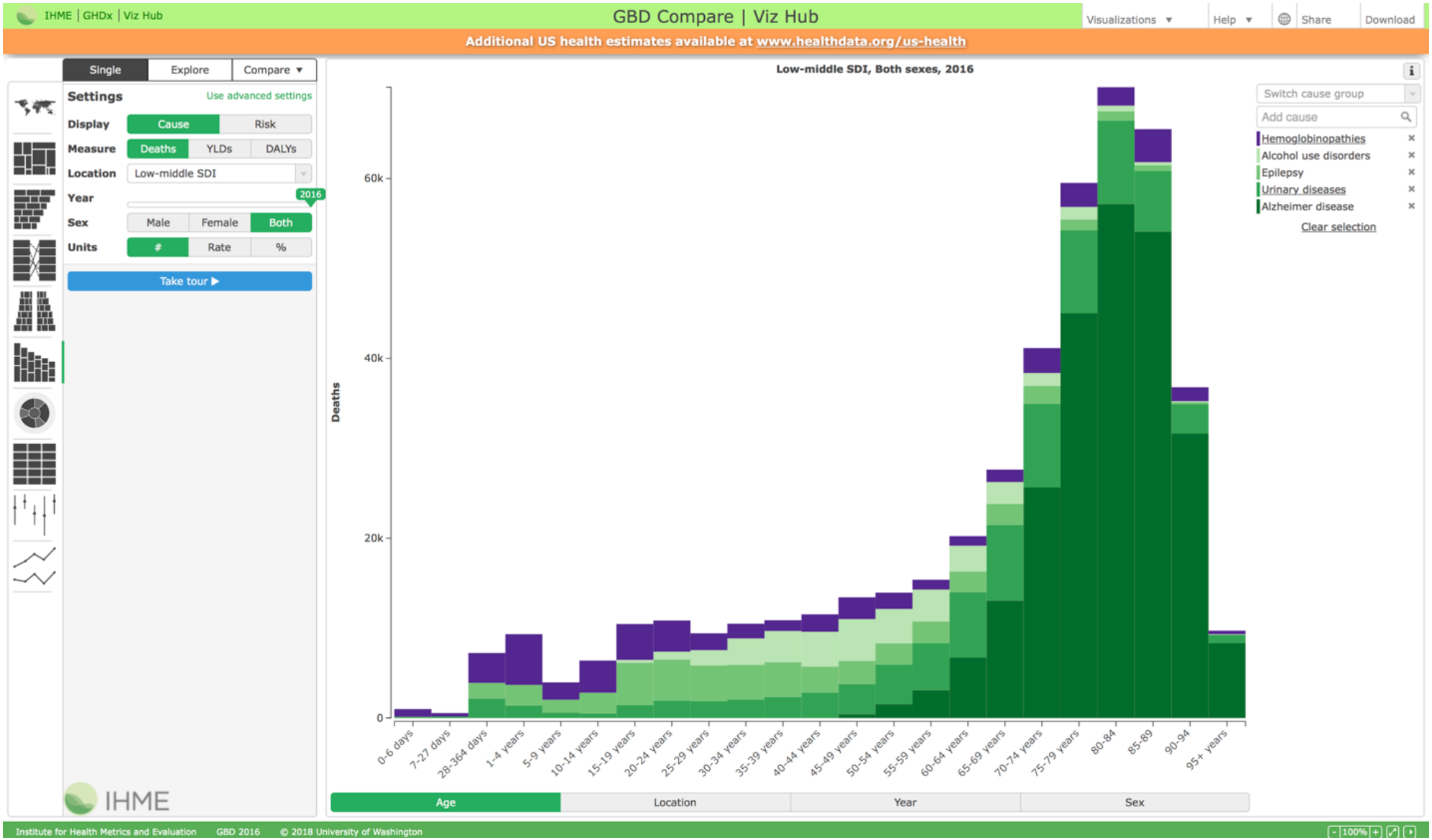
These GBD level 3 causes can then be subject to GBD visualisation tools. For example, if SmartVA were used and a high proportion of other NCDs were observed, the GBD tool can be used to input the appropriate GBD level 3 causes in Table 9 (Figure 34). As mentioned, this analysis should be done by country, since national-level GBD cause data and, increasingly, sub-national data, are available and updated every year.

By examining country data and GBD estimates, users can identify the major causes that are likely to lie within the VA residual categories that VA is not sensitive enough to capture. It is important to note that these are not VA COD predictions; the specific causes that MCCOD or GBD suggest are the main contributors to the residual categories that VA could not identify. In other words, they should be identified as indirect causes in the data, not direct causes that VA is able to diagnose. This is an important distinction when interpreting the data – the indirect causes are intended to give an approximate idea of the main causes included under each residual category, nothing more. As mentioned earlier, some of the data sources used to estimate these specific causes among the residual categories may be biased, especially in the case of MCCOD data from hospitals, as some causes are more likely to occur in hospital than in the communities in which VA is applied. This is not the case with the GBD data, where statistical methods have been applied to control for such biases and is likely a more useful data source to unpack these residual categories.

Finally, it is recommended that countries should not over-disaggregate the residual categories. Since the purpose of this post-hoc VA analysis is to try and identify what are likely to be the main diseases or injuries in each such category contributing to mortality in the VA population, criteria should be applied

to avoid attempting to identify the myriad of causes, all generally contributing only marginally to mortality, that comprise each residual category. As a rule, users should only attempt to identify causes among the residuals that account for about 1 per cent of deaths overall, since CSMFs lower than this threshold are likely to be uncertain and uninformative for deciding policy priorities.

Figure 34. Low and middle-income country top Global Burden of Disease (GBD) 2016 level 3 causes in SmartVA for 'other NCDs'



STEP 5: PRESENT THE MAIN FINDINGS OF YOUR VERBAL AUTOPSY DATA FOR POLICY ACTION

Previous steps 1–4 discussed how to assess the plausibility of the VA data, how to compile the data into useful formats and groupings according to the size of the dataset, and how to interpret such data. Step 5 shows you how to present the verbal autopsy (VA) data to policy-makers to maximise value and utility. If the VA data are not used to influence policy, there is little point in collecting them.

Some of the principles presented here are not unique to VA data, but they are important to follow to ensure that this new source of cause of death (COD) data is well received by those who need the information for developing evidence-based public health policies.

Data need to be interpreted and communicated in ways that produce knowledge, which can then lead to informed decision and action. We do not want policy-makers to struggle to understand the meaning and significance of the VA numbers due to poor-quality reports and graphics. As such, this step discusses the types of messages that are useful for policy and the kinds of illustrations that are effective in presenting the VA data in ways that make them relevant to the information needs of policy-makers.

This step deals with the following aspects of interpreting data for policy-making:

- What information from VAs do policy-makers need?
- What are the best type of visualisations to use to communicate the data?
- What are the principles for integrating the data with other sources for best results?

Presenting the message to policy-makers

If senior-level policy-makers have directed resources to implementing VA to scale in their countries, it is because they want to know about CODs in their populations but do not have enough information to inform public health planning. They will not need to know a lot about the VA method itself, which will be a matter for the technical experts and implementers. Rather, they will be looking for summaries of the VA findings in terms of their implications for policy. Generally, policy-makers require information that is clear, succinct, simple and – above all – actionable. In other words, VA data should be presented in a way that explicitly addresses the policy implications of the findings – not just as a descriptive report.

When sharing VA findings with policy-makers, it is helpful to adopt a combination of direct and indirect approaches using diverse communication media.

Direct approach to target policy-makers

Materials should be written in non-technical language and be relevant, succinct and action-oriented (see Appendix 12 for two examples). The most efficient vehicle for this purpose is a policy brief or report, which should comprise:

- A short presentation of the findings from VA directed to a non-specialised audience
- A succinct exploration of the challenges and lessons learned from the VA implementation
- An overview of policy options and advice.

The policy brief should be couched in positive terms, focusing on the value of the information on COD distributions and how the VA has helped address an urgent problem, namely the lack of data for public

health planning and management. It should highlight the policy relevance of the findings, particularly in the health sector, but also in other sectors – for example, efficiency savings through better allocation of resources to important health and development challenges (see Box 6).

Box 6. Components of a policy brief

Summary
One or two sentences that distil the key findings from VA implementation and provide an overview for busy people. It must be sufficiently interesting to entice the audience to read further. This section will be the first thing that readers will see (for some, it will be the only part they read) so it should be high in content but low on words.

Introduction
This section explains why VA has been implemented, describes the information gaps that it addresses, and explains the significance of and urgent need for reliable COD information for a population. For example, the introduction could emphasise the need to deal with emerging patterns of mortality, monitoring health progress and reporting on the Sustainable Development Goals. It gives a brief overview of the main findings.

Approach
This section should present an overview of the context – where, when and how VA was implemented. For example, it could state how VA is part of a broader strategy to improve birth and death registration. It should use non-technical language to explain how VA complements other information on mortality and CODs – for example, from hospitals. VA must be presented in terms of benefits and opportunities, not as an inferior method but as one that is entirely appropriate in circumstances where medical certification of cause of death is not an option.

Findings
The summary of the findings should provide visuals showing COD distributions in the areas where VA was implemented. It should focus on CODs in population groups of interest to policy-makers, such as infants and children, adolescents, women of reproductive age and older adults. It should highlight geographic disparities where available – for example, differences across administrative areas, between urban and rural populations, or other disparities as investigated as part of steps 1–3 of this guidance document.

Implications and recommendations
This section should be based on the VA findings but should also take the broader context into account – for example, how the VA outputs can complement and add value to other information on mortality in the country. The text should draw out the implications of the findings from policy, public health and community perspectives. It should also include some clear recommendations for health policy and planning. The recommendations should be relevant, credible and feasible. Since statistical organisations want to produce factual, unbiased information, recommendations should not go beyond what can be reasonably inferred from the VA data.

A policy brief should be brief (not more than 1500 words, or three pages) and based on and reference a longer, more detailed technical report that will include descriptions of purpose, implementation methods, detailed findings and implications. This detailed report will include references to key texts and technical standards.

Government officials may also want to include results in more comprehensive annual reports or other complementary reports for mortality analysis, in which case the data may need to be presented in a prescribed format. However, similar principles to those for a policy brief apply in terms of highlighting key results and the implications of these results on policy.

Indirect approaches that target secondary audiences that influence policy-makers

Indirect approaches can complement direct approaches. Secondary targets include academics and researchers, the media, health professional entities, nongovernment organisations (NGOs) and civil society.

Health professionals will have a good understanding of the need for COD data but may not know – or have confidence in – VA methods and their outputs, so they will be looking for reassurance that the method generates viable results. Technical audiences will respond well to detailed reports of methods and findings, but reaching out to non-technical audiences, such as civil society and the media, requires using a variety of communication methods, including video clips, human interest stories and social media. NGOs and civil society organisations who focus on interest groups can become powerful supporters if the findings are relevant to their audiences. Possible communication channels for different target audiences are included in 'Topic 5: Presentation, communication and dissemination of vital statistics, Sub-topic: Improving quality and presentation of civil registration and vital statistics data' on the CRVS Knowledge Gateway.[80]

Presenting, communicating and disseminating verbal autopsy data

Whether you are preparing visualisations for a policy brief or for another audience, there are some key considerations to ensure that the visualisations you include have the effect you want. For instance, what is appropriate to include in a policy brief is different from what you would want to have in a professional journal or PowerPoint presentation. The types of visualisations and communication means to use with different audiences are discussed in 'Topic 5: Presentation, communication and dissemination of vital statistics, Sub-topic: Improving quality and presentation of civil registration and vital statistics data' in the CRVS Knowledge Gateway.[81]

Visualising charts and tables for a policy brief

If you are preparing a policy brief and are targeting the policy-makers themselves, your selection of graphical material could, for example, comprise some of the following:

- A map of the areas targeted for the VA or the areas where the VA instrument has been piloted
- A basic summary table showing the proportion of people dying outside hospitals in the VA areas, the number of VAs collected or to be collected in a given period in each area
- A pie or bar chart with all the VAs broken down into neonatal, child and adults
- If applicable, another pie or bar chart showing the total VAs by different language/ethnic groups
- Two bar charts of the 10–20 leading causes by sex, ordered by the rankings, one for children and one for adults (see Step 4.1) and an additional bar chart for neonatal deaths.

In general, a policy brief, as stated above, should not exceed three pages, which means that the limited space will restrict the number of figures that can be included. Hence, it is important to carefully select

[80] crvsgateway.info
[81] Ibid.

these. Some of the graphs for VA included in these guidelines may be useful starting point for these figures.

In the final section discussing the policy implications of knowing the CODs for those who die outside hospital, it would be appropriate to have a table or bar chart comparing the 10 leading CODs in hospitals and in communities. Given that the age structure may also vary significantly between the two populations, this could be shown in form of two death pyramids or in a bar chart with three age groups for each population (see Step 3).

Basic guidelines for visualising statistics, including examples of good and bad charts and tables, can be found in 'Topic 5: Presentation, communication and dissemination of vital statistics, Sub-topic: Improving quality and presentation of civil registration and vital statistics data' on the CRVS Knowledge Gateway.[82]

Integrating verbal autopsy and medical certification of cause of death data

For countries to understand their overall national mortality statistics and to be able to track national and international targets, different sources of mortality data will need to be integrated. The quality, completeness and accuracy of the different datasets (e.g. VA, medical certification of cause of death [MCCOD]) need to be carefully examined and adjusted based on known biases. If the integrated data sources include deaths from different populations (e.g. community deaths vs hospital deaths), the data will need to be weighted according to the fraction of all deaths happening in these discrete populations.

The data post-aggregation will also need to be examined to ensure overall mortality statistics are plausible, based on principles outlined in the ANACONDA guidance and software.[83] This is an iterative process that aims to produce national mortality statistics, and helps users to better understand the quality of different data sources and to put in place actions to improve them.

This section provides some general analytical guidance and principles designed to assist countries when integrating MCCOD and VA CODs.

For countries to comprehensively monitor trends in COD patterns in their populations, such as is required to monitor progress towards the Sustainable Development Goals, COD information for the whole population, not just those served by MCCODs in hospitals, is required. National-level monitoring requires national-level data – that is, information on CODs that pertains to the entire country. This means that information on CODs in hospitals (in principle, correctly certified by physicians) needs to be combined with COD information on home deaths obtained from VA.

This integration assumes a large number of VAs from community deaths are available. Such integration is not recommended if VA is at early stages of implementation.

Analyse the data sources to be integrated

These guidelines outline steps for analysing the plausibility of CSMF from VA alongside other mortality data. It is important to review the VA data and other mortality data sources separately to identify the

[82] crvsgateway.info
[83] ANACONDA mortality data quality assessment tool (crvsgateway.info/ANACONDA-Mortality-Data-Quality-Assessment-Tool~686)

strengths and limitations of each data source. Interrogation of the data should broadly follow the assessment criteria included under steps 1-4 in these guidelines,[84] and focus on the following questions:

- How complete is the coverage of deaths from each data source?
- How well do the COD patterns represent the different data sources?
- What are the likely main biases affecting the accuracy and representativeness of the cause-specific mortality fractions (CSMFs) from each of the different data sources; how common are unknown, undetermined or unusable causes in each dataset?
- How plausible are the CSMFs obtained from each dataset? Are there any obvious problems with the CSMFs, such as CSMFs for a cause that appear too high or too low, based on a general understanding of the epidemiological and development profile of the population?

Once these separate analyses have been done, the data sources used to obtain consolidated COD patterns for a national population can be harmonised. However, if there are serious doubts about the quality or representativeness of either of the data sources, it may not be wise to integrate them, or it may be necessary to choose a higher level of aggregation of CODs for the integration.

Decide on the cause list and level of aggregation for the integration of data

Integration of VA and MCCOD data requires that the same cause list be used for both data sources. To be able to compare and consolidate data from two or more different sources, the COD list can only be as detailed as the level of the lowest common denominator of causes that appear in all data sources. Each MCCOD death will, in principle, have an International Classification of Diseases–coded COD, which would need to be mapped to and aggregated to be identical to either the SmartVA or WHO VA cause list, depending on which VA diagnostic platform was used (see Appendix 2 and 3). Alternatively, MCCOD data and VA data could both be mapped to a different cause list – for example, Global Burden of Disease (GBD) level 3 (see also Appendix 8).

If there are queries about the quality of MCCOD data, VA and MCCOD data can be mapped at higher levels of cause aggregation. For example, this could be done by aggregating causes with a similar aetiology or for which prevention efforts are likely to be broadly similar, such as:

- HIV/AIDS/tuberculosis; vaccine preventable diseases; pneumonia and diarrhoea; other communicable, maternal, neonatal and nutritional diseases
- Cardiovascular diseases
- Chronic respiratory diseases
- All cancers
- Other non-communicable diseases
- Injuries.

An even broader grouping of causes, such as GBD Groups I, II and III could be used where:

- Group I includes communicable, maternal, neonatal and nutritional diseases
- Group II includes non-communicable diseases
- Group III includes all injuries.

Confining the COD analysis to broader cause groups (e.g. all cancers) minimises the impact of diagnostic errors in the component datasets, but equally reduces the policy value of the integrated COD dataset.

[84] For MCCOD data, the ANACONDA tool can be used to assess data quality. For VA data, these VA interpretation guidelines and accompanying tool (VIPER) can be used to assess the plausibility of results.

This trade-off between diagnostic comparability across different data sources and the need for more epidemiological specificity to guide policy decisions is a critical first step in the integration of various COD datasets. Deciding which cause list to use should first consider epidemiology and likely diagnostic accuracy of causes from specific sources such as MCCOD and VA. Decisions can also be based on the level of cause detail required by policy-makers and purpose(s) of the data.

All cases of VA–MCCOD data integration should routinely separate tabulation and comparison of CSMFs arising from the two data sources using the same cause list. This is especially so when COD data quality is likely to be questionable given current data collection practices, or where completeness is low.

Calculate overall consolidated CSMFs from MCCOD and VA

Calculating an overall CSMF by integrating VA and MCCOD data requires knowledge of the:

- Total number of deaths in the population of interest
- Number of these deaths that occurred within and outside hospitals (i.e. at home)
- Actual (rather than reported) number of deaths that occurred within each age group, separately for VA and MCCOD sources, if available.

The approach to calculating a CSMF by integrating MCCOD and VA data depends on the availability of data about the total number of deaths. Such data should be available from a complete routine death reporting or notification system, such as a vital registration system.

There are two broad approaches to integrating CSMFs from the different sources, depending on the level of death registration completeness in a population:

- Death registration completeness[85] greater than 95 per cent
- Death registration completeness above 50 per cent but less than 95 per cent.

Death registration completeness greater than 95 per cent

If there is a death registration system (or another source of routine death reporting/notification) that records at least 95 per cent of all deaths in that population and includes information on the place (hospital/non-hospital) and age of each death, then this data source can be used for the total number of deaths.

CSMFs can then be estimated for each sex and five-year age group using the following approach:

1. Number of non-hospital deaths from a specific cause = number of non-hospital deaths multiplied by the CSMF from the VAs
2. Number of hospital deaths from a specific cause = number of hospital deaths multiplied by the CSMF for the same cause from MCCOD
3. Overall CSMF for a specific cause = (sum of non-hospital and hospital deaths from a specific cause) divided by total deaths.

Conceptually, this is the most appropriate way to calculate age–sex-specific integrated CSMFs, but it may not be possible in most cases because of small numbers of deaths, especially from VAs. Small numbers of deaths could easily lead to large, spurious, implied CSMFs in a given 5-year or even 10-year age group. In cases where the numbers of VAs are comparatively small, and hence large stochastic variations in the CSMFs are likely, it is recommended that the integration of VA and MCCOD CSMFs be done for broader

[85] This refers to completeness of all-cause mortality, rather than completeness of VA death reporting.

age groups that are less likely to be affected by variation due to small numbers of deaths.[86] An example of broader age groups is neonatal, 28 days – 11 years, 12–44 years, 45–64 years and 65+ years; this approach assumes that true CSMFs do not vary significantly among adjacent 5-year ager groups, therefore, it is not recommended to use age groups broader than these.

For example, if a population has an ischemic heart disease (IHD) CSMF for males aged 45–64 years of 15 per cent according to MCCOD data, and 25 per cent according to VA data, and a total of 1000 hospital and 2000 non-hospital deaths for males aged 55–59 years according to vital registration data, then the overall IHD CSMF for males aged 55–59 years would be (following the steps above):

1. Number of non-hospital deaths from IHD for males 55–59 = 2000 × 25% = 500 deaths
2. Number of hospital deaths from IHD for males 55–59 = 1000 × 15% = 150 deaths
3. Overall CSMF for IHD for males 55–59 = (500+150) / 3000 = 21.7%.

This approach is similar to that used in a large nationally representative study of COD in Thailand.[87] Cause-specific death rates (i.e. number for deaths from a specific cause divided by population multiplied by 1000 or 100 000) can also be derived using this approach.

Death registration completeness above 50 per cent but less than 95 per cent

Where death registration (or routine death reporting/notification) completeness is less than 90–95 per cent, it is difficult to accurately estimate overall CSMFs by age because there is insufficient information to be able to reliably estimate the total of number deaths in each age group.[88] However, CSMFs can still be estimated for all ages based on the estimate of VA reporting completeness calculated in Step 2 (and Appendix 7) , as long as completeness of death reporting for VAs is at least 50 per cent.[89] This information can be used to calculate the total number of deaths (and the number of hospital and non-hospital deaths) in a population. This should be calculated separately for males and females. Step 2 and Appendix 7 of these guidelines provides more detail of how to calculate the total number of deaths and total number of non-hospital deaths when death registration completeness is known to be less than 95 per cent.

For example, if a population has a CSMF for stroke among males of all ages of 12 per cent according to MCCOD data, and 18 per cent according to VA data, and a total of 11 000 hospital and 24 000 non-hospital deaths for males of all ages according to vital registration data, then the overall IHD CSMF for males would be (following the steps above):

1. Number of non-hospital deaths from stroke for males (all ages) = 24 000 × 18% = 4320 deaths
2. Number of hospital deaths from stroke for males (all ages) = 11 000 × 12% = 1320 deaths
3. Overall CSMF for IHD for males (all ages) = (4320 + 1320) / (24 000 + 11 000) = 5630 / 35 000 = 16.1%.

