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Guidance paper for selection of a verbal autopsy instrument

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Guidance paper for selection of a verbal autopsy instrument

This guidance paper summarises current evidence on existing verbal autopsy (VA) instruments and methods, and is intended to be used to inform decisions about the selection of a suitable VA instrument. Further information and guidance on VA application and data interpretation can be found on the CRVS Knowledge Gateway: https://crvsgateway.info/

Executive summary

Verbal autopsies (VAs) have revolutionised civil registration and vital statistics (CRVS) systems by enabling the assignment of causes of death for deaths where physician certification is not possible. The expected utility of a VA is heavily dependent on using a VA instrument that is most appropriate for the setting. This decision must be guided by consideration of multiple factors, including cost, validity, feasibility, accompanying analytical methods, and potential future applications. This paper is intended to be used as a guidance document for countries considering the rollout of VA, and compares and summarises evidence for policymakers to assist with decisions about selecting an appropriate VA instrument.

Background and introduction to verbal autopsy

Accurate cause of death (COD) data are an essential component of good quality CRVS systems equipped to provide useful data for policy.[1] Investing in CRVS systems is regarded as crucial for multiple aspects of development in many countries. While medical certification of cause of death (MCCOD) is considered the gold standard for COD assignment, globally, a significant proportion of deaths do not undergo MCCOD for various reasons, including insufficient human resources and inadequate health system capacity for certifying community deaths. Assigning a COD for deaths that do not receive physician-certification has been a long-standing challenge, but one that can be addressed by implementing recently improved VA methodologies.[2]

The practical use of VA dates back to the 1950s,[3] however, the term "VA", has been used in the literature from the 1930s.[4] By the 1990s, the global focus on VA had shifted to a consideration of the quality of VA data and the validity of the VA instruments, with the first set of VA guidelines formulated in 1994, in relation to maternal deaths.[5] In 1999, the World Health Organization (WHO), with the London School of Hygiene and Tropical Medicine and Johns Hopkins University, published VA guidelines for "Investigating Causes of Death in Infants and Children".[6] Subsequently, the WHO published a VA instrument in

1 Lopez AD, Setel PW. Better health intelligence: a new era for civil registration and vital statistics? *BMC Medicine*. 2015;13:73.
2 Fottrell E, Byass P. Verbal autopsy: methods in transition. Epidemiol Rev. 2010;32:38-55
3 Thomas LM, D'Ambruoso L, Balabanova D. Verbal autopsy in health policy and systems: a literature review. *BMJ Glob Health*. 2018;3(2):e000639.
4 Akgun S, Colak M, Bakar C. Identifying and verifying causes of death in Turkey: National verbal autopsy survey. *Public Health.* 2012;126(2):150-8.
5 Campbell O, Ronsmans C. *Verbal autopsies for maternal deaths: World Health Organization workshop*, London, 10-13 January 1994 / report prepared on behalf of the Maternal Health and Safe Motherhood Programme Geneva: WHO; 1995
6 Anker M, Black RE, Coldham C, Kalter HD, Quigley MA, Ross D, et al. *A Standard Verbal Autopsy Method for Investigating Causes of Death in Infants and Children*. World Health Organization, The Johns Hopkins School of Hygiene and Public Health, The London School of Hygiene and Tropical Medicine 1999

2007 which was followed up with revised versions in 2012, 2014 and 2016.[7,8] The full version and the shortened versions of the Population Health Metrics Research Consortium (PHMRC) instrument came into existence as a result of the need for an automated VA instrument which was supported by robust empirical data.[9,10] Details of the WHO and PHMRC tools have been elaborated on in subsequent sections of this report.

Prior to the development of standardised questionnaires, different VA forms were used across countries, such as Kenya[11] and Liberia[12]. As standard questionnaire forms became the norm, there has been a tendency to use a translated, modified, or adapted version of current standardised VA instruments rather than developing new versions for different settings. Examples of countries in which the standard WHO instruments (the 2007, 2012, 2014 and 2016 versions) have been adapted and used include: Turkey[13], Pakistan[14,15], Indonesia[16], Thailand[17], and India[18]. Similarly, the original and shortened PHMRC instruments have been used in Bangladesh, Brazil, China, Colombia, Papua New Guinea, the Philippines, Myanmar, Peru, Rwanda, Solomon Islands, Sri Lanka and Zambia.[19]

VA has created a revolution in producing evidence for mortality statistics, particularly in countries where the majority of deaths occur outside of health facilities, by allowing the assignment of a COD in cases where a physician-diagnosis is not possible. This is done by interviewing the most appropriate respondent of the deceased (i.e. a close relative) about the signs and symptoms exhibited prior to death.

VA consists of two essential components:

1. A VA instrument (i.e. questionnaire). This refers to a set of questions asked of the respondent in order to collect information about the deceased's signs and symptoms prior to death for assignment of the COD.

