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2017 Inquérito Sobre Causas de Mortalidade (INCAM)-2 Pilot

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ABBREVIATIONS

BID	brought in dead
CISM	Manhica Health Research Centre
COMSA	Countrywide Mortality Surveillance for Action
CSMF	cause-specific mortality fraction
EA	enumeration area
HDSS	Health and Demographic Surveillance Systems
ICD-10	International Classification of Disease, Tenth Edition
IHME	Institute for Health Metrics and Evaluation
INCAM	Inquérito Sobre Causas de Mortalidade
INE	Mozambique National Institute of Statistics
MISAU	Ministry of Health
ODK	Open Data Kit
PHMRC	Population Health Metrics Research Consortium
USAID	United States Agency for International Development
VA	verbal autopsy
WHO	World Health Organization

INTRODUCTION

In advance of the August 2017 Population and Housing Census, the Mozambique National Institute of Statistics (INE) and Ministry of Health (MISAU) began discussing the implementation of a post-census mortality survey. This would be the country's second such survey. Following the 2007 Population and Housing Census, INE and MISAU conducted a post-census mortality survey (Inquérito Sobre Causas de Mortalidade [INCAM]) in 2007/2008 using verbal autopsies (Mozambique National Institute of Statistics, et al., 2012). Like the first INCAM, the 2017 Population and Housing Census included questions on household deaths in the previous 12 months, collecting the name, sex, age, and date of death for the deceased. A sample of census enumeration areas representative of the national and provincial levels would then be selected, and all deaths reported in the census in those areas would be visited to administer a verbal autopsy (VA) for each death.[1]

In 2008, INCAM used physician-based certification of cause of death based on the VAs. Given the cost of using physicians to determine the cause of death from verbal autopsies and the development in the past 10 years of alternative methods for interpreting VAs, it was decided that the pilot for INCAM-2 would focus on a comparison of multiple methods for determining the cause of death (Figure 1). The goal of the comparison is to help the government select the most appropriate interpretation method for full implementation of INCAM-2. Based on other studies, it was determined that a minimum of 300 completed VAs with at least 30 neonatal deaths would be needed (King, Lu, & Sibuya, 2010).

[1] This was the sample method followed in 2007 for the first INCAM and resulted in 10,080 deaths certified and coded.

METHODS

The INCAM-2 pilot used a set of three VA questionnaires that were modifications of the latest (2016) World Health Organization (WHO) set of VA questionnaires for deaths to neonates (less than 28 days), children ages 28 days to 11 years, and adults ages 12 years and older.[2] The VA questionnaires applied in the pilot included informed consent, all questions in the WHO 2016 questionnaires, and additional questions employed in VAs in Malawi and Zambia in recent years (2014–2015) that were considered to be valuable to physician coders in Malawi and Zambia. See Appendix 2 for the three questionnaires.

Enumerators, drawn from INE's pool of experienced interviewers, were selected and trained for five days in the first week of December 2017 to serve as VA interviewers. Both the United States Agency for International Development (USAID)-funded MEASURE Evaluation project and United States Census Bureau were present for the interviewer training. Tablets were used to administer the VA using the Open Data Kit (ODK) questionnaire application. INE expressed a preference for ODK because this application was being used in the Countrywide Mortality Surveillance for Action (COMSA) project in Mozambique, and staff were becoming more familiar with it. Programming and subject matter issues with the ODK application were addressed during training and fieldwork.

Deaths identified for VAs in the INCAM-2 pilot were not the result of a sampling process and are not nationally representative. Because the pilot took place after the 2017 Population and Housing Census and INE had strong institutional experience from the previous postcensus mortality survey, the INCAM-2 pilot focused solely on gathering a sufficient number of VAs to allow evaluation of multiple interpretation methods.[3] Travel restrictions led INE to reach out to local leaders in urban and rural areas of nearby Maputo Province to identify deaths for the INCAM-2 pilot. Local leaders in Boane District and the city of Matola were asked to provide a list of deaths that had occurred in their communities within the past year. The number of infant deaths on these lists was low and viewed as insufficient to meet the objective of the pilot. Therefore, Manhica District was added, and the Manhica Health and Demographic Surveillance Systems (HDSS) site provided a list of recent infant deaths for which VAs had not yet been administered. See Table 1 for the number of VAs completed in each area.

The households where the decedents had lived were then visited by the trained VA interviewers in the second and third weeks of December 2017. A local leader guided interviewers to the household. If no qualified respondent was available, or in the rare case that the household refused to participate, the interviewers moved to the next death on the list and repeated visits to households did not occur. Nearly 500 deaths were followed up with a VA interview. Verbal autopsy interviewers administered the questionnaire using tablets and data were transmitted to a server located in INE. Of the 469 deaths with completed VAs, 57 percent resided in urban areas and 43 percent in rural areas (Table 2). Verbal autopsies were completed for 254 male deaths and 212 female deaths, with sex missing for 3 VAs (Table 3). Fifty-five VAs were completed for neonates, 115 for children, and 296 for adults, with age missing for the same three VAs also missing information on the sex of the deceased (Table 4).