Although integration by age group is not recommended in such cases, VA CODs and MCCODs should be presented separately for broad age groups to provide some information about cause patterns in these

[86] These age groups align with the VA questionnaire age groups. If VA deaths are only available for ages 10–14 years, then use 40 per cent of these deaths in the 28 days to 11 years age group and 60 per cent in the 12–44 age group.

[87] Porapakkham et al. Estimated causes of death in Thailand, 2005: Implications for health policy. *Pop Health Metr*. 2010; 8:14. This study also adjusted MCCOD and VA data for quality using a misclassification study.

[88] Completeness of VA reporting can only be estimated for all ages, not for specific age groups.

[89] If completeness of death reporting for VAs is less than 50 per cent, it is not recommended to estimate total deaths.

age groups. As shown in Step 4, COD patterns by age are likely to differ significantly between VA and MCCOD data.

If death reporting is incomplete but the VA data are nationally representative, then the overall CSMFs for each sex and broad age group can be applied to the GBD total estimated deaths by sex and five-year age group using the method above for death reporting completeness greater than 95 per cent.

Conclusion

Integration of VA and MCCOD should be conducted with due consideration of the caveats outlined in this section, especially the completeness and representativeness of the data. If VA death reporting is incomplete (as assessed earlier) or from clusters that are not representative of the population, they may provide a biased representation of non-hospital deaths. If completeness of VA death reporting is above 50 per cent but less than 95 per cent of non-hospital deaths, reporting of the final CSMFs should state that the incompleteness of death reporting may lead to incorrect CSMFs if the cause patterns of non-hospital deaths without a VA differ from those with a VA. If VA death reporting is less than 50 per cent complete (see Step 2), then VA data should not be integrated with MCCOD data. Furthermore, if VA death reporting is from non-representative clusters, this should also be reported with the final results. Another factor to consider is relevant for integration of VA and MCCOD data at the subnational level. Hospital deaths should be only of usual residents of the population; where hospital data include non-residents, VA and MCCOD should be presented separately.

SUMMARY AND RECOMMENDATIONS

Verbal autopsy (VA) is an important source of information on causes of death (CODs), especially in populations where a large proportion of deaths occur outside hospitals and do not have a physician to complete a medical certificate of COD. As a relatively new source of routinely collected information, it is particularly important that the VA data are analysed to assess plausibility of cause-specific mortality fractions, given other known factors in the country and in the VA population. During the earlier stages of VA implementation, the data should be analysed often. During later stages, the data should be analysed ideally as part of routine monitoring (two or four times each year), and COD statistics compiled and assessed once a year.

PREPARATION FOR VERBAL AUTOPSY (VA) ANALYSIS AND INTERPRETATION

- **Establish a small group for assessing plausibility of causes of death (CODs).** For example, departments of health, statistics organisations, public health institutes, hospital managers, local World Health Organization representatives. This group might be members of the technical working group reporting to a high-level mortality committee in the country.

STEP 1: UNDERSTAND THE VA POPULATION

- **Assess the representativeness of your VA data**. If not based on a representative sample using an appropriate statistical method, assess the representativeness of the VA data according to:
    - geographical coverage
    - population age distribution
    - socioeconomic characteristics of the population
    - epidemiological profile.
- **Select an appropriate comparator dataset.** This might be a national or sub-national dataset. Assess the extent to which the population that these data come from are similar/dissimilar to the VA data. This will affect the interpretation of this data. If no quality dataset is available, consider using the Global Burden of Disease (GBD) estimates as a guide.

STEP 2: ESTIMATE THE COMPLETENESS OF DEATH REPORTING FOR VA DATA

- **Assess how complete your death reporting for VA is for your VA population(s)**. What is the completeness of VA death reporting as a proportion of all deaths and community deaths? Is completeness of VA death reporting different across the sites where VA is being implemented? How might the populations missed by VA death reporting differ to those where death reporting has occurred, and what are the implications on the COD patterns from VA? Describe how notification/registration practices and other external factors may have contributed, and how the situation could be improved.

STEP 3: ASSESS THE PLAUSIBILITY OF THE AGE–SEX DISTRIBUTION OF DEATH FROM VA

- **Assess whether the age–sex distribution of death is plausible.** This is based on the information on the VA population from Step 1 and completeness of death reporting for VA in Step 2. Compare the age–sex distribution of death with other datasets, considering the similarity or difference in the characteristics of the population. In the VA data, which age groups are likely to be missing deaths? How might this affect the COD distribution in the VA population?

STEP 4: CONDUCT A PLAUSIBILITY ANALYSIS ON THE CSMF FROM VA DATA

- **Conduct a review of COD data to identify what is clearly wrong.** For example, fraction of causes or patterns of causes that are very different from available data in the country or region. Ensure you understand the limitations of different data sources being used as comparator. For example, GBD are modelled estimates, HDSS provide longitudinal information in specific populations not representative of other areas, and hospital death data will show different patterns of causes to those of community deaths and may be incomplete if only public facilities are included.
- **Conduct an analysis appropriate to the stage of implementation/number of VAs available**. Understand the limitations of the VA analysis based on the stage of implementation (pilot, demonstration, scale-up) and the number of VAs available. For larger datasets, consider a more detailed analysis by breaking down by different age groups and by location.
- **Consider the main risk factors for diseases and their prevalence in the VA population.** Do the VA results make sense considering the major risk factors in the country/VA population?
- **Consider the reasons for unusual results.** If results do not seem plausible, consider questionnaire translation, staff training and capacity, and community acceptability towards VA data collection. This is particularly important in the early stages of the VA implementation, but issues of staff turnover, refresher training and monitoring may be an ongoing concern.
- **Review undetermined CODs**. Analyse the age groups where the undetermined CODs are occurring and whether they exceed a threshold of 20 per cent in any location. This may determine if there are systematic problems with VA implementation or whether support needs to be offered to particular sites.
- **Investigate the possible causes underlying VA residual categories.** Where residual ('other') categories of COD constitute a high CSMF in your VA data, investigate the possible causes that would come under these categories by examining external data, such as country MCCOD data or GBD data.
- **Assess trends in VA data**. As more VA data become available, it is possible to track trends in the CSMF and in the rates for different diseases. This should be done for monitoring purposes and to understand whether programs are effectively tackling the main CODs. It is important to understand potential confounders to trend analysis – for example, disease epidemics, immigration or changes to diagnostic definitions of diseases. Since computer algorithms for assigning COD are subject to updates and improvements, also consider if changes in trends are due to changes in the algorithm or simply due to comparison of results from different algorithms over time.

STEP 5: PRESENT THE MAIN FINDINGS OF YOUR VA DATA FOR POLICY ACTION

- **Consider the policy implications of your results**. Your VA results and results from other mortality data should be used to make decisions about health programming and resource allocation. Presenting data to emphasise key messages to policy-makers, producing more detailed reports for technical audiences and employing innovative ways of disseminating information to diverse stakeholders will assist in developing programs that are effectively targeted at the major causes of death and disease.
- **Consider whether VA COD results can be combined with other sources of mortality to produce national mortality statistics.** Once a separate and thorough analysis of the quality of different mortality datasets has been conducted, assess whether the data sources should be integrated. National mortality statistics can be used to monitor national and international targets such as the Sustainable Development Goals.

Appendix 1 Quick reference guide to SmartVA and WHO2016 VA instruments

Table 11. Elements of SmartVA and WHO2016 instruments

Element	SmartVA	WHO2016
Data collection at interview	Paper Mobile devices	Paper Mobile devices
Questionnaire modules	*General info / demographics* *Neonatal* *Child* *Adult* *Health service use before death* *Open narrative check list (key words taken from an open narrative by the respondent)* *Questions on civil registration of death*	*General info / demographics* *Neonatal* *Child* *Adult* *Health service use before death* *Health care treatment & experience before death* *Open narrative check list (key words taken from an open narrative by the respondent)* *Open narrative free text* *Questions on civil registration of death*
Data collection platform	Open Data Kit (ODK)	Open Data Kit (ODK)
Diagnostic algorithms	Tariff2.0	InterVA5 InSilicoVA Tariff2.0 Physician review
Number of target causes Stillbirths Neonatal Maternal Communicable Non-communicable External	46 causes 1 cause 5 causes 1 cause 11 causes 19 causes 9 causes	63 causes 2 causes 7 causes 9 causes 14 causes 20 causes 11 causes
Key publications and link to guidance documents	Website for software: • www.healthdata.org/verbal-autopsy/tools Publications: www.healthdata.org/verbal-autopsy/publications Manuals and user guides • SmartVA interviewer's manual www.crvsgateway.info/file/174/59 • SmartVA technical guide www.crvsgateway.info/file/175/60	• WHO2016 guidance document (interviewer's manual and technical guide) www.who.int/healthinfo/statistics/verbalautopsystandards/en/ • InterVA www.interva.net • InSilico cran.r-project.org/web/packages/InSilicoVA/index.html
Computing platform compatibility	Windows, Linux	Windows, Mac OS X, Linux
Technical advisory mechanism	University of Melbourne, Institute for Health Metrics and Evaluation	World Health Organization Verbal Autopsy Reference Group

Appendix 2: Cause lists for SmartVA and the International Classification of Diseases

Table 12. Cause of death list for SmartVA with corresponding ICD-10 codes (adult)

Text for Smart VA cause (ADULT)	ICD-10 code (to ICD)	ICD-10 codes (from ICD-10)
Diarrhoea/dysentery	A09	A00–A09
Tuberculosis	A16	A15–A19
AIDS	B24	B20–B24
Malaria	B54	B50–B54
Other infectious diseases	B99	A10–A14, A20–B19, B25–B49, B55–B99
Esophageal cancer	C15	C15
Stomach cancer	C16	C16
Colorectal cancer	C18	C18–C21
Lung cancer	C34	C34
Breast cancer	C50	C50
Cervical cancer	C53	C53
Prostate cancer	C61	C61
Leukemia/lymphoma	C96	C81–C85; C91–C96
Other cancers	C76	C00–C14, C17, C22–C33, C35–C49, C51–C52, C54–C60, C62–C80, C86–C90, C97–D48
Diabetes	E14	E10–E14
Other cardiovascular diseases	I99	I00–I19 I26–I59, I70–I99
Ischemic heart diseases	I24	I20–I25
Stroke	I64	I60–I69
Pneumonia	J22	J10–J22, J85
Chronic respiratory diseases	J44	J40–J46
Cirrhosis	K74	K70–K76
Chronic kidney disease	N19	N17–N19
Maternal	O95	O00–O99
Undetermined	R99	R00–R99
Road traffic	V89	V01–V89
Falls	W19	W00–W19
Drowning	W74	W65–W74
Fires	X09	X00–X19
Bite of venomous animal	X27	X20–X29
Poisonings (accidental)	X49	X40–X49
Suicide (intentional self-harm)	X84	X60–X84
Homicide (assault)	Y09	X85–Y09
Other injuries	X58	S00–T98, V90–V99, W20–W64, W75–W99, X30–X39, X50–X59, Y10–Y98
Other non-communicable diseases	UU1*	All other ICD-10 codes NCDs#

Notes: Column 1 lists the Smart VA cause text; column 2 lists the ICD-10 codes that would be used if the condition labelled by column 1 were coded to ICD-10; column 3 lists the ICD-10 categories that need to be grouped to match the content of the relevant VA entity.
This code is specific to SmartVA.
* This other non-communicable diseases group covers all non-communicable conditions/diseases that could not be assigned to a specific non-communicable disease.

Table 13. Cause of death list for SmartVA with corresponding ICD-10 codes (child)

Text for SmartVA cause (CHILD)	ICD-10 code (to ICD)	ICD-10 Codes (from ICD-10)
Diarrhoea/dysentery	A09	A00–A09
Sepsis	A41	A40–A41
Haemorrhagic fever	A99	A92–A99
Measles	B05	B05
AIDS	B24	B20–B24
Malaria	B54	B50–54
Other infectious diseases	B99	A10–A39, A42–A91, B00– B04, B06–B49, B55–B99
Cancers	C76	C00–D48
Meningitis	G03	G00–G03, A39,A87
Encephalitis	G04	G04, A83–A86
Cardiovascular diseases	I99	I00–I99
Pneumonia	J22	J10–J22, J85
Digestive diseases	K92	K00–K93
Undetermined	R99	R00–R99
Road traffic	V89	V01–V89
Falls	W19	W00–W19
Drowning	W74	W65–W74
Fires	X09	X00–X19
Bite of venomous animal	X27	X20–X29
Poisonings	X49	X40–X49
Homicide	X09	X85–Y09
Other defined causes of child deaths	UU2*	All other ICD-10 codes#

* This code is specific to SmartVA.

This other defined causes of child deaths group covers all diseases/conditions that could not be assigned to the above child cause list for SmartVA.

Table 14. Cause of death list for SmartVA with corresponding ICD-10 codes (neonate)

Text for SmartVA (NEONATE)	ICD-10 code (to ICD)	ICD-10 code (from ICD-10)
Preterm delivery	P07	P05–P07
Birth asphyxia	P21	P20–P22
Pneumonia	P23	P23–P25,J10–J22
Meningitis/sepsis	P36	P36, G00–G04, A39, A87
Stillbirth	P95	P95
Congenital malformation	Q89	Q00–Q99
Undetermined	R99	All other ICD-10 codes

Appendix 3: Cause lists for World Health Organization 2016 and International Classification of Diseases

Table 15. Cause of death list for WHO2016 with corresponding ICD-10 codes

WHO VA cause category	*ICD-10 code (to ICD-10)*	*ICD-10 codes (from ICD-10)*
01 Infectious and parasitic diseases		
01.01 Sepsis	A41	A40-A41
01.02 Acute respiratory infection, including pneumonia	J22/J18	J00-J22
01.03 HIV/AIDS related death	B24	B20-B24
01.04 Diarrhoeal diseases	A09	A00-A09
01.05 Malaria	B54	B50-B54
01.06 Measles	B05	B05
01.07 Meningitis and encephalitis	G03;G04	A39; G00-G05
01.08 Tetanus	A35 (obstetrical A34)	A33-A35
01.09 Pulmonary tuberculosis	A16	A15-A16
01.10 Pertussis	A37	A37
01.11 Haemorrhagic fever	A99	A92-A99
01.12 Dengue fever	A90;A91	A90-A91
01.99 Other and unspecified infectious disease	B99	A17-A19; A20-A38;A42-A89; B00-B19; B25-B49; B55-B99
02 Neoplasms		
02.01 Oral neoplasms	C06	C00-C06
02.02 Digestive neoplasms	C26	C15-C26
02.03 Respiratory neoplasms	C39	C30-C39
02.04 Breast neoplasms	C50	C50
02.05 Female reproductive neoplasms	C57	C51-C58
02.06 Male reproductive neoplasms	C63	C60-C63
02.99 Other and unspecified neoplasms	C80	C07-C14; C40-C49; C60-D48
03 Nutritional and endocrine disorders		
03.01 Severe anaemia	D64	D50-D64
03.02 Severe malnutrition	E46	E40-E46
03.03 Diabetes mellitus	E14	E10-E14
04 Diseases of the circulatory system		
04.01 Acute cardiac disease	I24 (acute ischemic)	I20-I25
04.02 Stroke	I64	I60-I69
04.03 Sickle cell with crisis	D57	D57
04.99 Other and unspecified cardiac disease	I99	I00-I09; I10-I15; I26-I52; I70-I99
05 Respiratory disorders		
05.01 Chronic obstructive pulmonary disease (COPD)	J44	J40-J44
05.02 Asthma	J45 (J46)	J45-J46
06 Gastrointestinal disorders		
06.01 Acute abdomen	R10	R10

06.02 Liver cirrhosis	K74	K70-K76
07 Renal disorders		
07.01 Renal failure	N19	N17-N19
08 Mental and nervous system disorders		
08.01 Epilepsy	G40	G40-G41
98 Other NCDs		
98 Other and unspecified non-communicable disease	R99	D55-D89; E00-E07; E15-E35; E50-E90; F00-F99; G06-G09; G10-G37; G50-G99; H00-H95; J30-J39; J47-J99; K00-K31; K35-K38; K40-K93; L00-L99; M00-M99; N00-N16; N20-N99; R00-R09; R11-R94
09 Pregnancy-, childbirth and puerperium-related disorders		
09.01 Ectopic pregnancy	O00	O00
09.02 Abortion-related death	O06	O03-O08
09.03 Pregnancy-induced hypertension	O13 (or O15 for eclampsia)	O10-O16
09.04 Obstetric haemorrhage	O46 (ante partum) O72 (post partum)	O46; O67; O72
09.05 Obstructed labour	O66	O63-O66
09.06 Pregnancy-related sepsis	O75.3 (ante partum) O85 (post partum)	O75.3; O85
09.07 Anaemia of pregnancy	O99	O99.0
09.08 Ruptured uterus	O71	O71
09.99 Other and unspecified maternal cause	O05	O01-O02; O20-O45; O47-O62; O68-O70; O73-O84; O86-O99
10 Neonatal causes of death		
10.01 Prematurity	P07	P05-P07
10.02 Birth asphyxia	P21	P20-P22
10.03 Neonatal pneumonia	P23	P23-P25
10.04 Neonatal sepsis	P63	P36
10.05 Neonatal tetanus	A33	A33
10.06 Congenital malformation	Q89	Q00-Q99
10.99 Other and unspecified perinatal cause of death	P96	P00-P04; P08-P15; P26-P35; P37-P94; P96
11 Stillbirths		
11.01 Fresh stillbirth	P95	P95
11.02 Macerated stillbirth	P95	P95
12 External causes of death		
12.01 Road traffic accident	V89	V01-V89
12.02 Other transport accident	V99	V90-V99
12.03 Accidental fall	W19	W00-W19
12.04 Accidental drowning and submersion	W74	W65-W74
12.05 Accidental exposure to smoke, fire and flames	X09	X00-X19
12.06 Contact with venomous animals and plants	X29	X20-X29

12.07 Accidental poisoning and exposure to noxious substance	X49	X40-X49
12.08 Intentional self-harm	X84	X60-X84
12.09 Assault	Y09	X85-Y09
12.10 Exposure to force of nature	X39	X30-X39
12.99 Other and unspecified external cause of death	X59	S00-T99; W20-W64; W75-W99; X50-X59; Y10-Y98
99 Unknown		
99 Cause of death unknown	R99	R95-R99

Appendix 4: Description of automated cause of death assignment algorithms

The SmartVA questionnaire collects only the information required by the Tariff method that uses SmartVA-Analyze software.[90] The SmartVA questionnaire and application have also been adapted to be used by physicians to help them assign a cause of death (COD) for people who are not their patients and for whom there are no medical records or reliable information (see Appendix 5).

The World Health Organization (WHO) 2016 verbal autopsy (VA) questionnaire,[91] asks several questions about symptoms, to run any one or all of the three automated diagnostic methods currently available:

- Tariff
- InterVA
- InSilicoVA.

This could lead to three different diagnoses of the most probable COD.

Tariff algorithm

Tariff is a simple method that assigns a score or 'tariff' to an item in the questionnaire according to the number of times a respondent answered 'yes' to a symptom question for a COD.[92]

In other words, the Tariff method identifies the strength of association between a symptom and a specific COD, based on the 'signal to noise' ratio (e.g. how closely a symptom was linked to a specific cause ('signal') compared with how frequently it was associated with other, unrelated causes ('noise'). That is, certain symptoms (such as cough) will be statistically associated with certain diseases (such as major respiratory diseases) more than with other conditions (such as heart attacks). Tariff scores are calculated for an individual death by applying the pattern of responses from the VA interview to a known matrix of tariff scores, where the true COD is known (using the Population Health Metrics Research Consortium [PHMRC] Gold Standard VA dataset) and a COD is then assigned to each individual death by ranking the tariff scores based on reported symptoms.

The method is entirely data-driven and does not rely on external expert opinion about symptom–cause associations. Free open-source software to collect (SmartVA Instrument) and analyse (SmartVA-Analyze) VA responses, as well as essential training materials including the interviewer's manual and user guides are available (see Appendix 1).