[2] These age categories are based on the WHO VA questionnaires.

[3] For the first INCAM, the pilot was conducted in conjunction with the pilot for the 2007 Population and Housing Census and served as a test of logistics, processes, and financial feasibility of a postcensus mortality survey in Mozambique. A sample of enumeration areas (EAs) for the INCAM pilot were drawn from the EAs participating in the pilot census.

CAUSE-OF-DEATH DETERMINATION

Three methods were used to interpret the completed VAs and determine a cause of death: physician coding, InterVA, and SmartVA. Physician coding was selected as the reference because this interpretation method was used in the 2007–2008 INCAM and has been the most commonly used method in sub-Saharan Africa. InterVA is an example of a probabilistic method for computer-coded VA interpretation (Figure 1) and recently has replaced physician coding at INDEPTH Network member HDSS sites.[4] SmartVA is an example of a data-driven algorithm. All three methods state that they follow the International Classification of Disease, Tenth Edition (ICD-10). Each method is described briefly below, followed by a summary of the results.

Physician-Based Coding

The MISAU director of hospital services supplied 13 medical officers who work at health facilities in Maputo and two doctors from the Manhica Health Research Centre (CISM) in Chokwe. These 15 medical officers were trained by MEASURE Evaluation for two weeks in February 2018. The first five days were in-class training on the VA methods and the tools used during data collection, and on international practices for cause-of-death certification, following ICD-10 rules and guidelines to determine and code the immediate and underlying causes of death. The second week was dedicated to actual coding work and data entry of completed death certificates, together with corresponding ICD-10 codes produced by the trained medical doctors. Two physicians independently reviewed a VA questionnaire and then each completed an international death certificate. The immediate and underlying causes of death were then compared between the two physicians. If they differed, the two physicians consulted and reached agreement on the immediate and underlying causes of death. If they could not reach agreement, the death was classified as undetermined cause of death.[5]

InterVA Coding

InterVA is an expert-based probabilistic method for determining cause of death from VAs (InterVA, n.d.). InterVA assigns likely causes of death from a range of input "indicators" relating to a particular death using a Bayesian model with *a priori* probabilities based on expert consensus. Indicators, posed as questions, include circumstances of a death, basic background characteristics, signs and symptoms of illness leading to death, previous medical history, etc. InterVA is designed to interpret VA data for deaths for all ages and from all causes. Research and development of InterVA is conducted by the Umea Center for Global Health Research in Sweden and the product has been in the public domain since 2003 (Byass, Huong, & Minh, 2003). InterVA is actually a suite of computer models used to interpret VAs: hence the name InterVA. For an individual death, InterVA produces the propensity of up to three causes if these largest propensities exceed a set threshold. At the community level, InterVA sums across all individual deaths the largest propensities for each cause to produce a population-level fraction of deaths resulting from each cause (Nichols, et al., 2018). The INCAM-2 pilot ultimately used InterVA-5, which is compatible with the WHO 2016 VA questionnaires and one of the coding methods being used by

[4] Both the Chókwè HDSS and Manhiça HDSS in Mozambique are members of the INDEPTH Network.

[5] Another recommended approach is to have two doctors independently review the verbal autopsy and code the cause of death; then if there is disagreement, have a third doctor independently review the verbal autopsy data and assign a cause of death. If the cause of death assigned by the third physician matched that assigned by the first or second doctor, then it would be considered the final cause of death. Our field experience suggests that having the first two doctors meet and discuss reduces the number of indeterminate cases.

COMSA in Mozambique.[6] Basic epidemiological parameters for malaria and HIV/AIDS were set to high for Mozambique in the analysis of pilot INCAM data using InterVA-5. InterVA started being used throughout the INDEPTH Network of demographic surveillance sites as early as 2017.

SmartVA Coding

SmartVA-Analyze implements the Tariff 2.0 method, the current successor to Tariff 1.0, for computer certification of VAs. The data-driven algorithms were developed by the Population Health Metrics Research Consortium (PHMRC) at the Institute for Health Metrics and Evaluation (IHME) (Serina, et al., 2015). Tariff calculates a score, or "tariff," for each cause, for each sign/symptom, across a pool of validated VA data. The tariffs are summed for a given response pattern in a VA, and this sum (score) provides the basis for predicting the cause of death in a dataset. The original Tariff method—Tariff 1.0—was trained using VAs for deaths that also had hospital records. Subsequently the model was adjusted to correct for observed biases of the model and the revised model became Tariff 2.0. SmartVA takes VA interview data as input and produces cause-of-death estimates at the individual and population levels. The SmartVA cause-of-death assignment system was designed and validated with the Population Health Metrics Research Consortium (PHMRC) Gold Standard VA database collected as part of the PHMRC Gold Standard VA Validation Study (Murray, et al., 2011). The SmartVA system is designed for analysing VA data collected electronically using the PHMRC Full and Shortened Questionnaires, which differ from the WHO standard VA questionnaires (IHME, n.d.). Similar to the situation with InterVA, a version of SmartVA compatible with the WHO 2016 questionnaires was not available when analysis of the Mozambique pilot data began. Abie Flaxman, who oversees SmartVA, provided some assistance in the use of the system for the INCAM-2 pilot and, ultimately, Version 2.0 (released on December 10, 2018) was used.