Tariff produces undetermined CODs if the uncertainty for assigning a COD is too high and a predefined threshold for causes in the SmartVA cause list is not met (Figure 35). However, the SmartVA software for Tariff also produces outputs that redistribute the undetermined COD among the causes that can be diagnosed using SmartVA (Appendix 2) (Figure 36). This is done in two ways.[93]

Firstly, a VA with an undetermined COD is fractionally distributed among all VA causes, with weights proportional to the likelihood that the particular cause was assigned to undetermined in the gold standard database. The gold standard database is the dataset on which the tariff analysis is based and includes VAs done on 12 542 deaths for which the true COD was known.[94] Certain deaths (such as pneumonia) are

[90] www.healthdata.org/verbal-autopsy/tools
[91] www.who.int/healthinfo/statistics/verbalautopsystandards/en/
[92] Serina P et al. Improving performance of the Tariff method for assigning causes of death to verbal autopsies. *BMC Med*. 2015; 13:291.
[93] Ibid.
[94] Murray CJL et al. Population Health Metrics Research Consortium gold standard verbal autopsy validation study: Design, implementation, and development of analysis datasets. *Pop Health Metr*. 2011; 9:27.

more likely to return an undetermined COD because this cause is inherently more difficult to diagnose using VA methods than a cause such as road traffic accident. The redistribution addresses this by applying a higher weighting to such deaths. Secondly, this fractional redistribution weight is averaged with a proportional redistribution weight selected according to the Global Burden of Disease age and sex cause of death distribution for the country.[95]

Figure 35 Andhra Pradesh (PHMRC) SmartVA output with undetermined causes of death

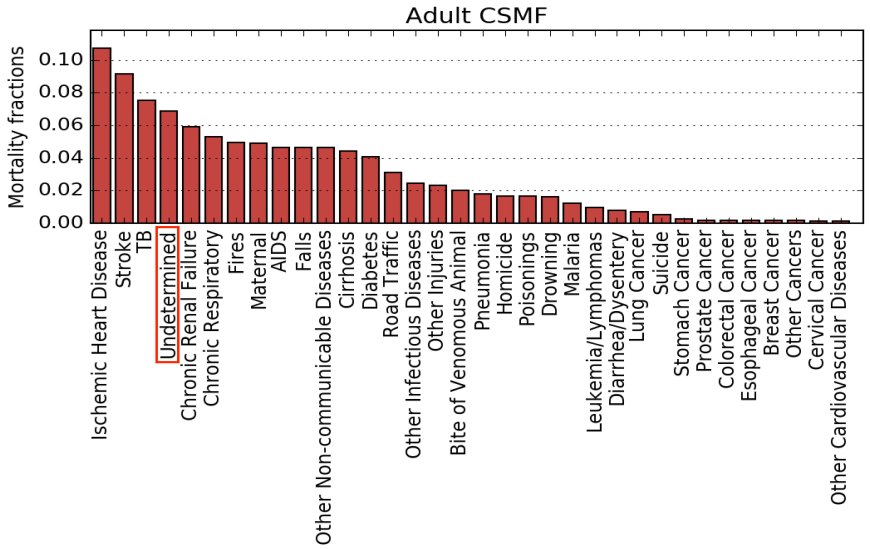
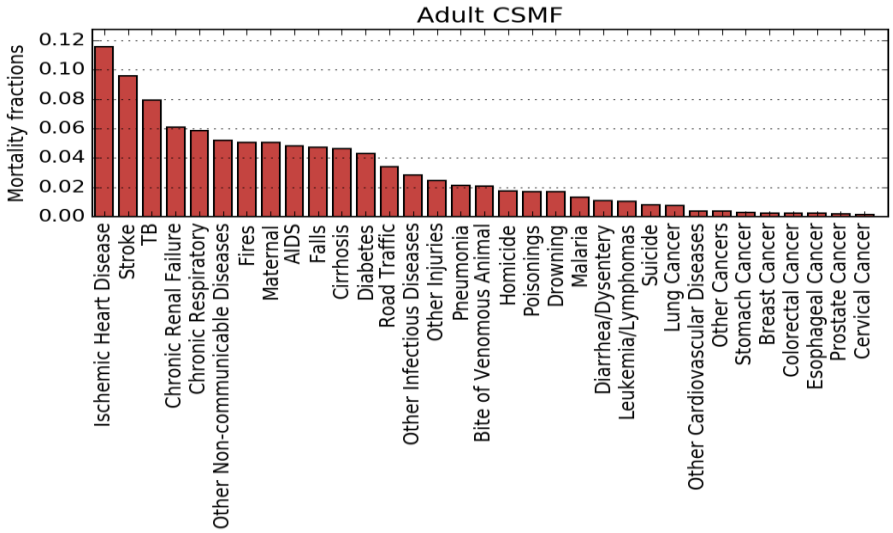


Figure 36 Andhra Pradesh (PHMRC) SmartVA output with undetermined causes of death redistributed



Source: Population Health Metrics Research Consortium[96]

[95] www.healthdata.org/gbd

[96] Population Health Metrics Research Consortium. *Population Health Metrics Research Consortium gold standard verbal autopsy data 2005–2011*. Seattle: PHMRC; 2013.

The SmartVA software also provides a 'likelihoods' file in its output. For each death, one to three CODs are provided with a corresponding 'likelihood' – very likely, likely, somewhat likely and possible. The output includes the most important symptom for each COD and the endorsed symptoms for the whole questionnaire. Users can filter the undetermined COD to view all the symptoms endorsed for these records. This tool is being used by physicians in the Philippines to, for example, assist them to certify the COD when the VA interview is less definitive.

InterVA algorithm

The InterVA (Interpret VA) algorithm was developed in 2003 and revised since then.[97] [98] The current version, released mid-2018, is InterVA-5. Based on Bayes' rule for conditional probabilities, for each death, InterVA produces values for the likelihoods of each cause, given the indicators reported as present in a VA interview and a set of evidence. It makes use of physician- and evidence-derived conditional probabilities that give the likelihoods of various indicators being associated with various causes.

For each death, InterVA reports single-value point estimates for the likelihoods of up to three causes with the largest likelihoods falling above a set threshold; otherwise, the cause is ruled 100% 'indeterminate'. If the sum of likelihoods for a death's reported causes is less than 100%, this reflects uncertainty around that case, and is recommended to be assigned as a residual 'indeterminate' component. Thus the total likelihoods, summed over all cases, equals the total number of deaths. Full details, source code and compiled executables that implement InterVA-5 (version 5.0) are available.[99]

Insilico algorithm

InSilicoVA is a statistical algorithm that, for a set of deaths, identifies the most likely joint probability distribution of CSMFs and probabilities of each cause for each individual death.[100] This is done using a Bayesian hierarchical model fit using a Gibbs sampling algorithm that uses information on both the presence and absence of VA indicators and the conditional probability of each VA indicator for each COD. Those conditional probabilities can be borrowed from InterVA or calculated from the PHMRC Gold Standard dataset or another source of reference deaths.

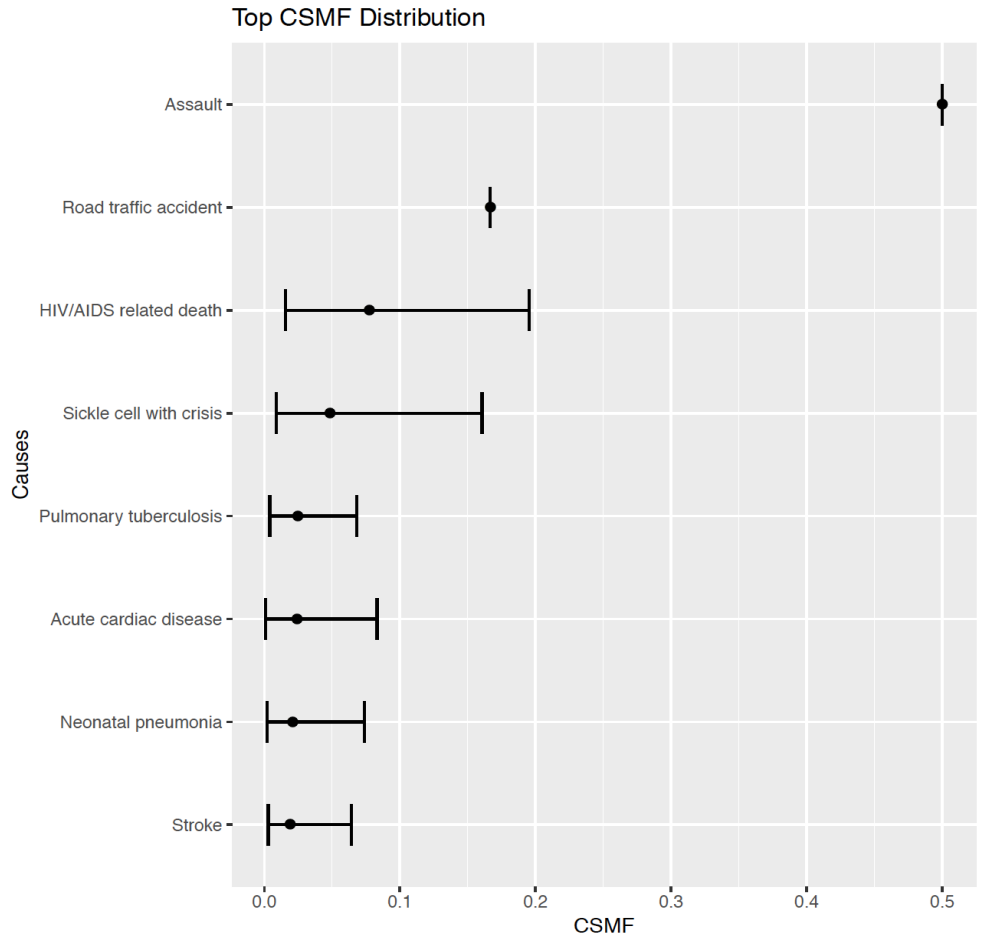
InSilicoVA reports probability distributions and summaries of those distributions for each CSMF, as well as the probability of each COD for each individual death. This is a first step in accounting for the inherent uncertainty in assigning CODs using VA. The current version of InSilicoVA supports the WHO 2012 and WHO 2016 standard VA indicators and cause lists, identical to InterVA-4 and InterVA-5. Free, open-source software (including source code) implementing InSilicoVA is available for the R statistical programming environment. [101]

InSilicoVA does not produce undetermined CODs in the same way that the other algorithms do. Rather, it reflects the confidence with which a COD can be identified in the population using the width of the credible intervals for each CSMF. A wide credible interval around a CSMF indicates that it is not possible to assign that cause with confidence, usually because there is insufficient information in the VA data. In

[97] Byass P et al. Strengthening standardised interpretation of verbal autopsy data: The new InterVA-4 tool. Glob Health Action. 2012; 5(1):19281.
[98] www.interva.net
[99] Ibid
[100] McCormick, T. H., Li, Z. R., Calvert, C., Crampin, A. C., Kahn, K., & Clark, S. J. (2016). Probabilistic cause-of-death assignment using verbal autopsies. Journal of the American Statistical Association, 111(515), 1036-1049.
[101] cran.r-project.org/web/packages/InSilicoVA/index.html

contrast to abruptly moving from *can assign a cause* to *indeterminate* like the other algorithms do, InSilicoVA presents a continuously variable metric of confidence. Causes with very wide credible intervals are causes that InSilicoVA identifies as difficult to classify. In most cases it is still possible to say something about the likely cause, even with low confidence. InSilicoVA retains that information and passes it on to the user rather than labelling the cause 'indeterminate'. See Figure 37 for example CSMF output from InSilicoVA. When interpreting results from InSilicoVA, the user must decide what level of confidence is necessary. External causes such as road traffic accidents will typically have narrow credible intervals because the VA interviews provide a lot of information relevant to these CODs. On the other hand, hard to identify causes such as HIV/AIDS-related deaths will have wide credible intervals because VA symptoms related to these causes are also related to a variety of other causes and therefore do not contain enough information to be highly confident about assigning one cause relative to the others, see Figure 37. This range of uncertainty around different CODs must be considered when interpreting the results, just as one needs to do with the fraction of undetermined deaths from Tariff and InterVA.

Figure 37 Example cause-specific mortality fractions (CSMFs) from InsilicoVA[102]



[102] cran.r-project.org/web/packages/InSilicoVA/index.html

Appendix 5: Verbal autopsy as an aid to physicians

In some countries, the law may require physicians to certify deaths that occur out of hospital. Physicians can use SmartVA to certify deaths. The order of the questions has been modified to suit the clinical process (see Table 16).

Table 16. Verbal autopsy as an aid to physicians

Clinical thinking	**SmartVA for physicians**
History of presenting symptoms	Open-ended narrative
Review of health records	Review of health records
Past medical history	Past medical history
System-based questions	System-based questions
Clinical examination	–
Laboratory results	Tariff analysis
Review history + examination + lab results	Review of endorsed symptoms
Final medical diagnosis	Final medical diagnosis

The following are the steps to using SmartVA for physicians (also see Figure 38):

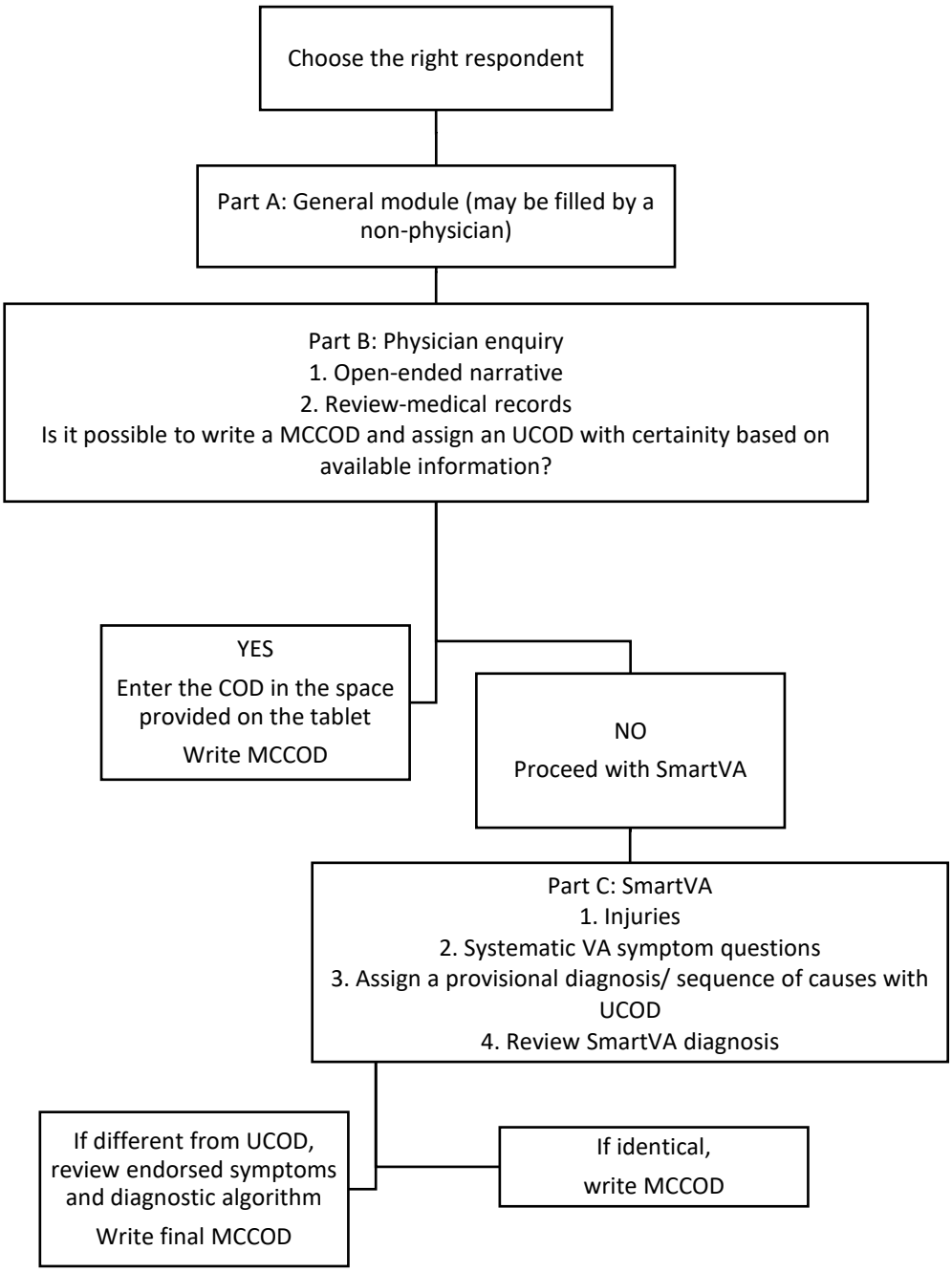
1. Choose the correct respondent, who should be the one who was with the deceased during their illness. If the person who visits the municipal health office is not the best respondent, request for the best respondent to be present. Details about the most appropriate respondent are provided in the interviewer's manual
2. Complete the general module
3. Depending on the age of the deceased, SmartVA will choose an age-specific module
4. Complete the narrative section
5. Complete the medical records section
6. SmartVA will ask you if you can certify the death based on these details

   - if yes, then enter the COD in the space provided on the tablet, and skip to Step 11

   - if no, then continue with the rest of the SmartVA questionnaire
7. Complete the injury section
8. Complete the structured questionnaire
9. Assign a provisional diagnosis/ sequence of causes with underlying COD
10. Review SmartVA diagnosis
    - if identical, then enter the COD in the space provided on the tablet

    - if different, then review endorsed symptoms and diagnostic algorithm
11. Certify the death.

Figure 38. Standard operating procedure while using SmartVA for physicians



COD = cause of death; MCCOD = medical certification of cause of death; UCOD = underlying cause of death; VA = verbal autopsy

Appendix 6: Estimating population by age and sex for years where data are not available

Estimating total population

To estimate the total population, you can extrapolate using population growth rates between the two most recent censuses.

$$\frac{P_1}{P_0} = e^{rt}$$

$$r = \frac{1}{t} * ln(\frac{P_1}{P_0})$$

Where:

r is the population growth rate

P_1 is the most recent census

P_0 is the previous census

t is the number of intercensal years

e is the exponential function (2.718).

For example, if a population's two most recent censuses were held on 30 June 2000 and 30 June 2010, the population growth rate is calculated as:

- P_0: Population 30 June 2000 = 453 697
- P_1: Population 30 June 2010 = 502 328
- P_2: Population 30 June 2014
- *t* = 10 years

$$r = \frac{1}{t} * \ln\left(\frac{P_1}{P_0}\right)$$

$$r = \frac{1}{10} * \ln\left(\frac{502\ 238}{453\ 697}\right)$$

= 0.0102 or 1.02% per year

If we want to know the population at 30 June 2014, and assume the population growth rate has remained at 1.02 per cent per annum:

$$P_2 = P_1 * e^{r*(2014-2010)}$$

$$P_2 = 502\ 238 * e^{0.0102*4}$$

$$= 523\ 153$$

The population at 30 June 2014 is about 523 153. The same method can be used to estimate total population for years between the two censuses.

Estimating population by age

If you have population by age and sex at two points in time from two censuses, you can estimate population by age and sex by projecting the percentage of the population at each age group.

For example, for the population above, if the percentage of the population aged less than 5 years at 30 June 2000 is 15.94 per cent and then in 30 June 2010 is 13.98 per cent, then you can estimate this percentage at 30 June 2014 as:

$$\Delta\% < 5 = \frac{1}{t} * \ln\left(\frac{\% < 5_1}{\% < 5_0}\right)$$

$$\Delta\% < 5 = \frac{1}{10} * \ln\left(\frac{15.94\%}{13.98\%}\right)$$

$$= -0.1312$$

$$\% < 5_2 = \% < 5_1 * e^{\Delta\%<5*(2014-2010)}$$

$$\% < 5_2 = 13.98\% * e^{-0.1312*(4)}$$

$$= 13.26\%$$

This should be repeated for every age group. The sum of the percentage of each age group should total 100 per cent. If they do not, then you can adjust each age group using a constant to ensure they total 100 per cent. Next, you multiply the percentage in the age group by the total population to have an estimate of the population in that age group. For example, 13.26 per cent × 523 153 = 69 366.

Appendix 7: Worked example of completeness method

The following equation is Model 2 of the empirical completeness method; only Model 2 is recommended to be used with the VA data. Model 1 includes a variable of the completeness of under-five death reporting, which can be relatively incomplete compared with that for all ages for verbal autopsy (VA) data.

$$logit\,(C^{ALL}) = (VACDRsq * -0.0238) \quad + (VACDR * 0.8419) \quad + (\%65 * -19.6118) + (ln(5q0) * -1.5135) + (Year * -0.0251) + 44.3755 + \gamma$$

Where:

C^{ALL} is the completeness of VA death reporting at all ages (i.e. $\frac{VA\ deaths}{Total\ deaths}$)

logit(C^{ALL}) is $ln\left(\frac{C^{ALL}}{1-C^{ALL}}\right)$

$VACDR$ is the VA crude death rate (CDR) (the number of VAs per 1000 population)

$VACDRsq$ is the square of *VACDR*, $\%65$ is the fraction of the population aged 65 years and over

$ln(5q0)$ is the natural log of the under-5 mortality rate, *k* is calendar year

γ is a country-level random effect (this adjusts the constant β_0 for each country in the dataset, for countries not in the dataset it is 0); this can be found in Adair and Lopez 2018.[103]

Predicted completeness is converted using the inverse logit: $\frac{e^{logit(C^{ALL})}}{e^{logit(C^{ALL})}+1}$

An application to Peru in 2014 is shown below.

VACDR	Pct65+	5q0	Random effect
3.077	6.60%	0.0181	0.147

$logit\left(C_{jk}^{All}\right)$ = (-0.0238 * 3.077^2) + (0.8419 * 3.077) + (-19.6118 * 0.0660) + (-1.5135 * *ln*(0.0181)) + (-0.0251 * 2014) + 44.3755 + 0.147 = 1.1138

= $\frac{e^{1.1138}}{e^{1.1138}+1}$ = **75.3% completeness**

The method estimates that VA deaths comprise 75.3 per cent of total deaths in this population.

[103] Adair T, Lopez AD. Estimating the completeness of death registration: An empirical method. *PLoS ONE*. 2018; 13(5):e0197047.