[6] Initially, InterVA-4, a version consistent with the older WHO 2012 verbal autopsy standard questionnaires and ICD-10, was applied to the verbal autopsy data; however, the results proved to be highly questionable. Since early 2017, the WHO website on verbal autopsy standards has stated, "The 2016 WHO VA instrument is fully compatible with publicly available analytical software for assigning the cause of death (SmartVA, InterVA, InSilicoVA). A conversion algorithm transforms the output of the WHO VA 2016 questionnaire in files that can be processed by SmartVA, InterVA, and InSilicoVA." In September 2017 we contacted Erin Nichols and others on the technical advisory board for WHO for help in tracking down the conversion algorithms and latest version of InterVA. We were told that they were still in development and not available. This delay forced us to start with InterVA-4, but after InterVA-5 was released, in September 2018, we switched to InterVA-5 after eventually gaining access to the new version.

RESULTS

Four hundred and sixty-six VA interviews containing age and sex data for the deceased were completed. Of these completed VA questionnaires, only 427 were reviewed by physicians and 466 were interpreted and coded for cause of death by SmartVA and InterVA.[7] The three interpretation methods differed in their ability to determine a cause of death.

Physicians classified 7.7 percent of neonate deaths, 21.6 percent of child deaths, and 11.7 percent of adult deaths as undetermined (Table 5). SmartVA was unable to determine a cause of death for 34.4 percent of neonate deaths, 40.6 percent of child deaths, and 19.6 percent of adult deaths. InterVA had the lowest share of undetermined cause of death for children and adults (14.6% and 1.0%, respectively) and assigned a specific cause for all but 7.8 percent of neonate deaths.

Both physician coding and InterVA produce causes of death consistent with the WHO 2016 cause-of-death tabulation list for VA (with correspondent ICD-10 codes). SmartVA results are not fully consistent with the WHO 2016 tabulation list. The three interpretation methods also differed in the number of different causes of death assigned to these VAs, with physicians and InterVA-5 identifying more than SmartVA 2.0. The tables showing cause-of-death results for adults, children, and neonates (Tables 6—Table 10) use the 2016 WHO tabulation list for the causes of death identified by the three methods. SmartVA results were mapped to the 2016 WHO list.[8] Causes of death are listed in the frequency order based on physician coding. The detailed original results for SmartVA are shown in Appendix 1, Tables A1-1 through A1-3.

The leading cause of death for adults (ages 12 and above) was HIV/AIDS for all three coding methods: 27.8 percent according to physician coding, 19.3 percent according to SmartVA, and 23.8 percent according to InterVA (Table 6). The second and third leading causes of death among adults were other and unspecified cardiac disease (7.7%) and stroke (7.7%) according to physician coding, stroke (15.2%) and other and unspecified noncommunicable disease (6.4%) according to SmartVA, and stroke (14.0%) and acute respiratory infection, including pneumonia (8.9%) according to InterVA.

Leading causes of death by sex are presented only for adults (ages 12 and over) because of the relatively large number of deaths in this age group (Table 7 for males and Table 8 for females). According to physician coding, the three leading causes of death among adult males were HIV/AIDS (27.0%), pulmonary tuberculosis (8.1%), and diabetes (7.4%). SmartVA determined the leading causes of death among adult males to be HIV/AIDS (18.4%), stroke (12.0%), and pulmonary tuberculosis (7.6%). The three leading causes of death among males ages 12 and over identified by InterVA were HIV/AIDS (21.3%), stroke (12.3%), and acute respiratory infection, including pneumonia (11.6%). Physicians determined the leading cause of death for adult females also to be HIV/AIDS (28.8%), accounting for a similar share of all deaths as for males. The second and third leading causes of death for adult females were other and unspecified cardiac disease (9.6%) and stroke (9.6%) under physician coding. The three leading

[7] The President of INE determined that doctors participating in the pilot should not be paid for reviewing the verbal autopsies and certifying and coding a cause of death; only a daily transportation allowance was to be paid. Prior to the completion of all verbal autopsies, INE said there were no more funds and doctors halted work therefore only 427 were physician reviewed

[8] For example, among adults SmartVA identified the following specific causes of death from cancer: cervical cancer, leukemia/lymphomas, prostate cancer, esophageal cancer, and other cancers. The WHO 2016 tabulation list includes oral neoplasms, digestive neoplasms, respiratory neoplasms, breast neoplasms, female reproductive neoplasms, male reproductive neoplasms, and other and unspecified neoplasms. Thus, SmartVA results for cervical cancer are mapped to female reproductive neoplasms; prostate cancer appears under male reproductive neoplasms; esophageal cancer is mapped to digestive neoplasms; and leukemia/lymphomas and other cancers are placed under other and unspecified neoplasms.

causes of death for adult females differed when SmartVA was used: HIV/AIDS (20.3%), stroke (18.8%), and malaria (6.5%). When InterVA was applied to VA data for females ages 12 and over, the leading causes of death were HIV/AIDS (26.6%), stroke (15.8%), and other and unspecified cardiac disease (10.8%).