Appendix 8: SmartVA and WHO2016 cause lists mapped to Global Burden of Disease cause list (Level 3)

Table 16. SmartVA and WHO2016 cause lists mapped to Global Burden of Disease (GBD) level 3 cause list

GBD cause	SmartVA	WHO2016 VA
Acute glomerulonephritis	Other non-communicable diseases/Other defined causes of child deaths	Other and unspecified non-communicable diseases
Acute hepatitis	Other Infectious Diseases	unspecified infectious disease
Adverse effects of medical treatment	Other Injuries	Other and unspecified external cause of death
African trypanosomiasis	Other Infectious Diseases	unspecified infectious disease
Alcohol use disorders	Other Non-communicable Diseases	other and unspecified non-communicable disease
Alzheimer disease and other dementias	Other Non-communicable Diseases	other and unspecified non-communicable disease
Animal contact	Bite of Venomous Animal	contact with venomous animals and plants
Aortic aneurysm	Other Cardiovascular Diseases	other and unspecified cardiac disease
Appendicitis	Other Non-communicable Diseases/Digestive Diseases	other and unspecified non-communicable disease
Asthma	Chronic Respiratory/Other defined causes of child deaths	Asthma
Atrial fibrillation and flutter	Other Cardiovascular Diseases	Other and unspecified cardiac disease
Bacterial skin diseases	Other infectious diseases/Sepsis	Unspecified infectious diseases
Bladder cancer	Other Cancers	Other and unspecified neoplasm
Brain and nervous system cancer	Other Cancers/Childhood cancer	Other and unspecified neoplasm
Breast cancer	Breast Cancer	Breast neoplasms
Cardiomyopathy and myocarditis	Other Cardiovascular Diseases/Childhood Cardiovascular Diseases	Other and unspecified cardiac disease
Cervical cancer	Cervical Cancer	Reproductive neoplasms MF
Chagas disease	Other Infectious Diseases	unspecified infectious disease
Chronic kidney disease	Chronic Kidney Disease/Other defined causes of child deaths	Renal Failure
Chronic obstructive pulmonary disease	Chronic Respiratory	Chronic obstructive pulmonary disease (COPD)

GBD cause	SmartVA	WHO2016 VA
Cirrhosis and other chronic liver diseases	Cirrhosis/Digestive diseases	Liver cirrhosis
Colon and rectum cancer	Colorectal Cancer	Digestive neoplasms
Acute hepatitis	Other Infectious Diseases	unspecified infectious disease
Conflict and terrorism	Other Injuries	Other and unspecified external cause of death
Congenital birth defects	Other non-communicable diseases/Other defined causes of child death/Congenital malformation	congenital malformation
Cystic echinococcosis	Other Infectious Diseases	unspecified infectious disease
Cysticercosis	Other Infectious Diseases	unspecified infectious disease
Decubitus ulcer	Other Non-communicable Diseases/Other defined causes of child death	Other and unspecified non-communicable disease
Dengue	Other Infectious Diseases/Haemorrhagic fever	Dengue fever
Diabetes mellitus	Diabetes/Other defined causes of childhood death	Diabetes mellitus
Diarrheal diseases	Diarrhea/Dysentery	Diarrhoeal diseases
Diphtheria	Other Infectious Diseases	unspecified infectious disease
Drowning	Drowning	Accidental drowning and submersion
Drug use disorders	Other Non-communicable Diseases/Other defined causes of child death	Other and unspecified non-communicable disease
Eating disorders	Other non-communicable diseases	Other and unspecified non-communicable disease
Ebola	Other Infectious Diseases/ Haemorrhagic fever	Haemorrhagic fever
Encephalitis	Other Infectious Diseases/ Encephalitis	Meningitis and encephalitis
Endocarditis	Other Cardiovascular Diseases/Childhood cardiovascular diseases	Other and unspecified cardiac disease
Endocrine, metabolic, blood, and immune disorders	Other Non-communicable Diseases/Other defined causes of child deaths	Other and unspecified non-communicable disease
Environmental heat and cold exposure	Other Injuries	Exposure to force of nature

GBD cause	SmartVA	WHO2016 VA
Epilepsy	Other Non-communicable Diseases/Other defined causes of child deaths	Epilepsy
Esophageal cancer	Esophageal Cancer	Digestive neoplasms
Executions and police conflict	Other Injuries	Other and unspecified external cause of death
Exposure to mechanical forces	Other Injuries	Other and unspecified external cause of death
Falls	Falls	Accidental fall
Fire, heat, and hot substances	Fires	Accidental exposure to smoke, fire and flames
Foreign body	Other Injuries	Other and unspecified external cause of death
Gallbladder and biliary diseases	Other Non-communicable Diseases/Digestive Diseases	Other and unspecified non-communicable disease
Gallbladder and biliary tract cancer	Other Cancers	Digestive neoplasms
Gynecological diseases	Other Non-communicable Diseases	Other and unspecified non-communicable disease
Hemoglobinopathies and hemolytic anemias	Other Non-communicable Diseases/Other defined causes of child deaths	Severe anaemia
Hemoglobinopathies and hemolytic anemias		Sickle cell with crisis
Hemolytic disease and other neonatal jaundice	NA	Other and unspecified perinatal cause of death
HIV/AIDS	AIDS	HIV/AIDS related death
Hodgkin lymphoma	Leukemia/Lymphomas/Childhood Cancer	Other and unspecified neoplasms
Hypertensive heart disease	Other Cardiovascular Diseases	Other and unspecified cardiac disease
Inflammatory bowel disease	Other Non-communicable Diseases/Digestive Diseases	Other and unspecified non-communicable disease
Inguinal, femoral, and abdominal hernia	Other Non-communicable Diseases/Digestive Diseases	other and unspecified non-communicable disease
Interpersonal violence	Homicide	Assault
Interstitial lung disease and pulmonary sarcoidosis	Other non-communicable diseases/Other defined causes of child deaths	Other and unspecified non-communicable disease

GBD cause	SmartVA	WHO2016 VA
Intestinal nematode infections	Other Infectious Diseases	unspecified infectious disease
Invasive Non-typhoidal Salmonella (iNTS)	Other Infectious Diseases	unspecified infectious disease
Ischemic heart disease	Ischemic Heart Disease	Acute cardiac disease
Kidney cancer	Other Cancers/Childhood cancer	Other and unspecified neoplasms
Larynx cancer	Other Cancers	Respiratory neoplasms
Leishmaniasis	Other Infectious Diseases	unspecified infectious disease
Leukemia	Leukemia/Lymphomas/ Childhood Cancer	Other and specified neoplasms
Lip and oral cavity cancer	Other Cancers	Oral neoplasms
Liver cancer	Other Cancers/Childhood cancer	Digestive neoplasms
Lower respiratory infections	Pneumonia	Acute respiratory infections including pneumonia
Malaria	Malaria	Malaria
Malignant skin melanoma	Other Cancers	Other and unspecified neoplasms
Maternal disorders	Maternal	Anaemia of pregnancy
Maternal disorders	Maternal	Ectopic pregnancy
Maternal disorders	Maternal	Abortion related death
Maternal disorders	Maternal	Obstructed labour
Maternal disorders	Maternal	Pregnancy-induced hypertension
Maternal disorders	Maternal	Pregnancy-related sepsis
Maternal disorders	Maternal	Ruptured uterus
Maternal disorders	Maternal	Obstetric haemorrhage
Measles	Other Infectious Diseases/Measles	Measles
Meningitis	Other Infectious Diseases/Meningitis	Meningitis and encephalitis
Mesothelioma	Other Cancers	Other and unspecified neoplasms
Motor neuron disease	Other Non-communicable Diseases/Other defined cause of child death	Other and unspecified non-communicable disease
Multiple myeloma	Other Cancers	Other and unspecified neoplasms
Multiple sclerosis	Other Non-communicable Diseases	Other and unspecified non-communicable disease

GBD cause	SmartVA	WHO2016 VA
Nasopharynx cancer	Other Cancers/Childhood cancer	Respiratory neoplasms
Neonatal encephalopathy due to birth asphyxia and trauma	Birth asphyxia	Birth asphyxia
Neonatal preterm birth	Preterm delivery	Prematurity
Neonatal sepsis and other neonatal infections	Meningitis/sepsis	neonatal sepsis
Neonatal sepsis and other neonatal infections	Neonatal Pneumonia	Neonatal pneumonia
Non-Hodgkin lymphoma	Leukemia/Lymphomas/ Childhood Cancer	Other and unspecified neoplasms
Non-melanoma skin cancer	Other Cancers	Other and unspecified neoplasms
Non-rheumatic valvular heart disease	Other cardiovascular diseases	Other and unspecified cardiac disease
Other cardiovascular and circulatory diseases	Other cardiovascular diseases/Childhood cardiovascular diseases	Other and unspecified cardiac disease
Other chronic respiratory diseases	Chronic Respiratory/Other defined causes of child deaths	Other and unspecified non-communicable disease
Other digestive diseases	Other Non-communicable Diseases/Digestive Diseases	Other and unspecified non-communicable disease
Other intestinal infectious diseases	Other infectious disease	Unspecified infectious diseases
Other malignant neoplasms	Other cancers/Childhood cancer	Other and unspecified neoplasms
Other musculoskeletal disorders	Other Non-communicable Diseases/Other defined causes of child deaths	Other and unspecified non-communicable disease
Other neglected tropical diseases	Other Infectious Diseases	unspecified infectious disease
Other neonatal disorder	NA	Other and unspecified perinatal cause of deaths
Other neoplasms	Other cancers/Childhood cancer	Other and unspecified neoplasms
Other neurological disorder	Other Non-communicable Diseases/Other defined causes of child deaths	Other and unspecified non-communicable diseases
Other nutritional deficiencies	Other Non-communicable Diseases/Other defined causes of child deaths	Other and unspecified non-communicable diseases

GBD cause	SmartVA	WHO2016 VA
Other pharynx cancer	Other cancers	Respiratory neoplasms
Other Skin and subcutaneous diseases	Other infectious diseases	Unspecified infectious disease
Other transport injuries	Road traffic	Other transport accident
Other unintentional injuries	Other injuries	other and unspecified external cause of death
Other unspecified infectious diseases	Other infectious diseases	Unspecified infectious diseases
Otitis media	Other infectious diseases	Unspecified infectious diseases
Ovarian cancer	Other cancers	Reproductive neoplasms MF
Pancreatic cancer	Other cancers	Digestive neoplasms
Pancreatitis	Other non-communicable disease/Digestive Diseases	Other and unspecified non-communicable diseases
Paralytic ileus and intestinal obstruction	Other non-communicable diseases/ Digestive diseases	Other and unspecified non-communicable diseases
Parkinson's disease	Other non-communicable diseases	Other and unspecified non-communicable diseases
Peripheral artery disease	Other cardiovascular diseases	Other and unspecified cardiac diseases
Pneumoconiosis	Chronic Respiratory	Other and unspecified non-communicable diseases
Poisonings	Poisonings (accidental)	Accidental poisoning and exposure to noxious substance
Prostate cancer	Prostate cancer	Reproductive neoplasms
Protein-energy malnutrition	Other Non-communicable Diseases/Other defined causes of child deaths	Severe malnutrition
Rabies	Other infectious diseases	unspecified infectious disease
Rheumatic heart disease	Other cardiovascular diseases/Childhood cardiovascular diseases	other and unspecified cardiac disease
Rheumatoid arthritis	Other non-communicable diseases/Other defined causes of child deaths	Other and unspecified non-communicable diseases
Road injuries	Road traffic	Road traffic accident
Schistosomiasis	Other infectious diseases	Unspecified infectious diseases
Self-harm	Suicide (intentional self-harm)	Intentional self-harm

GBD cause	SmartVA	WHO2016 VA
Sexually transmitted infections excluding HIV	Other infectious diseases	Unspecified infectious disease
Stomach cancer	Stomach cancer	Digestive neoplasms
Stroke	Stroke/Childhood cardiovascular diseases	Stroke
Sudden infant death syndrome	undetermined	undetermined
Testicular cancer	Other cancers	Reproductive neoplasms MF
Tetanus	Other infectious disease	Tetanus
Thyroid cancer	Other cancers	Other and unspecified neoplasms
Tracheal, bronchus, and lung cancer	Lung cancer	Respiratory neoplasms
Tuberculosis	TB/Other infectious diseases	Pulmonary tuberculosis
Typhoid and paratyphoid	Other infectious diseases	Unspecified infectious diseases
Upper digestive system diseases	Other non-communicable diseases	Other and unspecified non-communicable diseases
Upper respiratory infections	Other infectious diseases	Unspecified infectious diseases
Urinary diseases and male infertility	Other non-communicable diseases/Other defined causes of child death	Other and unspecified non-communicable diseases
Uterine cancer	Other cancers	Reproductive neoplasm MF
Varicella and herpes zoster	Other infectious diseases	Unspecified infectious diseases
Vascular intestinal disorders	Other cardiovascular diseases/Childhood cardiovascular diseases	Other and unspecified cardiac diseases
Whooping cough	Other infectious diseases	Pertussis
Yellow fever	Other infectious diseases/ Haemorrhagic fever	Haemorrhagic fever
Zika	Other infectious diseases/ Haemorrhagic fever	Haemorrhagic fever

Appendix 9: Calculations for uncertainty around different numbers of verbal autopsies

Table 17 shows, for various numbers of VAs, the 95 per cent uncertainty interval of the cause-specific mortality fractions (CSMF). For example, if you have collected 1500 VAs, and the top ranked cause has a CSMF of 25.0 per cent, then you can be 95 per cent confident that the true CSMF for that cause is in the range of 22.8–27.3 per cent.

CSMFs with wide uncertainty intervals compared with their level (shown in the first column of the table) should be interpreted very prudently and you should avoid inferring too much precision from your results. For example, suppose you have only 500 VAs and the CSMF for a particular cause was 2.0 per cent, then the 95 per cent uncertainty interval for that CSMF is 1.0–3.6 per cent. In other words, that cause could be responsible for 1.0 per cent of deaths, or 3.6 per cent of deaths, with 95 per cent certainty. For many public health purposes, that range of uncertainty may be too wide to be useful, in which case including more VAs to increase the sample size would be required. Note, however, that even if we doubled the sample size to 1000 cases, the range of uncertainty around a CSMF of 2.0 per cent is still comparatively large at 1.2–3.1 per cent.

Table 17 95% uncertainty intervals for cause-specific mortality fractions (CSMFs) at different number of verbal autopsies (VAs)

	Number of VAs			
CSMF	**500**	**700**	**1000**	**1500**
25.0	21.3–29.0	21.8–28.4	22.3–27.8	22.8–27.3
20.0	16.6–23.8	17.1–23.2	17.6–22.6	18.0–22.1
15.0	12.0–18.4	12.4–17.9	12.8–17.4	13.2–16.9
10.0	7.5–13.0	7.9–12.5	8.2–12.0	8.5–11.6
9.0	6.6–11.9	7.0–11.4	7.3–10.9	7.6–10.6
8.0	5.8–10.7	6.1–10.3	6.4–9.9	6.7–9.5
7.0	4.9–9.6	5.2–9.1	5.5–8.8	5.8–8.4
6.0	4.1–8.5	4.4–8.0	4.6–7.7	4.9–7.3
5.0	3.3–7.3	3.5–6.9	3.7–6.5	4.0–6.2
4.0	2.5–6.1	2.7–5.7	2.9–5.4	3.1–5.1
3.0	1.7–4.9	1.9–4.5	2.0–4.3	2.2–4.0
2.0	1.0–3.6	1.1–3.3	1.2–3.1	1.4–2.8
1.0	0.3–2.3	0.4–2.0	0.5–1.8	0.6–1.6

As mentioned earlier, for some policy purposes, it may be sufficient to be sure about the comparative ranking of causes based on their CSMFs calculated from application of VA. Table 18 gives the probability, for different numbers of VAs, that the CSMF for a cause at a specific rank is actually different from that for another rank. So, for example, Table 18 shows that if we have 1000 male VAs, then we can be 86.4 per cent confident that causes ranked 3 and 4 are actually ranked 3 and 4, in that order, but only 38.4 per cent confident that the true order of rankings of causes 5–10 is the same as what our CSMFs actually suggest. Note that this example uses a typical CSMF found at each rank based on experience with the VA adult cause list.

Table 18 Probability of difference in cause-specific mortality fraction (CSMF) for a cause at one rank compared with another rank, at different numbers of verbal autopsies (VAs)

Rank	Typical CSMF	Number of VAs			
		500	700	1000	1500
1 vs 2	22% vs 14%	0.999	1.000	1.000	1.000
2 vs 3	14% vs 11%	0.849	0.910	0.958	0.987
3 vs 4	11% vs 9%	0.708	0.788	0.864	0.932
4 vs 5	9% vs 7%	0.756	0.832	0.901	0.957
5–10 (each individual rank, e.g. 6 vs 7)	Between 4% and 7%	0.277	0.302	0.384	0.461

Appendix 10: Cause-specific mortality fractions by age group for leading causes of death by Socio-Demographic Index

All data in this appendix are from the Global Burden of Disease Collaborative Network.[104]

Figure 39. Cause-specific mortality fractions by age group for stroke, males, by Socio-Demographic Index (SDI)

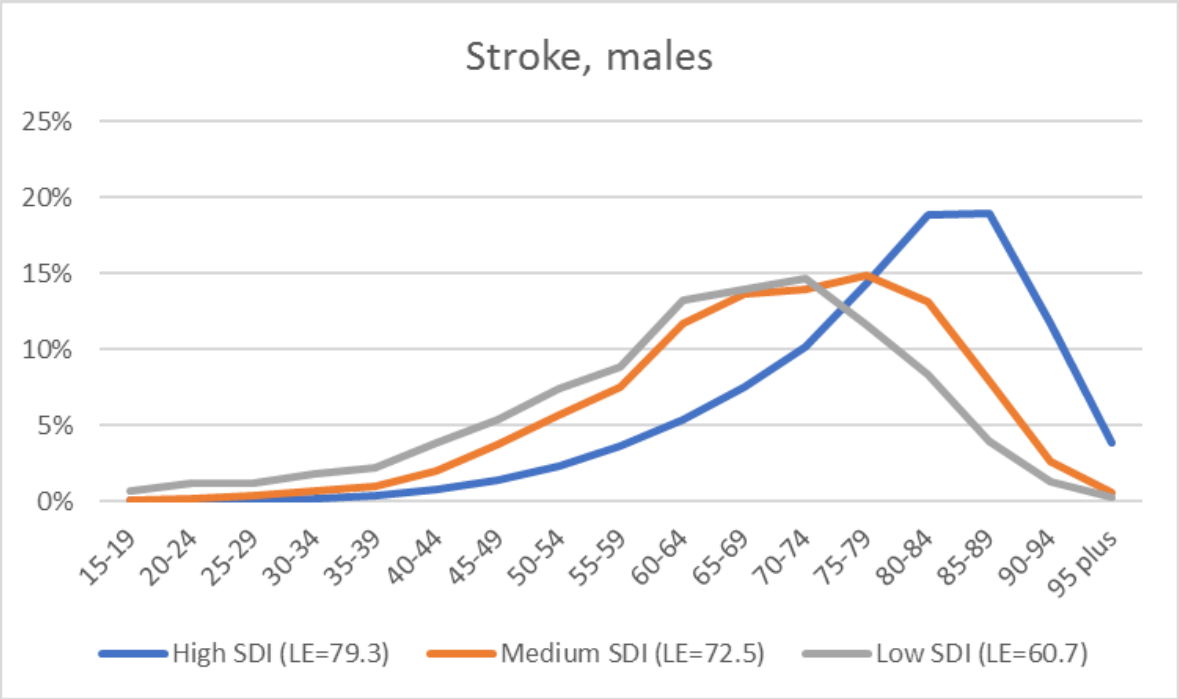
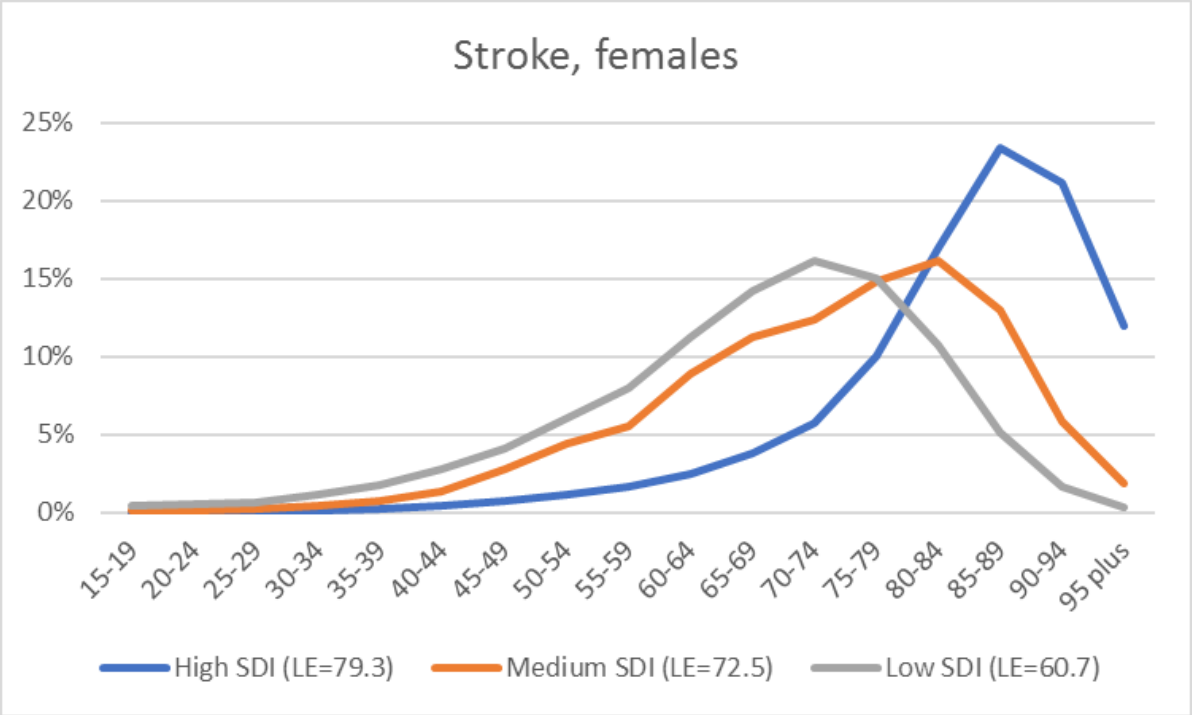


Figure 40. Cause-specific mortality fractions by age group for stroke, females, by Socio-Demographic Index (SDI)



High SDI – life expectancy = 79.3; middle SDI – life expectancy = 72.5; low SDI – life expectancy = 60.9

[104] Global Burden of Disease Collaborative Network. *Global Burden of Disease Study 2016 results*. Seattle: IHME; 2017.

Figure 41. Cause-specific mortality fractions by age group for Ischemic heart disease, males, by Socio-Demographic Index (SDI)

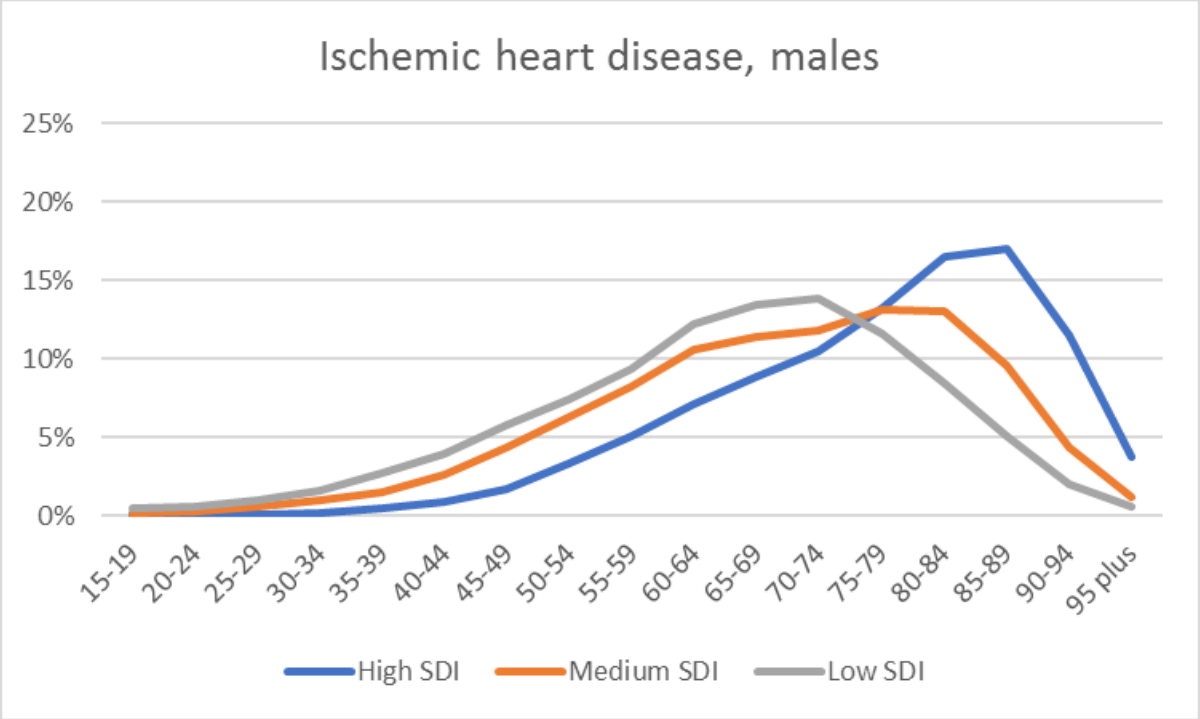
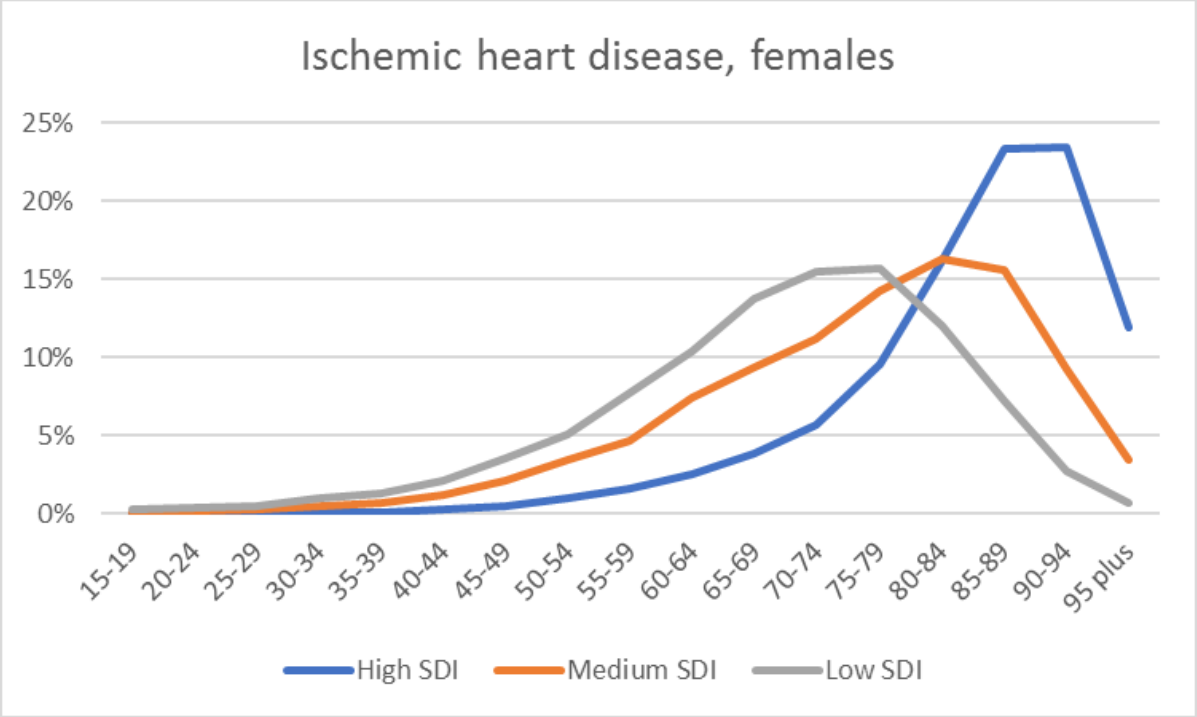


Figure 42. Cause-specific mortality fractions by age group for Ischemic heart disease, females, by Socio-Demographic Index (SDI)



High SDI – life expectancy = 79.3; middle SDI – life expectancy = 72.5; low SDI – life expectancy = 60.9

Figure 43. Cause-specific mortality fractions by age group for lower respiratory infection, males, by Socio-Demographic Index (SDI)

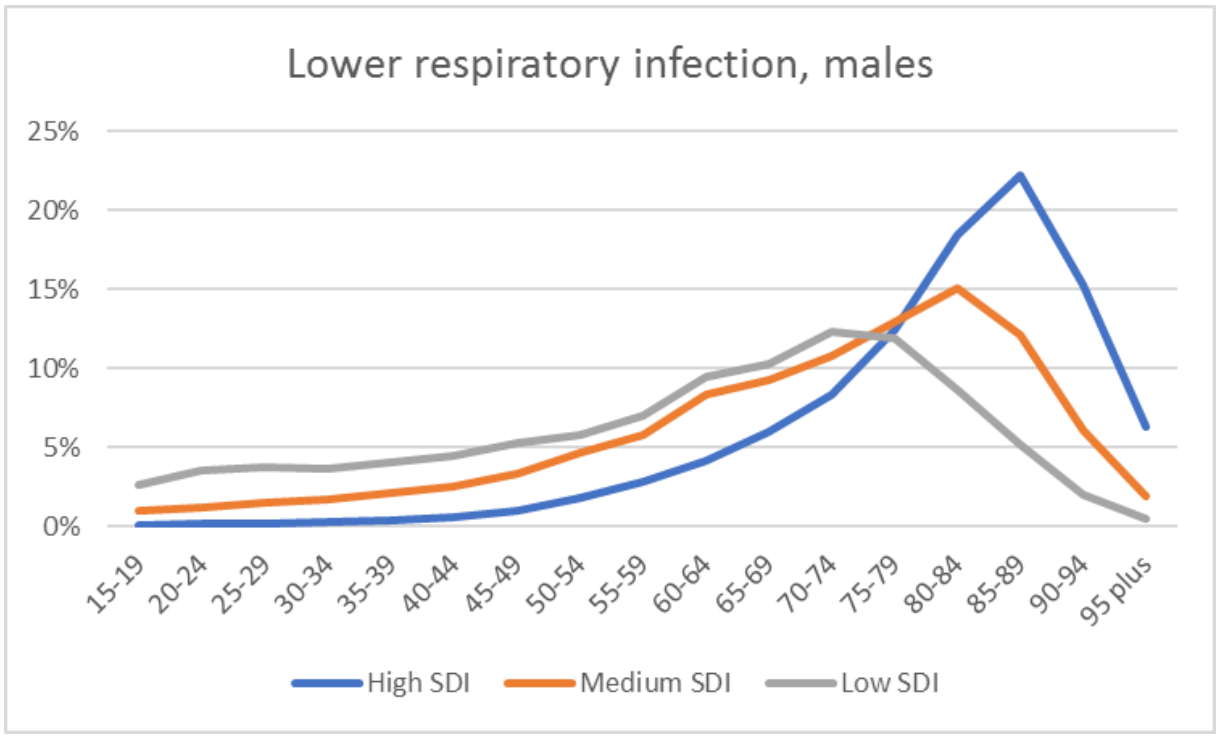
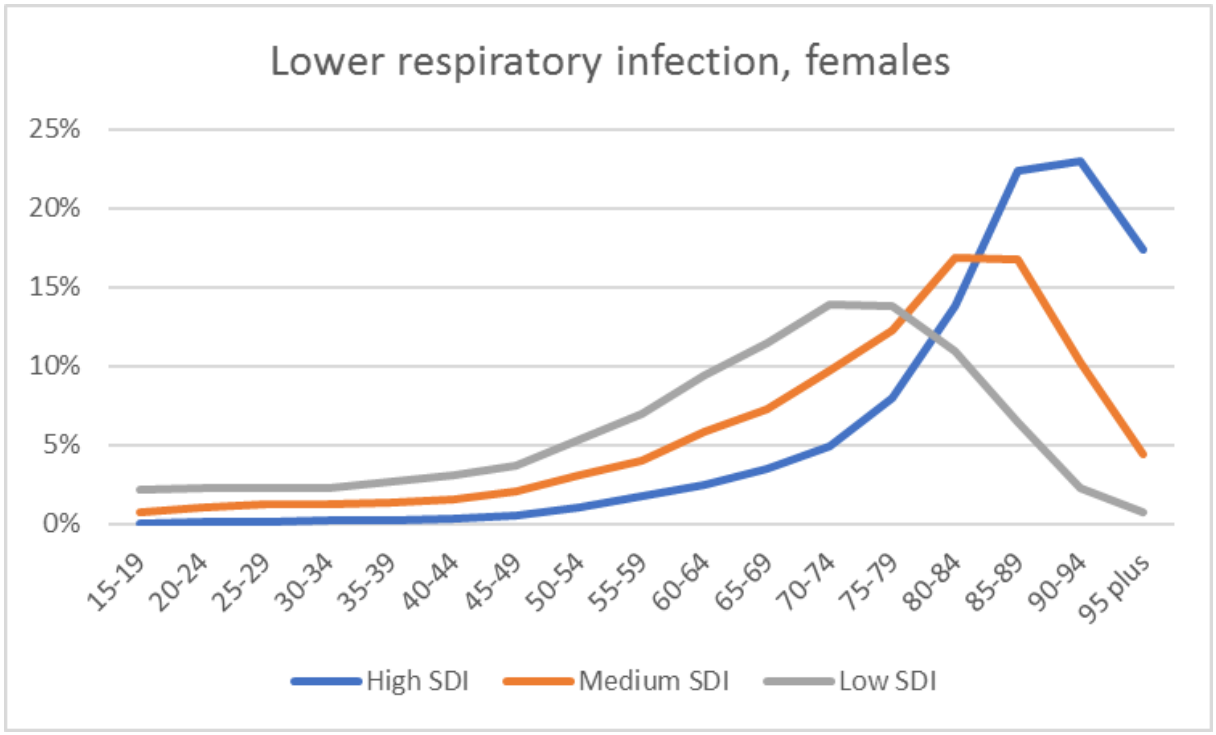


Figure 44. Cause-specific mortality fractions by age group for lower respiratory infection, females, by Socio-Demographic Index (SDI)



High SDI – life expectancy = 79.3; middle SDI – life expectancy = 72.5; low SDI – life expectancy = 60.9

Figure 45. Cause-specific mortality fractions by age group for diabetes, males, by Socio-Demographic Index (SDI)

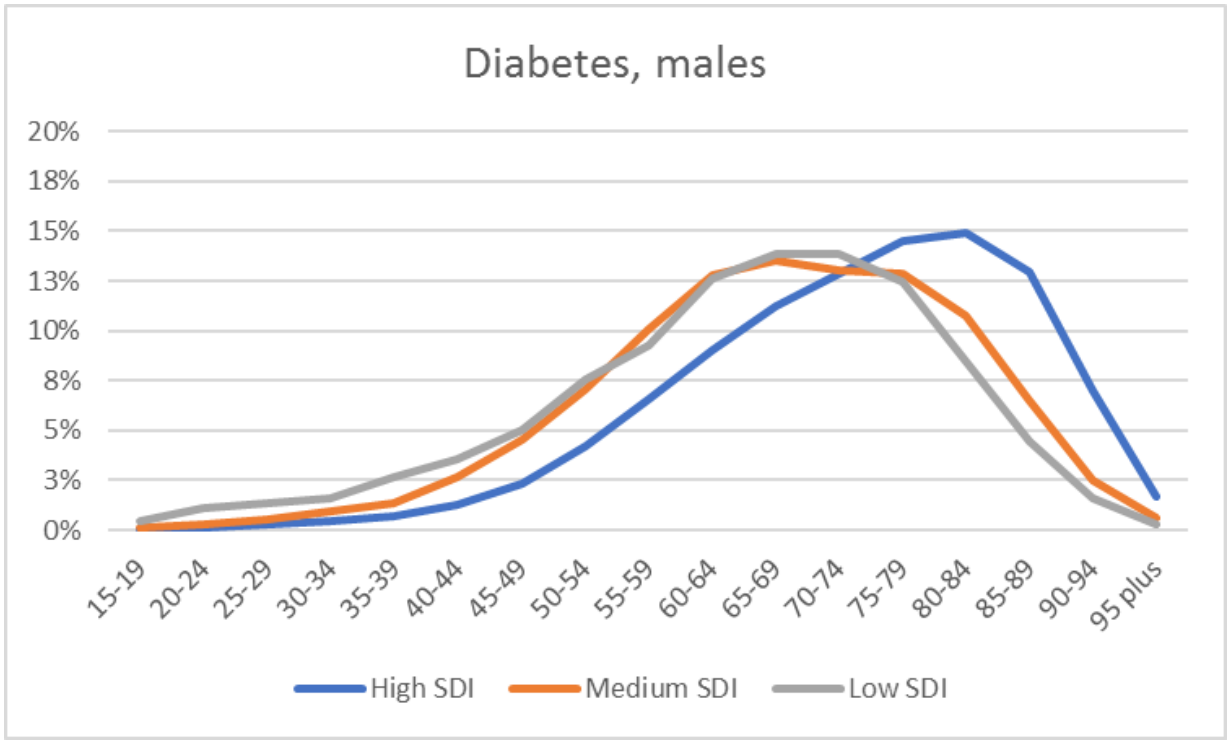
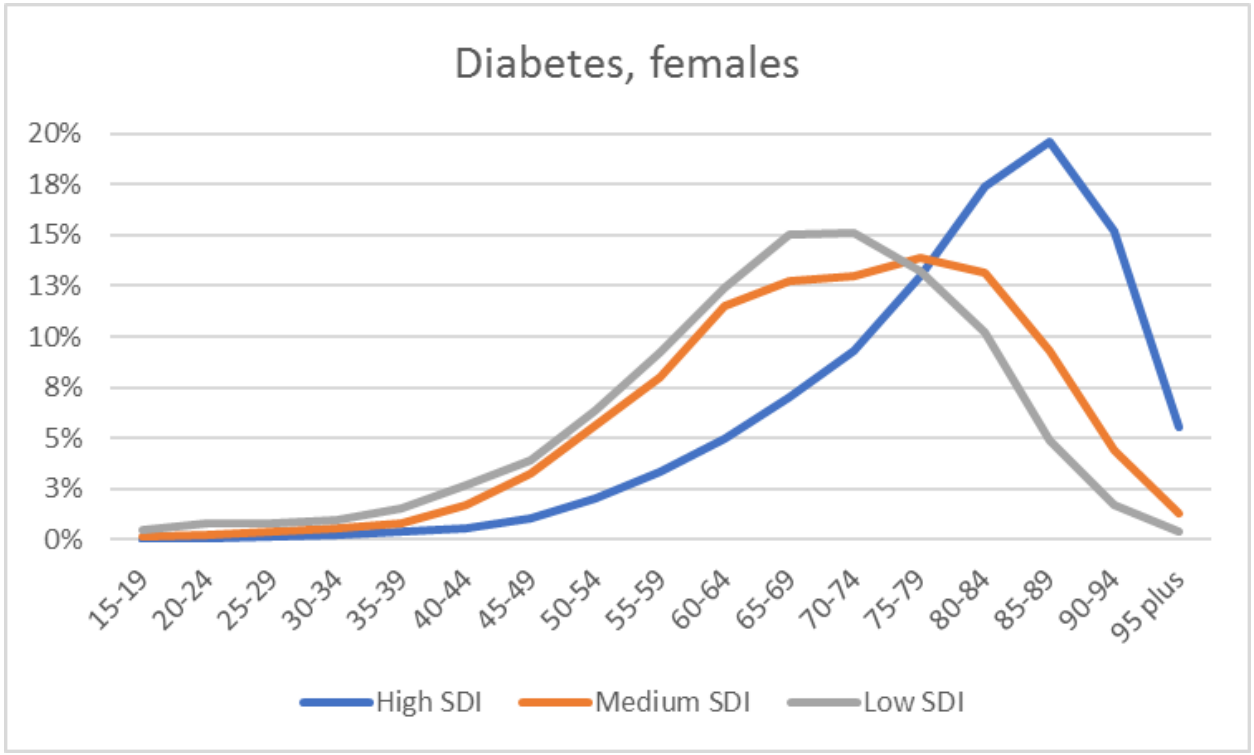


Figure 46. Cause-specific mortality fractions by age group for diabetes, females, by Socio-Demographic Index (SDI)



High SDI – life expectancy = 79.3; middle SDI – life expectancy = 72.5; low SDI – life expectancy = 60.9

Figure 47. Cause-specific mortality fractions by age group for cirrhosis, males, by Socio-Demographic Index (SDI)

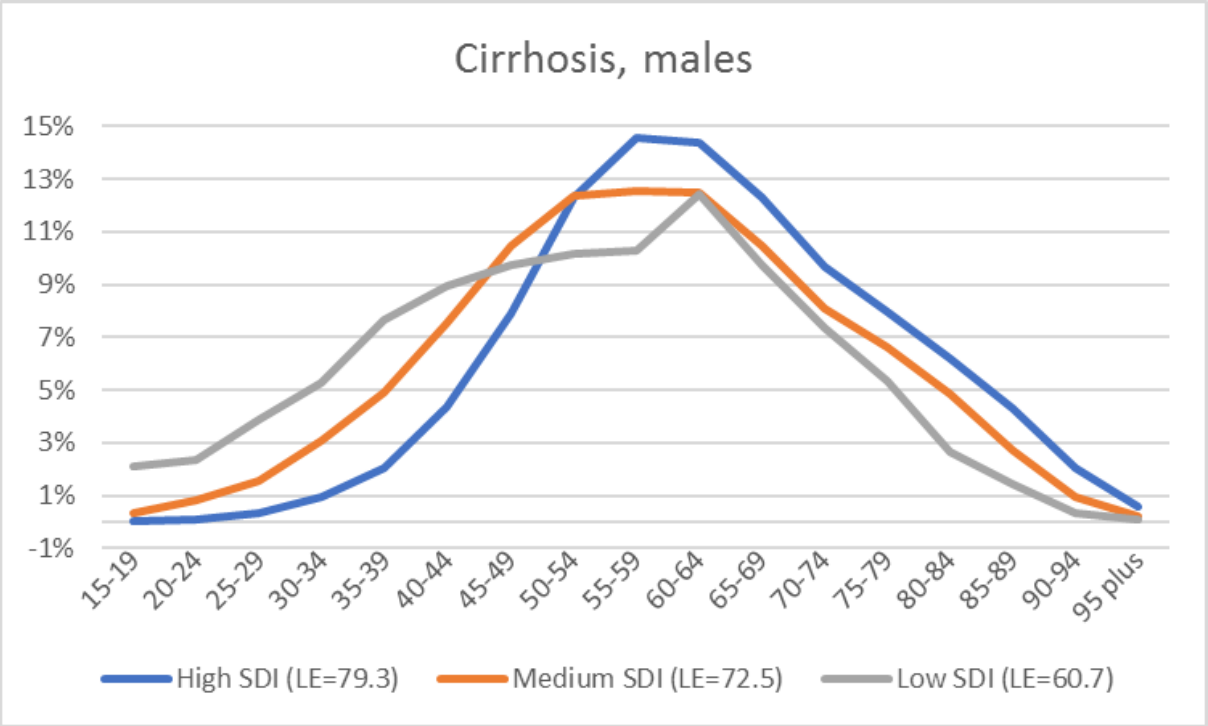
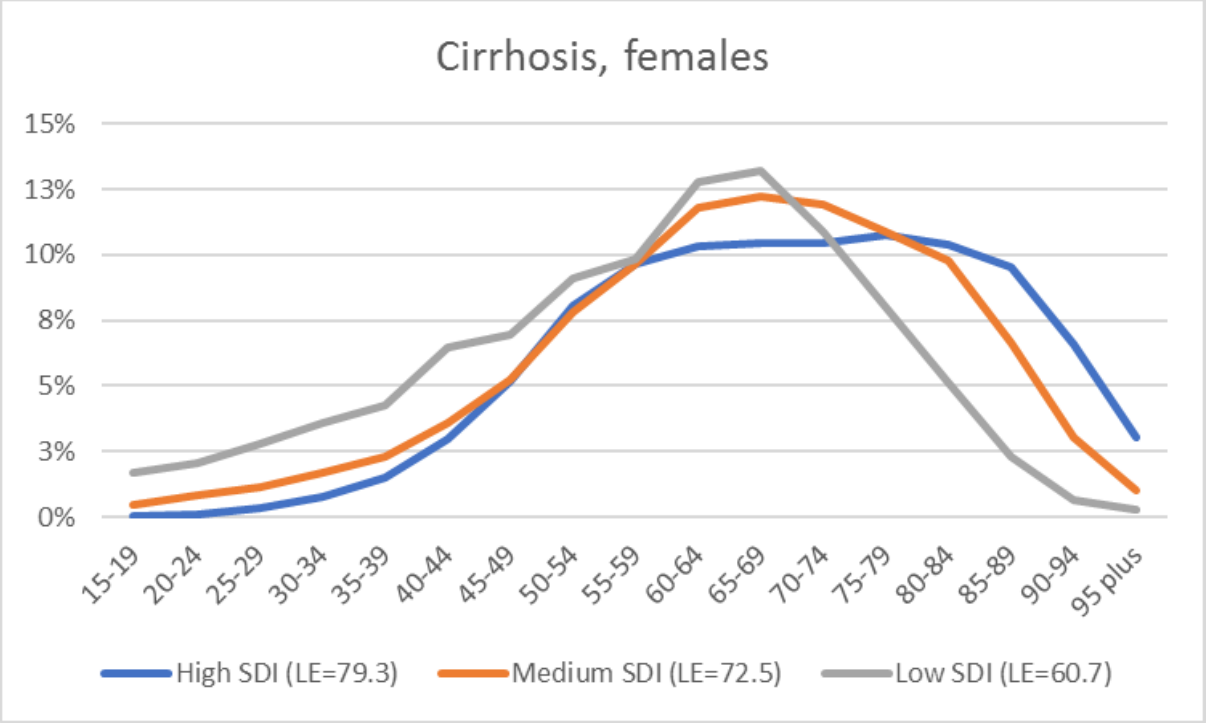