The leading cause of death for children ages 28 days to 11 years varied across the interpretation methods (Table 9). Physician coding determined that HIV/AIDS (13.7%) was the leading cause while SmartVA coded diarrheal diseases (20.8%) as the leading cause and did not code any deaths to HIV/AIDS. InterVA identified meningitis and encephalitis (16.5%) as the leading causes of death for children ages 28 days to 11 years.

Among neonates (ages 0 to 27 days), physicians coded a quarter of all deaths due to birth asphyxia and 21.2 percent as due to prematurity. SmartVA assigned nearly one-third of neonate deaths to prematurity (32.8%) and 15.6 percent to birth asphyxia. InterVA determined that prematurity accounted for 31.3 percent of neonate deaths and birth asphyxia accounted for 28.1 percent.

DISCUSSION

Both INE and MISAU have expressed a preference for a computer-driven method to interpret VA data in situations where VA methods can be applied for routine surveillance outside of hospital settings. The use of computer coding saves time and money. Relying on a computer-coded interpretation method instead of physician review and coding avoids the negative impact of diverting physicians from attending to patients and servicing the immediate health care needs at hospitals and health facilities.

Many computer-driven methods are available, and two were applied in the pilot: InterVA and SmartVA. InterVA was selected for the pilot because it has been around for over a decade, and it recently replaced physician review at INDEPTH Network-member HDSS sites, including at Manhiça HDSS. SmartVA represents a different methodological approach and has been used in many settings throughout Africa. The pilot presented an opportunity to see how these two computer-driven methods performed and how the results compared to physician review. The comparison to physician review is important because countries may wish to aggregate and compare cause-of-death data from hospital settings (typically relying on physician certification) with cause-of-death information obtained from the application of VA methods in community settings. If the computer-coded VA method is comparable to what physicians would have assigned, there is added value in merging the sources of cause-of-death data to obtain a more comprehensive and detailed understanding of the leading causes of death. If the two are comparable, then VA methods also could be applied to people in the communities who are brought in dead (BID) to the health facilities, where they often are classified as having died from undetermined causes. The application of VAs among facility-based BIDs will significantly reduce the facility-based undetermined causes of death.

The analysis comparing the performance of SmartVA and InterVA using pilot INCAM-2 data in Mozambique does not present a consensus opinion that clearly identifies a "best" computer-coded method that is comparable to the cause-of-death information generated by medical doctors. Overall, SmartVA was unable to assign a cause of death to 26.5 percent of the pilot deaths—double the share that physicians coded as unknown cause of death. In particular, SmartVA was unable to assign a cause of death to more than one-third of neonatal deaths and 40.6 percent of child deaths. On the other hand, InterVA assigned a cause of death to all but about 5 percent of deaths in the pilot.

Differences exist in the share of deaths attributed to major causes by age group. Although all three methods identified HIV/AIDS as the leading cause of death for adults (ages 12 and above), the share ranged from 27.8 percent for physician coding to 19.3 percent for SmartVA. In another example, physicians coded 5.9 percent of all adult deaths as due to cancer, while SmartVA coded 3.4 percent and InterVA 1.3 percent. Physicians assigned 5.6 percent of all female adult deaths to maternal causes similar to the SmartVA share of 5.1 percent but only half the 12.3 percent share from InterVA. Both SmartVA and InterVA had nearly double the share dying from strokes compared to physician coding.

Another important difference is the share dying from acute cardiac disease: 5.4 percent both for SmartVA and InterVA and only 0.4 percent for physician coding.

Among children ages 28 days to 11 years, SmartVA did not attribute any deaths to HIV/AIDS while physicians assigned 13.7 percent and InterVA 8.7 percent. In contrast, SmartVA blamed one in five child deaths on diarrheal diseases—roughly double the shares from InterVA and physicians. There is a sizeable range in the share of deaths attributed to malaria: only 1.9 percent from SmartVA, 4.9 percent from physicians, and 10.7 percent from InterVA. Another notable difference exists for deaths due to meningitis and encephalitis: about 2 percent from physicians and SmartVA but 16.5 percent from InterVA.

Although WHO identified both SmartVA and InterVA as compatible with the new 2016 set of VA questionnaires at time of release, this was not the case. There was nearly a two-year delay before InterVA was modified to accommodate the WHO 2016 questionnaires and SmartVA added support for the WHO 2016 questionnaires only in Version 2.0, released in late 2018. The SmartVA system is described on the IHME website as being designed for analysing VA data collected electronically using the PHMRC full and shortened questionnaires with the ODC Collect system on Android devices (IHME, 2019).