Figure 48. Cause-specific mortality fractions by age group for cirrhosis, females, by Socio-Demographic Index (SDI)



High SDI – life expectancy = 79.3; middle SDI – life expectancy = 72.5; low SDI – life expectancy = 60.9

Figure 49. Cause-specific mortality fractions by age group for HIV/AIDS, males, by Socio-Demographic Index (SDI)

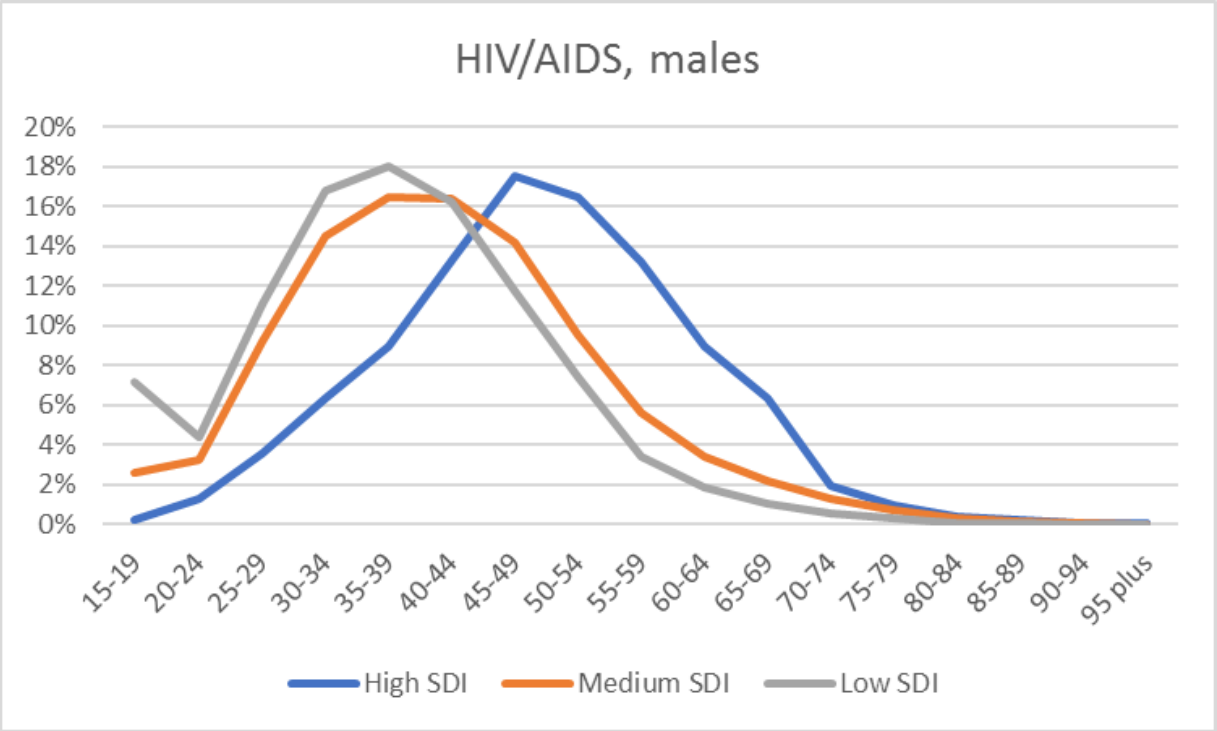
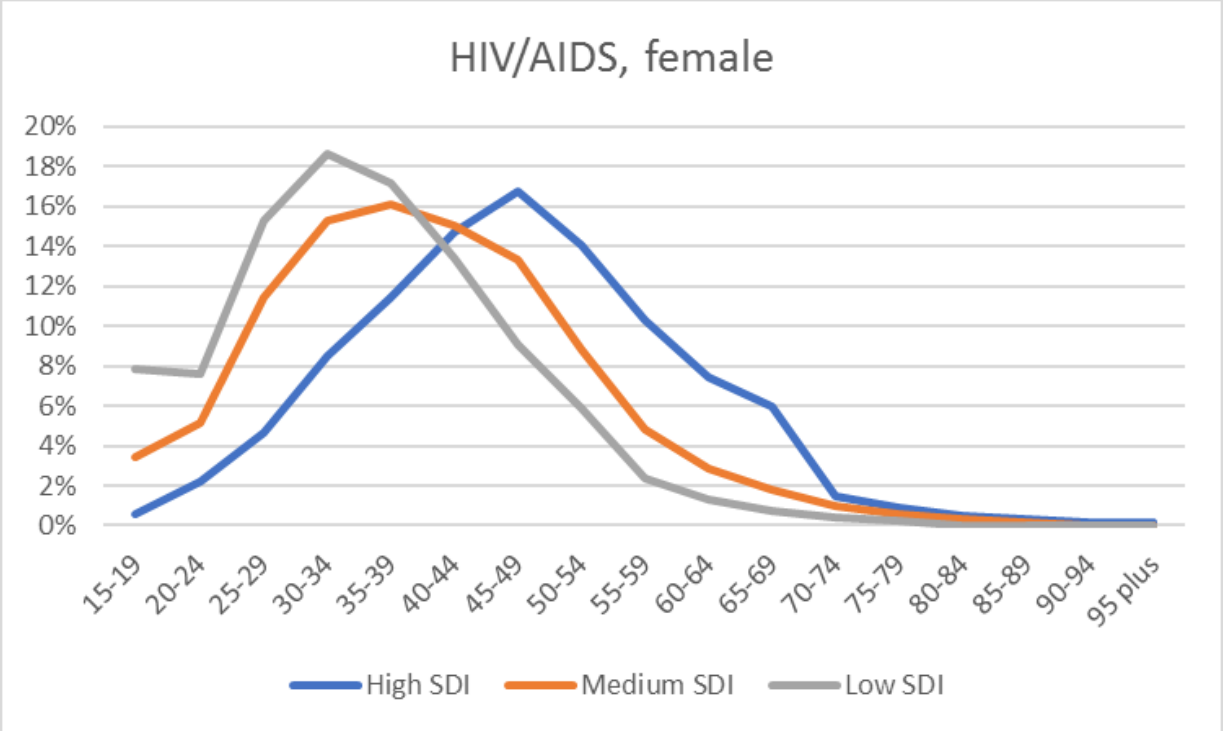


Figure 50. Cause-specific mortality fractions by age group for HIV/AIDS, females, by Socio-Demographic Index (SDI)



High SDI – life expectancy = 79.3; middle SDI – life expectancy = 72.5; low SDI – life expectancy = 60.9

Figure 51. Cause-specific mortality fractions by age group for TB, males, by Socio-Demographic Index (SDI)

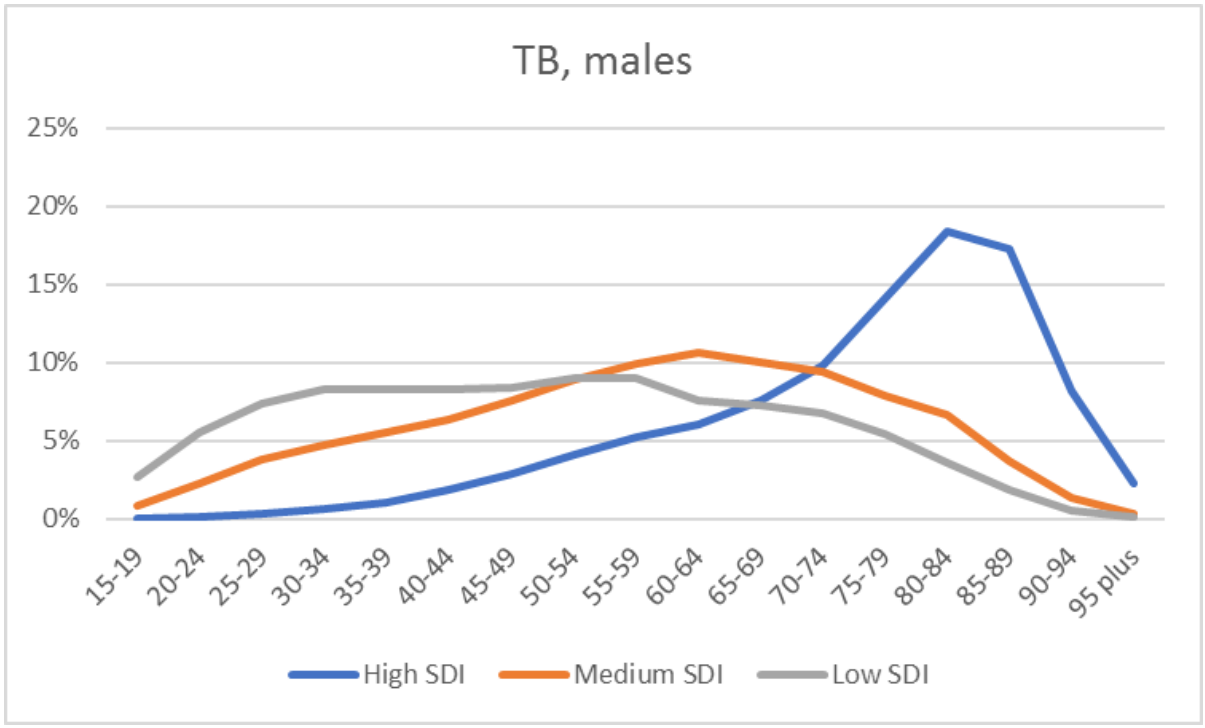
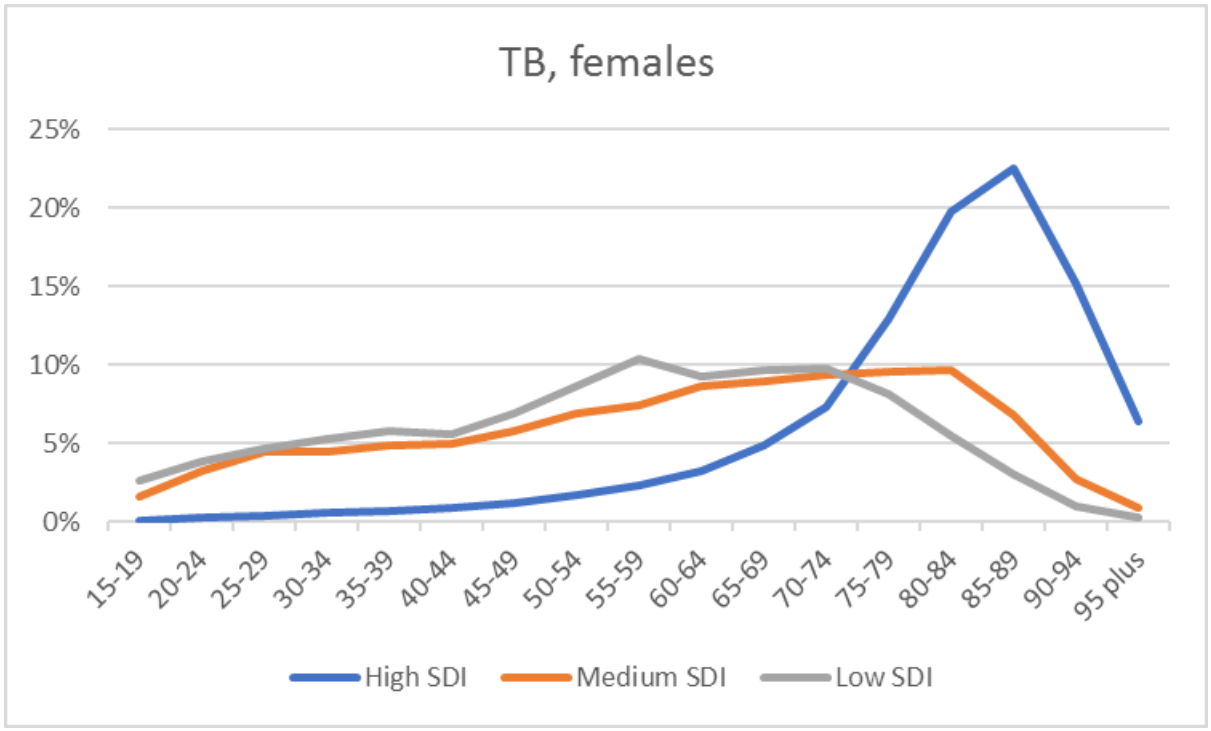


Figure 52. Cause-specific mortality fractions by age group for TB, females, by Socio-Demographic Index (SDI)



High SDI – life expectancy = 79.3; middle SDI – life expectancy = 72.5; low SDI – life expectancy = 60.9

Figure 53. Cause-specific mortality fractions by age group for Road traffic accident, males, by Socio-Demographic Index (SDI)

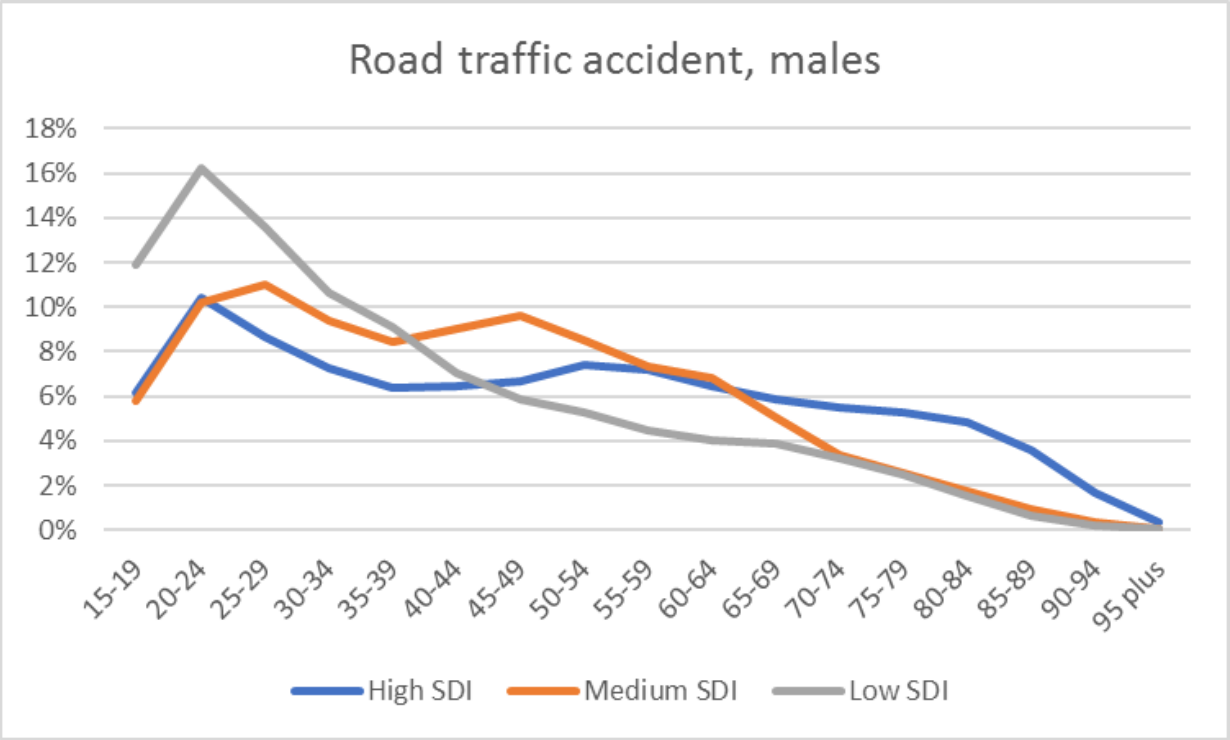
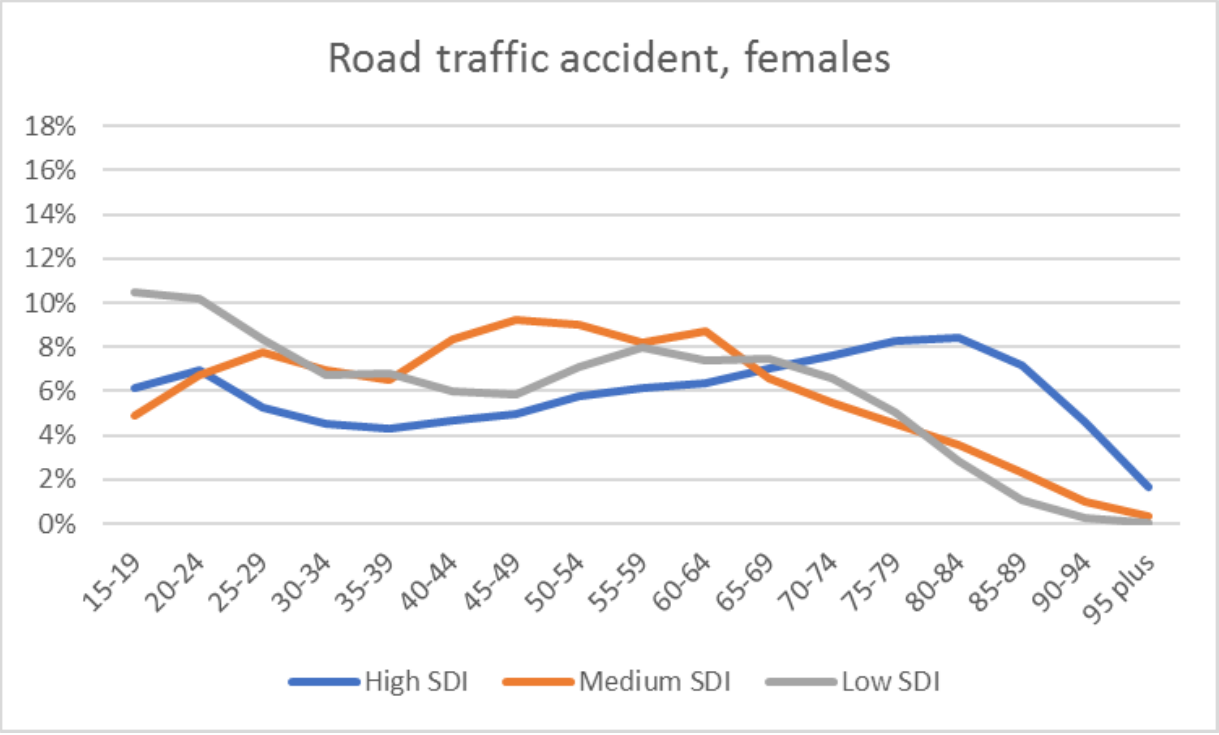


Figure 54. Cause-specific mortality fractions by age group for Road traffic accident, females, by Socio-Demographic Index (SDI)



High SDI – life expectancy = 79.3; middle SDI – life expectancy = 72.5; low SDI – life expectancy = 60.9

Appendix 11: Major risk/preventive factors and co-variates against leading communicable, non-communicable and injury conditions

Table 19 Major risk/preventive factors and covariates against leading COD

Cause	Co-variate/risk factor
Asthma	Indoor air pollution
	Outdoor air pollution
	Tobacco use
Breast cancer	Alcohol use
	Tobacco use
	High body mass index
Chronic kidney disease	Diabetes age-standardised prevalence (proportion)
	High body mass index
	High systolic blood pressure
Chronic obstructive pulmonary disease	Tobacco use
	Outdoor air pollution
	Indoor air pollution
Cirrhosis and other chronic liver diseases	Alcohol use
	Diabetes age-standardised prevalence (proportion)
	High body mass index
	Schistosomiasis prevalence (proportion)
	Hepatitis B (HBsAg) seroprevalence
	Hepatitis C (IgG) seroprevalence
Colon and rectum cancer	Alcohol use
	Tobacco use
	Diabetes age-standardised prevalence (proportion)
Dengue	Latitude under 15 (proportion)
	Population density (>1000 people/km^2, proportion)
	Elevation <100 m (proportion)
	Rainfall quintile 4 (proportion)
Diabetes mellitus	High body mass index
	Tobacco use
Diarrhoeal diseases	Improved water source (proportion with access)
	Rotavirus coverage (proportion)
	Underweight, stunting, wasting (proportion <2 SD weight for age, <5 years)
	Sanitation (proportion with access)
	Vitamin a deficiency prevalence (age-standardised)
	Zinc deficiency
Drowning	Alcohol use
	Coastal population within 10 km (proportion)
	Rainfall quintile 5 (proportion)
Oesophageal cancer	Alcohol use
	Smoking prevalence
	High body mass index

Cause	Co-variate/risk factor
	Indoor air pollution
HIV/AIDS	Unsafe sex
	Alcohol and drug use
Ischaemic heart disease	Diabetes age-standardised prevalence (proportion)
	High body mass index
	High systolic blood pressure
	Indoor air pollution
	Outdoor air pollution
	Tobacco use
Lower respiratory infections	DTP3 coverage (proportion)
	Indoor air pollution
	Outdoor air pollution
	Child and maternal malnutrition
	Tobacco use
Neonatal disorders	Antenatal care (4 visits) coverage (proportion)
	In-facility delivery (proportion)
	Child and maternal malnutrition
	Indoor air pollution
	Tobacco use
Road injuries	Alcohol use
	Population 15 to 30 (proportion)
	Vehicles – 2 and 4 wheels (per capita)
Stroke	Diabetes age-standardised prevalence (proportion)
	High body mass index
	High systolic blood pressure
	Indoor air pollution
	Outdoor air pollution
	Tobacco use
Tracheal, bronchus and lung cancer	Tobacco use
	Indoor air pollution
	Outdoor air pollution
Tuberculosis	Alcohol use
	Tobacco use
	Indoor air pollution
	Outdoor air pollution
	Population density (>1000 people/km^2, proportion)
	Age-standardised proportion adult underweight

Stimulant  Preventive 

Appendix 12: Examples of policy briefs

The Republic of the Union of Myanmar

2014 Myanmar Population and Housing Census

Policy Brief on Maternal Mortality

Department of Population
Ministry of Labour, Immigration and Population
With technical assistance from UNFPA

Key points

(1) Based on results from the 2014 Myanmar Population and Housing Census, there were 2,797 maternal deaths in the 12-months preceding the Census. This translates to a maternal mortality ratio (MMR) of 282 maternal deaths for every 100,000 live births. It is two times higher than the MMR ratio in South-East Asia, which is 140 per 100,000 live births. Myanmar is committed to reducing maternal mortality as part of its commitment to the Sustainable Development Goals.

(2) The MMR is high especially among the youngest and oldest population groups. There were 171 maternal deaths among those aged 15-19, translating to a MMR of 228.6 per 100,000 live births, while it was 1,132 per 100,000 live births for the age group 45-49 years, with the number of maternal deaths recorded at 129.

(3) High fertility rates impact on maternal mortality. Although overall fertility rates are relatively low, declines in fertility among high-risk age groups, i.e. the youngest and the oldest, could decrease maternal mortality levels significantly.

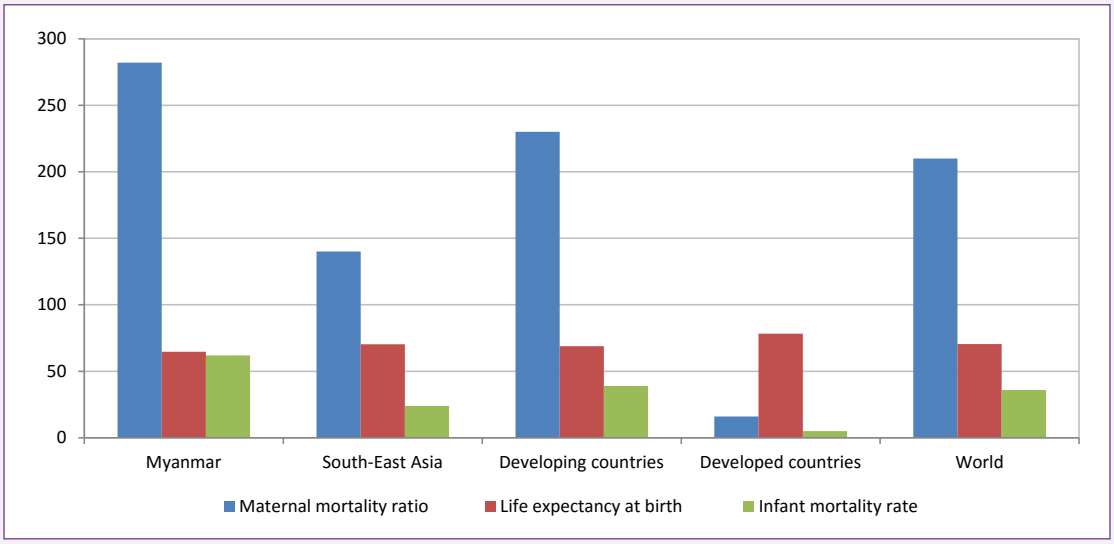
(4) Maternal mortality levels vary between states/regions and between urban and rural areas. Chin (357 per 100,000 live births) and Ayeyawady (354 per 100,000 live births) had the highest MMR, while Tanintharyi (157) had the lowest. The MMR in urban areas was 193 per 100,000 live births compared to 310 in rural areas. For maternal mortality to decline further, maternal mortality must be addressed as a priority in rural areas and in states/regions where population groups live in remote places or in relatively under-developed areas.

(5) Fertility is relatively high in some states/regions such as Chin where the total fertility rate is five children per woman. A reduction in fertility rates through stronger family planning and reproductive health programmes in those states/regions where both fertility and maternal mortality are correspondingly high, could help reduce maternal mortality.

(6) Analysis shows that the availability of health facilities and physical access to health facilities alone does not reduce the risk of maternal deaths. Low educational levels of women, and cultural factors affecting the status of women in the community could account for women's lack of understanding about the risks associated with pregnancy and when medical attention is essential. More attention should be given to reducing the barriers that uneducated and poor women face in remote areas that prevent them from accessing health facilities. Higher levels of socioeconomic development in every part of the country will also contribute to reduced maternal mortality.

(7) Maternal deaths during the postnatal period (42 days after delivery) account for 38.5 per cent of all maternal deaths. The current focus of resource allocation is concentrated in antenatal care and delivery care. Allocation of resources for postnatal maternal care must be given equal importance.

Figure 1: Mortality indicators, Myanmar 2014 and the world



Counting maternal deaths helps to measure progress

Maternal mortality is a serious public health issue in many less developed countries. It refers to deaths among women while pregnant, during delivery, or within 42 days of delivery from any cause arising from the pregnancy or its management. The improvement of maternal health is recognized as an international development goal, and the reduction of the maternal mortality ratio to 70 deaths per 100,000 live births by 2030 is an important target under the Sustainable Development Goals (SDGs).

In the absence of complete and reliable death registration statistics, the 2014 Myanmar Population and Housing Census provides an authentic platform to measure maternal mortality both at the Union and subnational levels. From this data, estimates of different maternal mortality indicators can be drawn, of which the most commonly used is the maternal mortality ratio (MMR). Using the indicator from the Census data as a benchmark would enable Myanmar to track and report progress on the state of maternal health.

Using accepted statistical methods, the 2014 Census counted 2,797 cases of maternal deaths during the 12-month period preceding the Census. From this information on maternal deaths and the number of live births from the Census, the MMR was estimated at 282 maternal deaths for every 100,000 live births in the same period. This level is over three times higher than the global 2030 target of 70 per 100,000 live births.

Myanmar maternal mortality levels - issues and challenges

Myanmar faces a challenge with respect to maternal health and mortality. As shown in Figure 1, the MMR for Myanmar is two times higher than the MMR ratio in South-East Asian countries, and is higher than the global and developing country averages.

One in ten of all deaths among women of reproductive age (15-49 years) were maternal deaths. This proportion was much higher, at 21 per cent, among women in the 20-24 age group, while it was 18 per cent for those in the 25-29 age group. The usual pattern is for the share to be lower for the 20-24 age group than that of the 25-29 age group, where fertility rates are higher. See Figure 2 for the relationship between age-specific fertility rates (ASFR) and the proportion of maternal deaths (PMFD). The general pattern is for the ASFRs and PMFD distributions to be similar. However this is not the pattern here where there is a spike in the proportion of maternal deaths for the age group 20-24. Further details are found in the 2014 Census thematic report on Maternal Mortality. More research is needed to understand the reasons behind the higher proportion of maternal deaths for the 20-24 age group.

If maternal deaths among those in the 15-19 age group, where the MMR is 228.6 per 100,000 live births, are added to the number of maternal deaths among the 20-24 year olds, then 15.3 per cent of deaths among women in the age group 15-24 years are maternal deaths. This is a high proportion of maternal deaths among young women, and should be of concern to policymakers.

Figure 2: Relationship between fertility (ASFR) and the proportion of maternal deaths (PMFD).

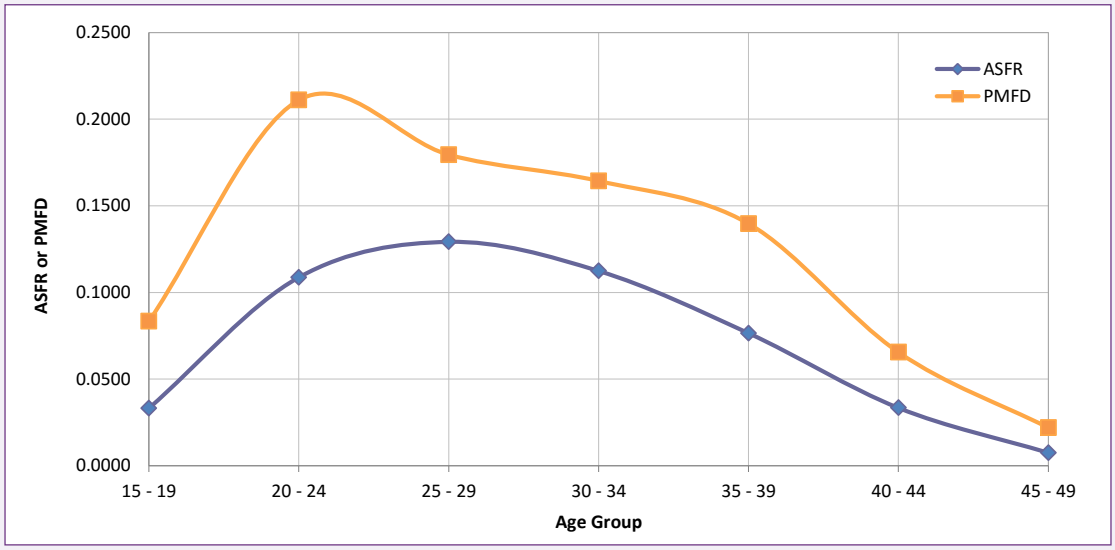
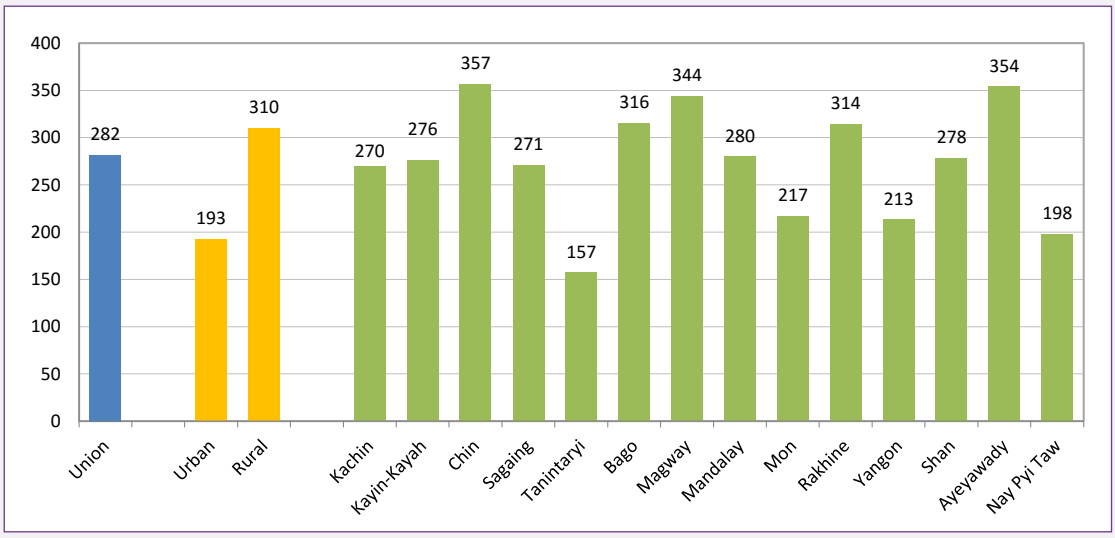


Figure 3: Maternal mortality ratios, Union, urban-rural and state/region, Census 2014



The MMR for the age group 45-49 is 1,132.4 per 100,000 live births, which is four times higher than the overall MMR. While the actual number of maternal deaths among this age group is small, at around 5 per cent of all maternal deaths, it is likely that women at such an advanced age who become pregnant are unable to access contraception and reproductive health information due to inherent social and economic constraints, which need to be addressed.

Maternal mortality varies by urban and rural areas, and among states/regions

Figure 3 shows the variations in the MMR between urban (193) and rural (310) areas. Similarly, variations can also be seen across the 15 states/regions. Chin (357) and Ayeyawady (354) have the highest MMRs, while Tanintharyi (157) and Nay Pyi Taw (198) have the lowest. Five of the states/regions have an MMR higher than the average at the Union level.

Note: Due to its small population, and therefore, its small number of recorded maternal deaths, the data for Kayah has been combined with that of Kayin.

continued

Maternal Mortality: understanding the dynamics

The discussion so far raises an important set of questions: Why is maternal mortality high? Why does it vary across states/regions and between urban and rural areas?

Several analyses were undertaken in the past to try to understand the dynamics of maternal mortality. One of the findings was that the risk of maternal death is related to whether a woman delivers her child in a facility with basic and emergency obstetric services. However, to reach this facility, she faces three barriers: (i) a delay in the decision to look for care; (ii) a delay in reaching care; and (iii) a delay in receiving adequate care.

Another finding relates to the timing of the pregnancy, that is complications related to pregnancy, during delivery, or during the postnatal period. This sequence of events, pregnancy, related complications, and maternal death is influenced by a woman's: (i) health status; (ii) reproductive status; (iii) access to health services; (iv) health care behaviour, and (v) some unknown factors. All these, in turn, are affected by socioeconomic and cultural factors.

Based on those findings, variation in maternal mortality between urban and rural areas and among states/regions could easily be explained by the differentials in health facilities and services across the country. If the lack of facilities is the cause of delay, then the answer would be to have more facilities and more services. Analysis however, shows otherwise. There was no significant relationship between maternal mortality levels and indicators of the availability of health services such as the number of nurses, midwives and hospital beds per 100,000 population. The mere availability of health services does not guarantee lower maternal mortality levels.

The analysis also revealed that only: (i) the percentage of women with no education or only primary education, and (ii) the percentage of households with access to communications means show a relationship with maternal mortality. According to the 2014 Census thematic report on Maternal Mortality, the first indicator is indicative of the first delay as a result of women being unable to identify pregnancy-related complications that require urgent medical attention. It could also correspond to women's status in the family and community. The second indicator refers more to the remoteness and the level of development in the area in which the woman lives. Thus, states/regions who have a lower proportion of their population with access to communication devices would mean that the second delay related to reaching care, and the third delay, that is receiving adequate care due to adequacy of facilities, poor quality staff or inadequate referral systems could negatively impact on maternal mortality.

Policymakers may want to consider addressing the underlying issues that cause the three delays that in turn result in high maternal deaths. This would include efforts to improve health care behaviour and the utilization of health services, especially by women living in under-developed areas and in isolated communities. Overall socioeconomic development in all parts of the country would also contribute to a reduction in maternal mortality. Reducing poverty and increasing income levels; improving transportation and communications; enhancing educational opportunities; and improving access to health care services among the entire population will help to eliminate barriers and delays that keep maternal mortality ratios high.

Maternal mortality levels were also found to be higher among women living in households without motorized transport and electricity, and with unimproved sanitation facilities and sources of drinking water. This finding confirms that the physical availability of health services alone does not help overcome the barriers to accessing health care. Economic, social and cultural factors also have to be addressed before the poor and uneducated can have better access to antenatal and emergency obstetric health care.

High fertility rates also have an impact on maternal mortality. However, Myanmar is a relatively low fertility country, and there are limits to how much a reduction in fertility can assist in decreasing maternal mortality. The 2014 Census thematic report on Maternal Mortality argues that high maternal mortality occurs most among the youngest and the oldest. In light of this, if fertility were to decline further among high risk women in the age groups 15-19, 40-44, and 45-49, then there would be a reduced risk of maternal deaths among these women.

Furthermore, fertility levels in some states/regions are high. Chin for instance has a total fertility rate (TFR) of five. It has also the highest MMR of 357 per 100,000 live births. Improvements in family planning and reproductive health programmes that particularly target the young and older populations could reduce maternal mortality in those states/regions where fertility levels are relatively high.

continued

Table 1: Per cent distribution of the timing of maternal mortality, 2014 Census

Age group	Death occurred during:				
	Pregnancy	Delivery	6 weeks after delivery	Total	Number of cases
15 - 19	26.6	32.3	41.1	100.0	171
20 - 24	19.1	35.5	45.4	100.0	512
25 - 29	30.8	29.7	39.5	100.0	505
30 - 34	29.6	30.1	40.3	100.0	562
35 - 39	29.4	37.2	33.4	100.0	584
40 - 44	31.3	33.3	35.4	100.0	334
45 - 49	55.3	17.0	27.7	100.0	129
Total	**29.1**	**32.4**	**38.5**	**100.0**	**2,797**

Do not disregard postnatal maternal health care

Census data on the timing of maternal deaths revealed that the postnatal period (42 days after delivery) accounted for the largest proportion (38.5 per cent) of all maternal deaths. Deaths during pregnancy and during delivery accounted for 29.1 per cent and 32.4 per cent of all maternal deaths respectively, as reflected in Table 1.

This finding will necessitate changes in the current resource allocation practices, as the practice is to concentrate resources for maternal health care in antenatal and delivery care. If maternal mortality is to be lowered, resources should be allocated for all the above three phases - antenatal, delivery and postnatal health care. Most of these deaths during the 42 days after delivery could be prevented if only more care and resources were provided.

Note: *The analysis in this policy brief does not cover the non-enumerated populations. Some populations in three areas of the country were not enumerated. This included an estimate of 1,090,000 persons residing in Rakhine State, 69,800 persons living in Kayin State and 46,600 persons living in Kachin State (see Department of Population, 2015, for the reasons that these populations were not enumerated). In total, therefore, it is estimated that 1,206,400 persons were not enumerated in the Census.*

Thematic Report on Maternal Mortality
can be downloaded at:

www.dop.gov.mm
or
http://myanmar.unfpa.org/census

The Republic of the Union of Myanmar

POLICY BRIEF ON MATERNAL MORTALITY

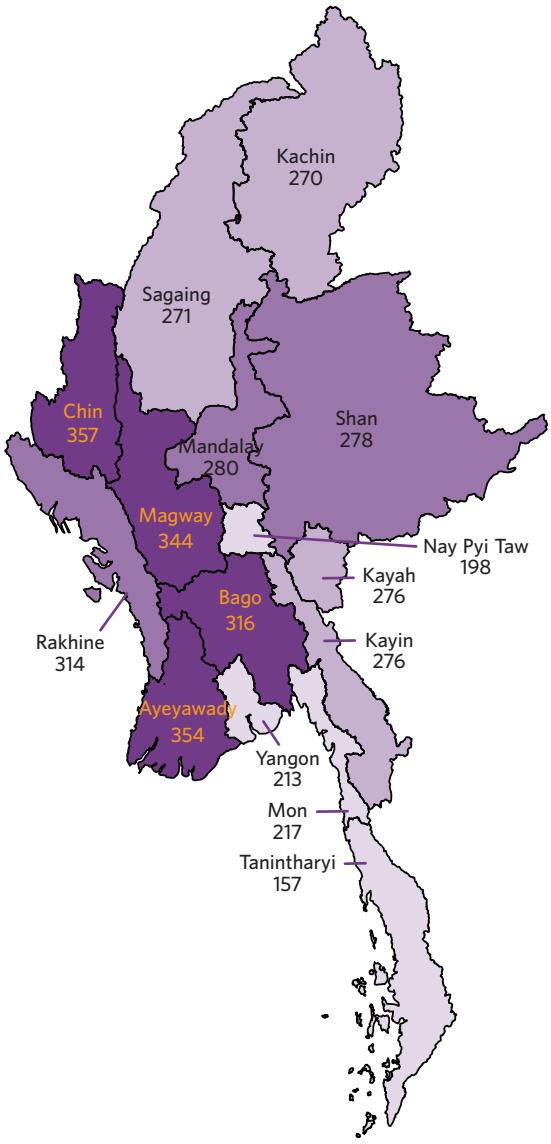
MATERNAL MORTALITY RATIO (MMR)* MYANMAR = 282 per 100,000 live births = almost 8 maternal deaths a day

MYANMAR IS COMMITED TO THE SUSTAINABLE DEVELOPMENT GOALS

3 GOOD HEALTH AND WELL-BEING

GOAL 3, TAGRET 3.1: REDUCE MMR TO LESS THAN
70 deaths per 100,000 live births by 2030

MMR varies between STATES/REGIONS



CHALLENGES

66.5% women with NO education or only primary education

▼

Low social status of women
No ability to identify complications

DELAYS
Looking for care
Reaching care
Receiving adequate care

Higher MMR for households with NO ACCESS to

- communication facilities
- motorized transport
- electricity
- sources of drinking water
- improved sanitation

▼

Low level of development, remote areas & poor families

MMR URBAN = 193 RURAL = 310

Most maternal deaths are avoidable

SOLUTIONS

Overall SOCIO-ECONOMIC development

Improve HEALTH-CARE BEHAVIOUR utilization & quality of HEALTH SERVICES

▼

FOCUS: under-developed areas & isolated communities

*MYANMAR MATERNAL DEATHS 12 MONTHS PRECEDING THE 2014 CENSUS

MATERNAL MORTALITY AMONG WOMEN OF REPRODUCTIVE AGE (15-49)

1 in 10 deaths = maternal death

- 21% 20-24 yr olds
- 18% 25-29 yr olds

▶ Further research is needed to find out why MMR high for the 20-24 yr age group.