When we examine other studies that applied InterVA, SmartVA, and physician review, some results are similar and other results are not necessarily consistent with the INCAM-2 pilot findings. A study in Tanzania compared cause-specific mortality fraction (CSMF) concordance among InterVA-4, InSilico, and physician coding for 616 VAs and found high concordance between InterVA-4 and InSilico but very low concordance between physician coding and each of the two computerized methods (Kabadi, 2018). A South Africa study examining the accuracy of these three coding methods in determining HIV-associated causes of death had findings similar to the INCAM-2 pilot (Karat, et al., 2018). The study focused on mortality of adults with known HIV status. The WHO 2012 VA questionnaires were used with antiretroviral therapy questions added. Cause of death was assigned using physician certification, InterVA 4.03, InterVA-5, SmartVA V.1.1.1, and SmartVA V.1.2.1. The study found that the four computer-coded methods underestimated the HIV-associated mortality fraction whereas the fraction estimated by physician coding was closer to the correct figure. However, the newer versions of InterVA and SmartVA performed better than earlier versions.

We used the proposed WHO 2016 tabulation list linked to the ICD-10 codes to produce causes of death from physicians' review of VAs. For SmartVA, the output tabulation list is somewhat different, and validation was based on the PHMRC Gold Standard Dataset, which may not be ideal for Mozambique. The PHRMC Gold Standard Dataset consists of mortality data from Andhra Pradesh and Uttar Pradesh, in India; Bohol, Philippines; Dar es Salaam and Pemba Island, in Tanzania; and Mexico City, Mexico (Murray, et al., 2011).

Using both InterVA and SmartVA posed challenges and were time-consuming. Neither can yet be described as user-friendly and most countries would require assistance from the developers of these programs to use them effectively. We are not aware of any countries that have successfully implemented a mortality survey or routine mortality surveillance using automated-coding methods without extensive external support.

Verbal autopsy cause-of-death assignment using computer-coded methods rely mainly on three components: (1) VA data from completed VA interviews, (2) the relationship of symptoms to cause-of-death information, and (3) logical algorithms that combine (1) and (2) to identify CSMFs and/or assign a likely cause of death to each death.

The symptoms-to-cause-of-death relationship describes how VA symptoms are related to each cause—either elicited directly from physicians or in the form of a dataset of VAs and causes assigned using a different mechanism (trained dataset), such as a medical records review. As a result, even though both physician-coded VA (PCVA) and computer algorithms create cause-specific mortality fractions, the different methods produce different outputs. Some computer-coded methods assign one cause to each death while others assign a propensity or a probability to every cause for each death. Those that assign a number to each cause report a summary of those numbers for each death—often the three causes with the largest number.

Based on the design of the different computer-based interpretation methods, the major contributor to the differences in outputs by the two used here is mainly the symptoms-cause information. In a presentation summarizing the findings of a study on comparability of VA cause of death, Samuel Clark (2018) reported that using symptom-cause information from the same populations as the deaths was more important than the computer method chosen in obtaining the most useful results. There needs to be guidance from WHO and consensus as to which cause-of-death tabulation list to use for all these different computer methods that are being developed, and indeed there is a need to improve and standardize the symptoms-to-cause-of-death relationship that these programs use in order to replicate the outputs that are comparable to cause-of-death information from physicians' review. This also was the recommendation of the technical committee advising WHO at the *Mortality Analysis with Verbal Autopsy* technical meeting held in Washington, D.C., USA, September 12–14, 2018.

SmartVA and InterVA obviously are complex algorithms and models. They also have been revised and refined over the years. Most users are not in a position to know all the assumptions and relationships between symptom and cause embedded in the programs. Some of the methodological changes from version to version can have a significant impact on the results.

SmartVA publishes changes for version updates, which provides some insight into the underlying assumptions. For example, a May 2017 update of SmartVA added rules to predict injury or stillbirth if a key symptom is endorsed, and the next update in June 2017 made it so stillbirth is no longer predicted in neonates who live at least one day. The June 2017 update also allowed maternal causes to be predicted in ages 12 through 14 (relevant for Mozambique) and AIDS was no longer deterministically predicted for a child in cases where the mother was told by a health worker that she had HIV (SmartVA assigned no child deaths to HIV/AIDS in the INCAM-2 pilot). The latest version (used for the INCAM-2 pilot) added stricter criteria to predict child cardiovascular diseases, prohibited women who were reported to have gone through menopause from being assigned a maternal cause of death, and adjusted the child thresholds used to determine if an observation has enough information to generate a valid prediction. (This change was made to help reduce the proportion of undetermined cause of death among children.)

A "rapid and cost-effective" method of determining cause of death using computers is desirable, especially for deaths that do not occur in health facilities. However, more work needs to be done to improve and standardize computer-based methods so that they produce reliable and comparable information on causes of death that can be linked to the facility-based routine health management information system.

For the purpose of informing health sector policies and programs and for the purpose of complementing cause-of-death information generated from health facility data, we view physician review of VA as the standard reference for comparison and, in most situations, the preferred method.

RECOMMENDATIONS

As suggested by the medical doctors, Mozambique could develop its own tabulation list based on ICD-10, in consultation with WHO, that reflects causes most relevant to the country to improve comparisons with routine systems, including the health management information system. InterVA, for example, is compatible only with the WHO 2016 tabulation list.

If funds are sufficient, physician coding should be used for all VAs. This will allow direct linkage and comparison to health facility-based cause-of-death certification. Only two computer coding methods were evaluated for the pilot and the pilot was not a nationally representative sample. Therefore, recommendations concerning SmartVA and InterVA-5 should be viewed with caution.

If funds are short, a computer-coded system, such as InterVA-5, can be used and physician coding can be applied to a subset of VAs. For example, all ill-defined causes of death could be reviewed by physicians. Another example is to use physician coding for deaths among women of reproductive age if experience suggests that the computer-coded method is ineffective in correctly identifying maternal deaths.

If funds are extremely limited, rely solely on a computer-coded system but note that the output may not give a correct picture of the causes of death and cannot be linked to facility-based mortality data.

If a computer-coded system is going to be used, the VA questionnaires should incorporate the numbering system used by the selected system or systems.

At this stage, locking into a single computer-coded system is risky. Therefore, the VA questionnaires should include all questions required by multiple computer-coded systems.

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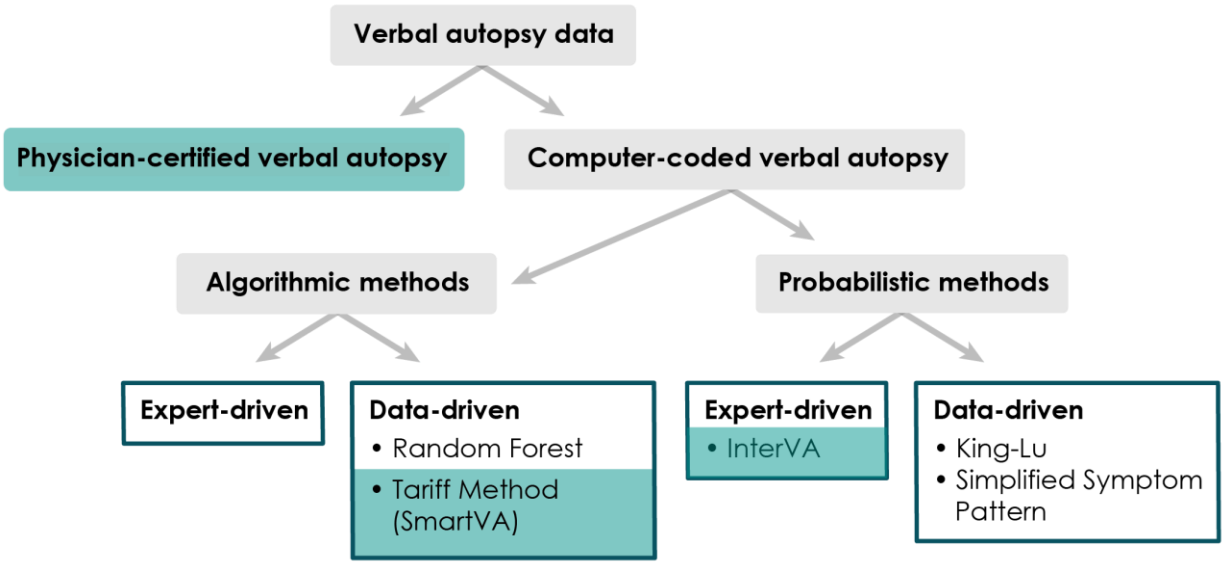
APPENDIX.

Figure 1. Options for verbal autopsy interpretation



Source: Leitao, et al., 2014; Figure 1. Classification of verbal autopsy interpretation methods.

Table 1. Distribution of pilot INCAM-2 deaths, by area

Area	Completed verbal autopsies	Percentage
Boane District	77	16.4
Matola (city)	233	49.7
Manhiça District	159	33.9
Total	469	100.0

Table 2. Distribution of pilot INCAM-2 deaths, by residency

Residency	Count	Percentage
Urban	266	56.7
Rural		43.3
Total		100.0

Table 3. Sex of deceased with completed verbal autopsies in pilot INCAM-2

Sex	Count	Percentage
Male	254	54.2
Female	212	45.2
Missing sex	3	0.6
Total		100.0

Table 4. Age group of deceased with completed verbal autopsies in the pilot of INCAM-2

Age group	Count	Percentage
Neonate (0–27 days)	55	11.7
Child (28 days–11 years)	115	24.5
Adult (12 years and over)	296	63.1
Missing age	3	0.6
Total	469	100.0

Table 5. Undetermined share of all causes of death, by interpretation method (in percentages)

	Neonates	Children	Adults
Physician-coding	7.7	21.6	11.7
InterVA-5	7.8	14.6	1.0
SmartVA	34.4	40.6	19.6

Table 6. Leading causes of death for adults (ages 12 and above), by interpretation method (percentage of adult deaths)