15-24 yr old women

15.3% of deaths = maternal deaths ▶ High proportion of maternal deaths among young women ▶ **CONCERN FOR POLICY MAKERS**

HIGH RISK AGE GROUPS

45-49 yr
MMR= 1,132.4

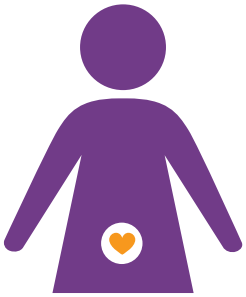
15-19 yr
MMR= 228.6

SOLUTIONS

DECREASE FERTILITY in high risk age groups

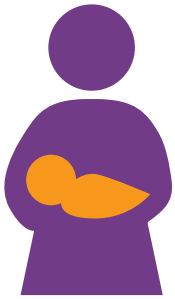
Target young and older populations in family planning and reproductive health programmes

TIMING OF MATERNAL DEATHS



29.1% antenatal

32.4% during delivery



38.5% postnatal

CHALLENGE
Maternal mortality is highest within 42 days after delivery

POSSIBLE SOLUTION
Allocate recources for all 3 phases of pregnancy/childbearing

Note: *The analysis in this policy brief does not cover the non-enumerated populations. Some populations in three areas of the country were not enumerated. This included an estimate of 1,090,000 persons residing in Rakhine State, 69,800 persons living in Kayin State and 46,600 persons living in Kachin State (see Department of Population, 2015, for the reasons that these populations were not enumerated). In total, therefore, it is estimated that 1,206,400 persons were not enumerated in the Census.*

Department of Population
Ministry of Labour, Immigration and Population
With technical assistance from UNFPA

MRC POLICY BRIEF

No. 3, December 2003

What are the leading causes of death among South African children?

Debbie Bradshaw,
David Bourne,
Nadine Nannan

Burden of Disease Research Unit, Medical Research Council,
PO Box 10970, Tygerberg, 7505, South Africa.
Tel. +27 (0)21 938 0327. http://www.mrc.ac.za/bod/bod.htm

Investing in the health and wellbeing of the children of South Africa is an investment in the future development of our country. South Africa still has a relatively youthful population with a third of the population under 15 years of age[3], although we are in the midst of demographic transition. The health of these children needs to be a priority, a principle adopted through the ratification of the1990 United Nations Convention of the Rights of the Child.

The level of mortality is a fundamental indicator of child health and understanding the causes of death of children provides insight as to how it can be reduced. The lack of reliable vital statistics has created a void when it comes to these indicators, but the recent burden of disease study has made use of available data from the emerging health information system to estimate the levels and causes[1].

The Medical Research Council published the Initial Burden of Disease Estimates for South Africa, 2000 in March 2003[1,2]. This was the first attempt to derive consistent and coherent estimates of all causes of death from a range of data sources and models. A major finding of the study was the quadruple burden of disease experienced in South Africa resulting from the combination of the pre-transitional causes related to underdevelop-ment, the emerging chronic diseases, the injury burden and HIV/AIDS. This policy brief examines the causes of mortality among children in more detail.

The 1998 Demographic and Health Survey[4] found that the Infant Mortality Rate was 45 per 1000 live births for the preceding 10 years. This overall figure is lower than the WHO 'Health for All' target of 50 per 1000 births, but does conceal the variations between population groups, according to socio-economic status or region. The survey also highlighted the wide racial and socio-economic status inequalities in child mortality. It also conceals the reversal in the downward trend that occurred during the 1990's. This has largely been ascribed to the impact of the HIV/AIDS epidemic. Furthermore, the level of mortality has not given any insight into the causes of mortality.

The South African National Burden of Disease Study (NBD)

Since the disease burden in South Africa is undergoing rapid change due to the spread of HIV/AIDS[5], the usual burden of disease approach was considered inappropriate and a modelling approach calibrated to empirical data was adopted. An adapted version of the 1990

MRC SOUTH AFRICA

unicef

Global Burden of Disease (GBD) list of causes of death[6,7] was developed for the South African National Burden of Disease study. The total number of deaths, as well as the age-specific population was calculated using the ASSA2000 model of the Actuarial Society of South Africa[8]. Empirical estimates from surveys and vital registration of the level of childhood and adult mortality were used in the model for the period prior to the AIDS epidemic. Ill-defined causes within a disease category were reallocated proportionally by age and sex to specified causes within that category. Cause of death information processed by the Department of Home Affairs was used to estimate the overall proportion of deaths due to injuries by age and sex. Finally the UNISA/MRC national injury mortality surveillance system (NIMSS)[9] was used to estimate the profile of deaths arising from injury. The estimates are hence a synthesis derived by analysis of a variety of often incomplete data sources. Full details of the methodology appear in the complete report[1]. Variations of prevalence at a subnational level are not reflected in this study.

The NBD study estimated just over half a million deaths of which 106 000 were of children under the age of 5 years and a further 7800 were children aged 5-14 years. In general, young babies are much more vulnerable than older. In addition, the cause of death patterns in the different age groups are very different.

Infant and Under-5 mortality

The NBD study estimates that by the year 2000, the Infant Mortality Rate had risen to 60 per 1000 live births and the Under-5 mortality rate had risen to 95 per 1000. This deterioration in child health occurred despite the introduction of free health care and nutrition programmes and was attributable to paediatric AIDS, commensurate with the high prevalence of HIV observed among pregnant women.

The top twenty causes for children under the age of 5 are shown in Table 1 and by age and sex in Figures1 and 2. HIV/AIDS is the leading cause of death among young children and accounts for 40% of the deaths in 2000. Although the percentage of deaths due to HIV/AIDS is higher in the 1-4 year age group, the largest number of deaths occurs in the under-one age group. Low birth weight, diarrhoea, lower respiratory infections and protein energy malnutrition account for a further 30% of the childhood deaths. A large number of these deaths are preventable through the delivery of the standard conventional primary health care package approach. Birth defects, particularly of the heart and neural tubes also are among the top ranking infant deaths. Protein-energy malnutrition begins to show in the 1-4 age group. There is little gender difference in mortality among the under-fives.

Projections indicate that without effective prevention of mother-to-child transmission (PMTCT), the child mortality rate is likely to have continued to rise in subsequent years[10]. This pattern, however, can be expected to change as the epidemic matures and as the roll-out of PMTCT takes effect, reducing the number of infected babies.

Table 1: Top twenty specific causes of death in children under 5 years, South Africa 2000

Rank	Cause of death	Deaths	%
1	HIV/AIDS	42749	40.3
2	Low birth weight	11876	11.2
3	Diarrhoeal diseases	10786	10.2
4	Lower respiratory infections	6110	5.8
5	Protein-energy malnutrition	4564	4.3
6	Neonatal infections	2920	2.8
7	Birth asphyxia and trauma	2584	2.4
8	Congenital heart disease	1238	1.2
9	Road traffic accidents	1219	1.1
10	Bacterial meningitis	1141	1.1
11	Fires	1102	1.0
12	Neutral tube defects	1019	1.0
13	Septicaemia	980	0.9
14	Tuberculosis	743	0.7
15	Homicide/violence	654	0.6
16	Drowning	532	0.5
17	Cot death	491	0.5
18	Down syndrome and other chromosomal	445	0.4
19	Congenital disorders of GIT	379	0.4
20	Congenital syphilis	257	0.2
	All causes	**106070**	

Most of the other causes of death of infants and toddlers are associated with poor socio-economic conditions. The 2001 census reveals extensive variations in living conditions. Over two thirds of households have formal homes, 16% are informal and 14% are traditional. Access to clean water and basic sanitation is important from a health perspective. The census shows that the majority of households do have access to piped water (84.5%) – whether it is in the home, the yard or a public facility. However, the Eastern Cape has a much lower proportion with only 62.4% of households having access to piped water. The Eastern Cape also had a very high proportion of households without any toilet facilities (30%). Nationally, 13.6% of households have no toilet facility, also a health hazard. Just over half the households have regular refuse removal services. The high levels of poverty and unemployment are clearly

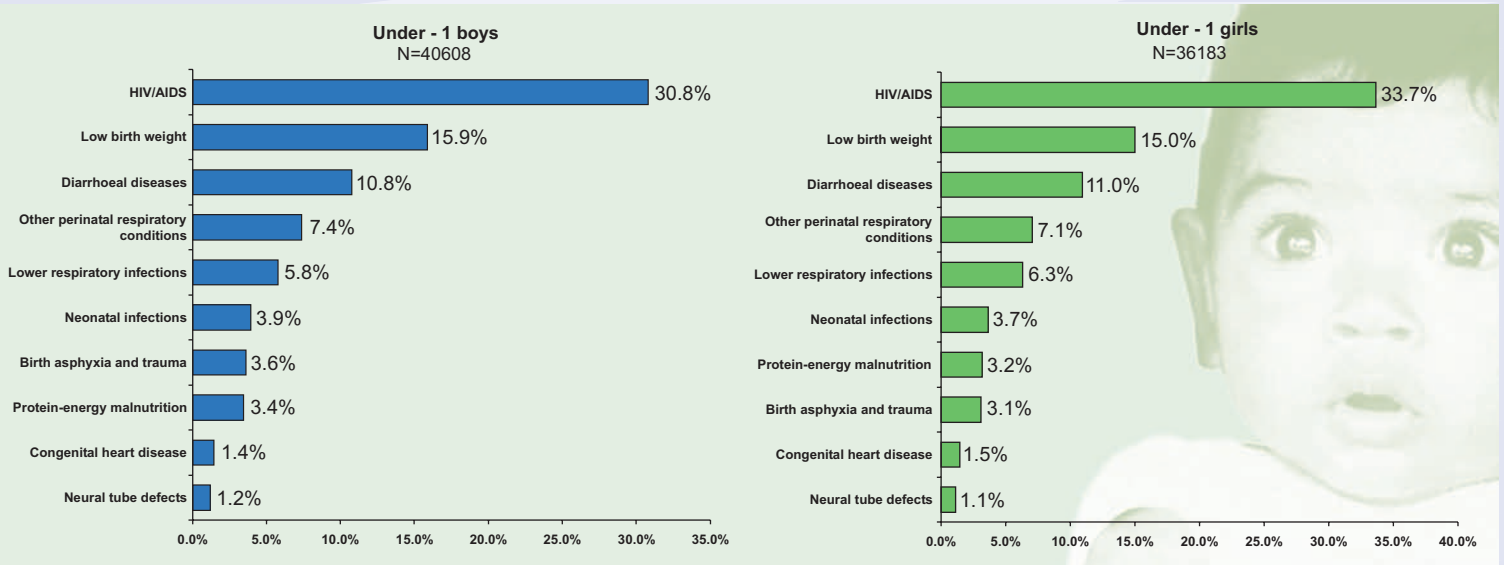


Figure 1. Leading causes of death among infants under 1 year of age, South Africa 2000

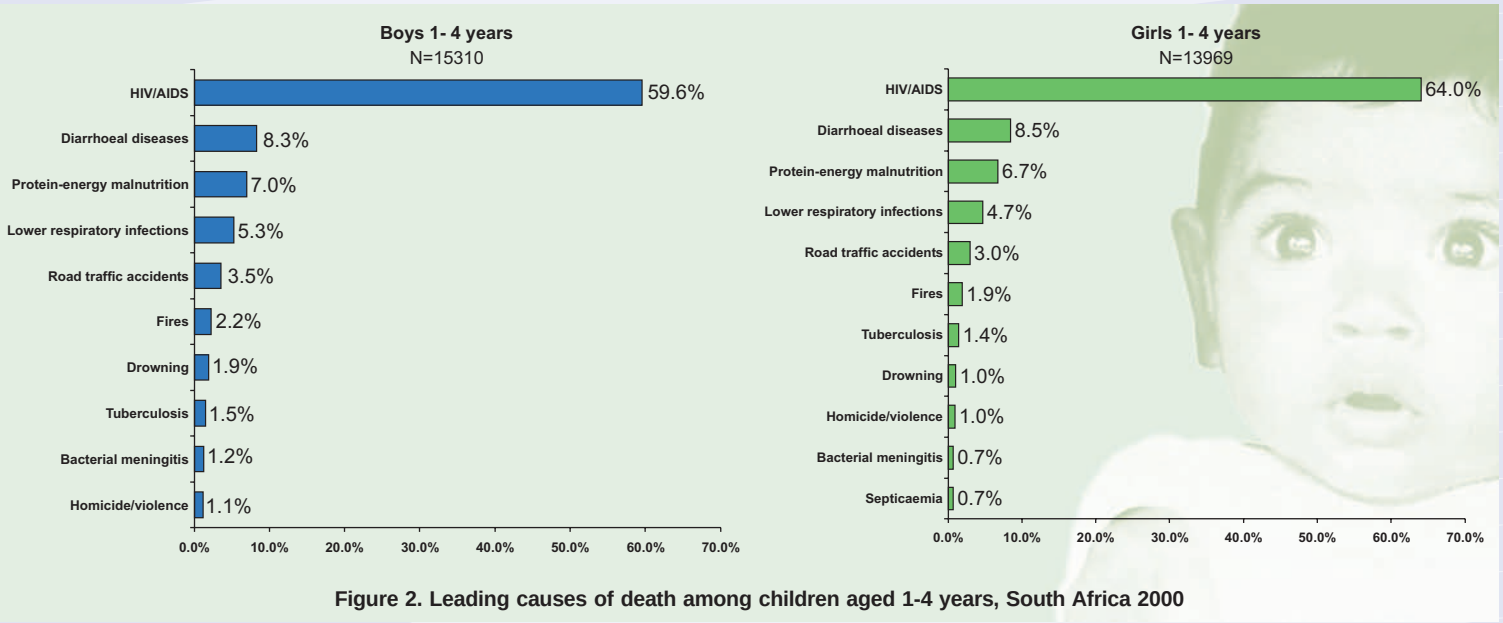


Figure 2. Leading causes of death among children aged 1-4 years, South Africa 2000

fundamental issues that bear on child health, also indicated by the estimated 4564 deaths from protein-energy malnutrition (Kwashiorkor). Many of these deaths can be prevented. Reducing poverty, meeting basic needs and adopting a comprehensive primary health care approach with renewed vigour must be high on the agenda in the next few years.

Older children 5-14 years

As children get older, external causes of death (eg. road traffic injuries and drowning) rise in importance. This is particularly noticeable among boys who die in greater numbers than girls. This pattern becomes particularly marked among the 10 -14 year age group, where road traffic accidents is the leading cause of death. Homicide and suicide feature in the top causes

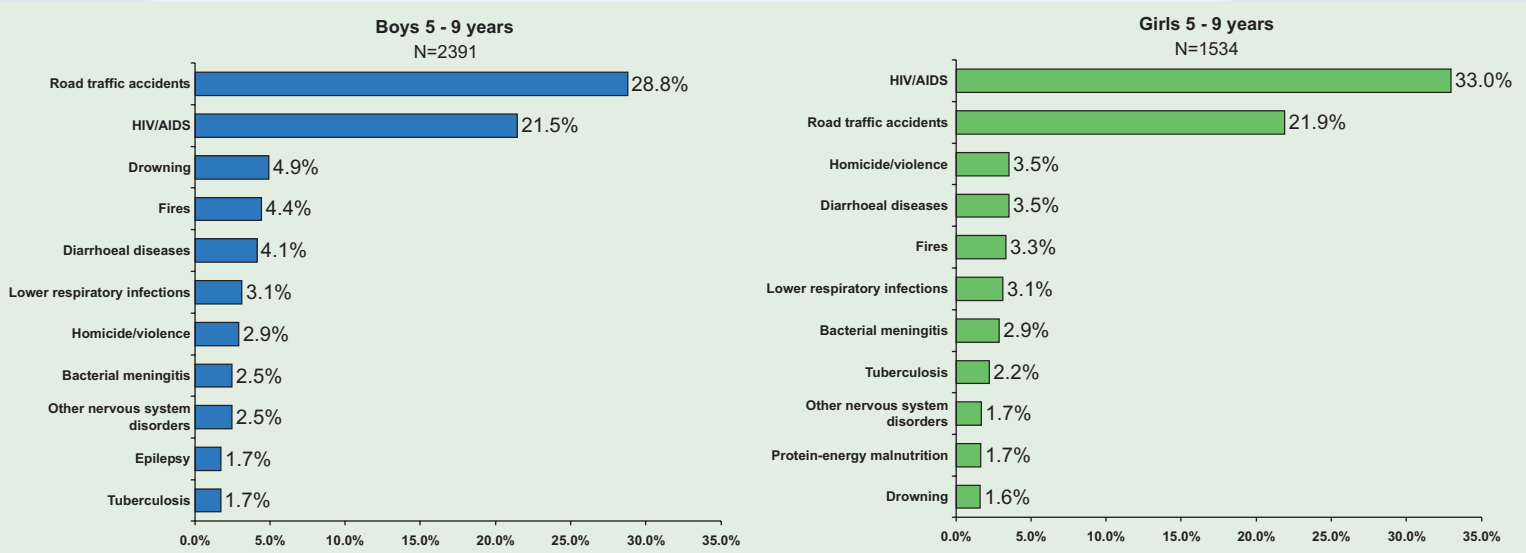


Figure 3. Leading cause of death among children aged 5-9 years, South Africa 2000

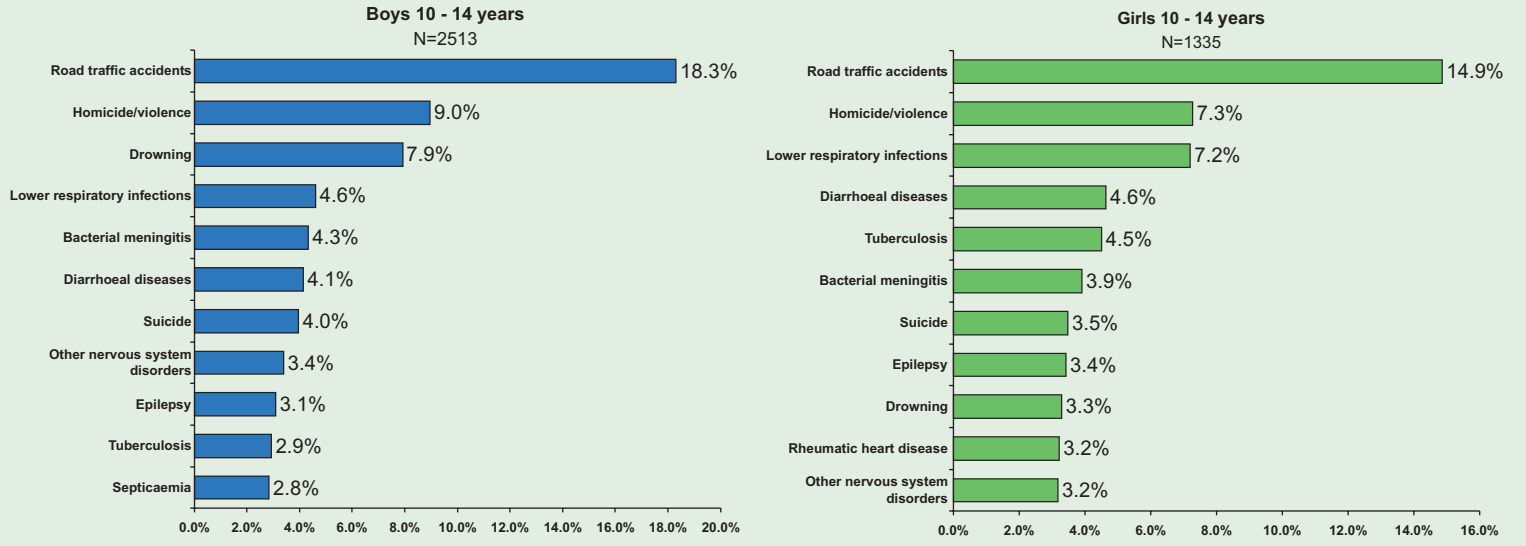


Figure 4. Leading Causes of death among children aged 10-14 years, South Africa 2000

Policy Implications

The mortality data indicates that many of the child deaths occurring in South Africa are preventable. We have identified three broad areas that will require differing approaches for intervention:

- The prevention of mother-to-child transmission of HIV, even at its current efficacy, is the single most effective intervention to reduce mortality among under-5-year olds, eclipsing all other interventions for other causes of death combined.
- Although dominated by the rise of HIV/AIDS, the classic infectious diseases such as diarrhoea, respiratory infections and malnutrition are still important causes of mortality. Environment and development initiatives such as access to sufficient quantities of safe water, sanitation, reductions in exposure to indoor smoke, improved personal and domestic hygiene as well as comprehensive primary health care will go a long way to preventing these diseases. Poverty reduction initiatives are also important in this regard.
- Road traffic accidents and violence, which includes homicide and suicide is another group of high mortality conditions that will require dedicated interventions.

The data presented in this policy brief represent an average for the whole country and do not highlight the inequalities in health care and outcomes that exist in different parts of the country. Detailed investigation of these inequalities will, however, require more comprehensive information systems than are currently available, and are beyond the scope of this policy brief.

of death in these ages and among the 10-14 year age group, homicide is the second leading cause of death. HIV/AIDS is no longer a leading cause of death, in this age group, although other infectious diseases make up a large proportion of the remaining top causes.

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The Impact of Adult Mortality on Child Mortality

In recent years, mortality among young adults, and in particular young women, has increased dramatically as a result of HIV/AIDS. Such mortality and also the illness preceeding it, has a devastating effect on children leading to increased morbidity, mortality and orphanhood. One of the most important results of the roll-out of anti-retroviral therapy among the general population will be the extension of the lives of AIDS sick parents leading to a dramatic decline in the number of orphans. [11]

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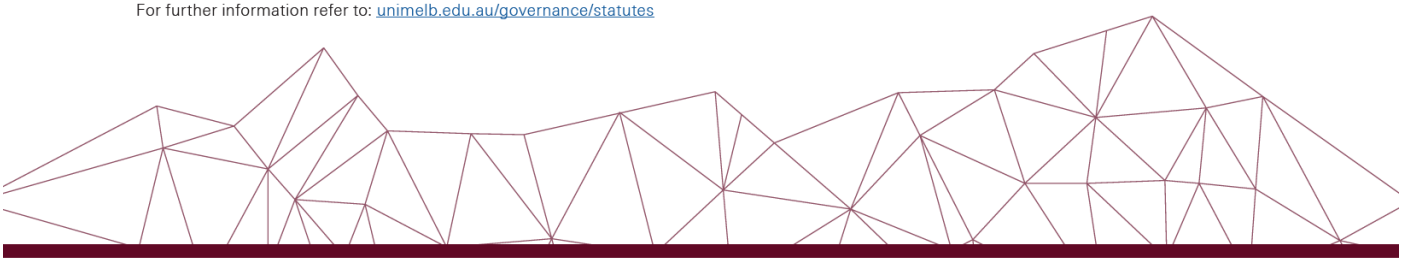

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