Cause of death	Physician coding	SmartVA	InterVA-5
HIV/AIDS related death	27.8	19.3	23.8
Cause of death unknown	11.7	19.6	1.0
Other and unspecified cardiac disease	7.7	-	8.5
Stroke	7.7	15.2	14.0
Diabetes mellitus	5.1	4.7	5.8
Pulmonary tuberculosis	5.1	5.7	1.4
Malaria	4.4	5.1	3.1
Road traffic accident	4.4	2.4	2.7
Other and unspecified noncommunicable disease	3.7	6.4	-
Other and unspecified neoplasms	2.9	1.4	0.3
Female reproductive neoplasms	2.2	1.0	-
Assault	1.5	0.3	2.0
Intentional self-harm	1.5	1.4	0.7
Liver cirrhosis	1.5	-	2.7
Meningitis and encephalitis	1.1	-	0.7
Unspecified infectious disease	1.1	2.0	2.7
Other and unspecified external causes	1.1	1.4	-
Other and unspecified maternal cause	1.1	2.4	-
Renal failure	1.1	-	0.3
Severe anaemia	1.1	-	-
Acute respiratory infection, including pneumonia	0.7	-	8.9
Diarrheal diseases	0.7	0.7	0.4
Digestive neoplasms	0.7	0.3	0.3
Abortion-related death	0.4	-	2.4
Accidental fall	0.4	0.7	0.7
Accidental poisoning and exposure to noxious substance	0.4	-	0.3
Acute cardiac disease	0.4	5.4	5.4
Asthma	0.4	-	0.3
Ectopic pregnancy	0.4	-	-
Epilepsy	0.4	-	1.0
Exposure to force of nature	0.4	-	0.3
Obstetric haemorrhage	0.4	-	2.7
Pregnancy-induced hypertension	0.4	-	1.0
Pregnancy-related sepsis	0.4	-	2.0

Chronic obstructive pulmonary disease (COPD)	-	2.7	0.4
Male reproductive neoplasms	-	0.7	0.7
Chronic kidney disease	-	1.4	-
Severe malnutrition	-	-	0.3
Acute abdomen	-	-	1.7
Other transport accident	-	-	1.4

Table 7. Leading causes of death for male adults (ages 12 and above), by interpretation method (percentage of adult male deaths)

Cause of death	Physician coding	SmartVA	InterVA-5
HIV/AIDS related death	27.0	18.4	21.3
Cause of death unknown	12.2	20.3	1.9
Pulmonary tuberculosis	8.1	7.6	2.6
Diabetes mellitus	7.4	5.7	8.4
Other and unspecified cardiac disease	6.1	-	6.4
Road traffic accident	6.1	3.8	4.5
Stroke	6.1	12.0	12.3
Other and unspecified noncommunicable disease	3.4	7.0	-
Malaria	2.7	3.8	2.6
Other and unspecified neoplasms	2.7	-	-
Assault	2.0	-	3.2
Liver cirrhosis	2.0	-	3.9
Meningitis and encephalitis	2.0	-	0.6
Unspecified infectious disease	2.0	2.5	3.9
Diarrheal diseases	1.4	0.6	0.7
Intentional self-harm	1.4	1.3	-
Renal failure	1.4	1.3	0.7
Accidental fall	0.7	0.6	0.6
Accidental poisoning and exposure to noxious substance	0.7	-	0.7
Acute cardiac disease	0.7	7.0	8.4
Acute respiratory infection, including pneumonia	0.7	-	11.6
Asthma	0.7	-	-
Epilepsy	0.7	-	1.3
Exposure to force of nature	0.7	-	0.6
Other and unspecified external causes	0.7	2.5	-
Severe anaemia	0.7	-	-
Male reproductive neoplasms	-	1.3	-
Chronic obstructive pulmonary disease (COPD)	-	4.4	-
Severe malnutrition	-	-	-
Acute abdomen	-	-	1.9
Other transport accident	-	-	1.9

Table 8. Leading causes of death for female adults (ages 12 and above), by interpretation method (percentage of adult female deaths)

Cause of death	Physician coding	SmartVA	InterVA-5
HIV/AIDS related death	28.8	20.3	26.6
Cause of death unknown	11.2	18.8	-
Other and unspecified cardiac disease	9.6	-	10.8
Stroke	9.6	18.8	15.8
Malaria	6.4	6.5	3.6
Female reproductive neoplasms	4.8	2.2	2.2
Other and unspecified noncommunicable disease	4.0	5.8	-
Other and unspecified neoplasms	3.2	2.9	-
Diabetes mellitus	2.4	3.6	2.9
Other and unspecified maternal cause	2.4	5.1	-
Road traffic accident	2.4	0.7	0.7
Digestive neoplasms	1.6	0.7	0.7
Intentional self-harm	1.6	1.4	1.4
Other and unspecified external cause	1.6	-	-
Pulmonary tuberculosis	1.6	3.6	-
Severe anaemia	1.6	-	-
Abortion-related death	0.8	-	5.1
Acute respiratory infection, including pneumonia	0.8	-	5.8
Assault	0.8	0.7	0.7
Ectopic pregnancy	0.8	-	-
Liver cirrhosis	0.8	-	1.4
Obstetric haemorrhage	0.8	-	5.8
Pregnancy-induced hypertension	0.8	-	2.2
Pregnancy-related sepsis	0.8	-	4.3
Renal failure	0.8	1.5	-
Diarrheal diseases	-	0.7	-
Acute cardiac disease	-	3.6	2.2
Chronic obstructive pulmonary disease (COPD)	-	0.7	0.8
Accidental fall	-	0.7	0.7
Unspecified infectious disease	-	1.4	1.4
Meningitis and encephalitis	-	-	0.7
Severe malnutrition	-	-	0.7
Acute abdomen	-	-	1.4
Asthma	-	-	0.7
Epilepsy	-	-	0.7
Other transport accident	-	-	0.7

Table 9. Leading causes of death for children ages 28 days to 11 years, by interpretation method (percentage of child deaths)

Cause of death	Physician coding	SmartVA	InterVA-5
Cause of death unknown	21.6	40.6	14.6
HIV/AIDS related death	13.7	-	8.7
Diarrheal diseases	8.8	20.8	10.7
Other and unspecified noncommunicable disease	6.9	-	-
Other and unspecified neonatal causes	6.9	-	-
Severe anaemia	5.9	-	-
Acute respiratory infection, including pneumonia	4.9	12.3	6.8
Malaria	4.9	1.9	10.7
Other and unspecified neoplasms	2.9	5.7	1.0
Road traffic accident	2.9	-	1.0
Sepsis (nonobstetric)	2.9	-	1.0
Accidental fall	2.0	2.8	2.9
Accidental poisoning and exposure to noxious substance	2.0	0.9	-
Asthma	2.0	-	1.0
Meningitis and encephalitis	2.0	1.9	16.5
Other and unspecified cardiac disease	2.0	1.9	1.0
Other and unspecified external causes of death	2.0	-	2.9
Severe malnutrition	2.0	-	1.0
Accidental drowning and submersion	1.0	0.9	1.0
Congenital malformation	1.0	-	0.9
Unspecified infectious disease	1.0	1.9	5.8
Prematurity	1.0	-	-
Other defined causes of child deaths	-	2.8	-
Measles	-	2.8	-
Digestive diseases	-	1.9	-
Haemorrhagic fever/Dengue	-	0.9	1.0
Acute abdomen	-	-	2.9
Sickle cell with crisis	-	-	1.9
Epilepsy	-	-	1.9
Contact with venomous plant/animal	-	-	1.9
Diabetes mellitus	-	-	1.0
Stroke	-	-	1.0
Liver cirrhosis	-	-	0.9

Table 10. Leading causes of death for neonates (ages 0 to 27 days), by interpretation method (percentage of neonate deaths)

Cause of death	Physician coding	SmartVA	InterVA-5
Birth asphyxia	25.0	15.6	28.1
Prematurity	21.2	32.8	31.3
Stillbirth	19.2	9.4	10.9
Other and unspecified perinatal cause of death	15.4	-	6.3
Cause of death unknown	7.7	34.4	7.8
HIV/AIDS related death	5.8		
Neonatal meningitis/sepsis	3.9	1.6	7.8
Sepsis (nonobstetric)	1.9	-	-
Meningitis and encephalitis	-	-	-
Congenital malformation	-	1.6	3.1
Neonatal pneumonia	-	4.7	4.7

Table A1-1. SmartVA leading causes of death for adults (ages 12 and above) (percentage of adult deaths)

Cause of death	Percentage
Undetermined	19.6
AIDS	19.3
Stroke	15.2
Other noncommunicable diseases	6.4
TB	5.7
Ischemic heart disease	5.4
Malaria	5.1
Diabetes	4.7
Chronic respiratory	2.7
Maternal	2.4
Road traffic	2.4
Other infectious diseases	2.0
Other injuries	1.4
Suicide	1.4
Chronic kidney disease	1.4
Cervical cancer	1.0
Leukaemia/lymphomas	1.0
Diarrhoea/dysentery	0.7
Falls	0.7
Prostate cancer	0.7
Esophageal cancer	0.3
Homicide	0.3
Other cancers	0.3

Table A1-2. SmartVA leading causes of death for children ages 28 days to 11 years (percentage of child deaths)

Cause of death	Percentage
Undetermined	40.6
Diarrhoea/dysentery	20.8
Pneumonia	12.3
Childhood cancer	5.7
Falls	2.8
Measles	2.8
Other defined causes of child deaths	2.8
Malaria	1.9
Meningitis	1.9
Other infectious diseases	1.9
Childhood cardiovascular diseases	1.9
Digestive diseases	1.9
Bite of venomous animal	0.9
Drowning	0.9
Haemorrhagic fever	0.9

Table A1-3. SmartVA leading causes of death for neonates (ages 0 to 27 days) (percentage of neonate deaths)

Cause of death	Percent
Undetermined	34.4
Preterm delivery	32.8
Birth asphyxia	15.6
Stillbirth	9.4
Neonatal pneumonia	4.7
Congenital malformation	1.6
Neonatal meningitis/sepsis	1.6

WORKING PAPER

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