2. A VA analytical method. This consists of a set of rules/algorithms run on the variables extracted from the VA interview data which are used in assigning the COD. A number of analytical methods or algorithms are available and include: InterVA, Insilico-VA, Random Forest (RF), Simplified Symptom Pattern (SSP), Tariff method (Tariff), King-Lu (KL) and Physician Certified Verbal Autopsy (PCVA).[20,21] Brief accounts of four of the most commonly used analytic methods are given in **Supplementary section 1**.

Aims

This guidance paper summarises current evidence on existing VA instruments and methods, and is intended to be used to inform decisions about the selection of a suitable VA instrument.

7 Nichols EK, Byass P, Chandramohan D, Clark SJ, Flaxman AD, Jakob R, et al. The WHO 2016 verbal autopsy instrument: An international standard suitable for automated analysis by InterVA, InSilicoVA, and Tariff 2.0. *PLoS Med*. 2018;15(1):e1002486.

8 Baiden F, Bawah A, Biai S, Binka F, Boerma T, Byass P, et al. Setting international standards for verbal autopsy. *Bull World Health Organ*. 2007;85(8):570-1.

9 Murray CJ, Lopez AD, Black R, Ahuja R, Ali SM, Baqui A, et al. Population Health Metrics Research Consortium gold standard verbal autopsy validation study: design, implementation, and development of analysis datasets. *Popul Health Metr.* 2011;9:27.

10 Serina P, Riley I, Stewart A, Flaxman AD, Lozano R, Mooney MD, et al. A shortened verbal autopsy instrument for use in routine mortality surveillance systems. *BMC Med.* 2015;13:302.

11 Quigley MA, Armstrong Schellenberg JR, Snow RW. Algorithms for verbal autopsies: a validation study in Kenyan children. *Bull World Health Organ*. 1996;74(2):147-54.

12 Pacque-Margolis S, Pacque M, Dukuly Z, Boateng J, Taylor HR. Application of the verbal autopsy during a clinical trial. *Soc Sci Med*. 1990;31(5):585-91.

13 Akgun S, Colak M, Bakar C. Identifying and verifying causes of death in Turkey: National verbal autopsy survey. *Public Health*. 2012;126(2):150-8.

14 Soofi SB, Ariff S, Khan U, Turab A, Khan GN, Habib A, et al. Diagnostic accuracy of WHO verbal autopsy tool for ascertaining causes of neonatal deaths in the urban setting of Pakistan: a hospital-based prospective study. *BMC Pediatr*. 2015;15:144.

15 Nausheen S, Soofi SB, Sadiq K, Habib A, Turab A, Memon Z, et al. Validation of verbal autopsy tool for ascertaining the causes of stillbirth. *PLoS One*. 2013;8(10):e76933.

16 Pane M, Imari S, Alwi Q, Nyoman Kandun I, Cook AR, Samaan G. Causes of mortality for Indonesian Hajj Pilgrims: comparison between routine death certificate and verbal autopsy findings. *PLoS One*. 2013;8(8):e73243.

17 Polprasert W, Rao C, Adair T, Pattaraarchachai J, Porapakkham Y, Lopez AD. Cause-of-death ascertainment for deaths that occur outside hospitals in Thailand: application of verbal autopsy methods. *Popul Health Metr*. 2010;8:13.

18 Rai SK, Gupta A, Srivastava R, Bairwa M, Misra P, Kant S, et al. Decadal transition of adult mortality pattern at Ballabgarh HDSS: evidence from verbal autopsy data. *BMC Public Health.* 2015;15:781.

19 Hazard RH, Buddhika MPK, Hart JD, Chowdhury HR, Firth S, Joshi R, et al. Automated verbal autopsy: from research to routine use in civil registration and vital statistics systems. *BMC Med*. 2020;18(1):60.

20 Murray CJ, Lozano R, Flaxman AD, Serina P, Phillips D, Stewart A, et al. Using verbal autopsy to measure causes of death: the comparative performance of existing methods. *BMC Med*. 2014;12:5.

21 McCormick TH, Li ZR, Calvert C, Crampin AC, Kahn K, Clark SJ. Probabilistic Cause-of-death Assignment using Verbal Autopsies. *J Am Stat Assoc*. 2016;111(515):1036-49.

The need for careful selection of a verbal autopsy instrument

The accuracy and quality of COD outputs will depend on a number of characteristics of the VA method employed, including the instrument itself, as well as the training of VA interviewers and supervisory procedures to ensure the quality of the interview. Hence, it is essential that a VA instrument undergo processes of validation in multiple settings to ensure it can measure what it is expected to measure.

For a VA instrument to be incorporated into routine use within a CRVS system, five necessary characteristics have been identified in *"Guiding principles in introducing VAs into CRVS systems"*, developed by the University of Melbourne.[22] In summary, these are:

I. Short VA interview duration. A short interview time for completion of the VA interview provides multiple benefits to both the respondent and interviewer. Additionally, a robust but short instrument raises the efficiencies of the training and supervision. This characteristic is evaluated irrespective of the travel time (i.e. time needed to reach the household), which is constant regardless of the instrument used.

II. Inclusion of age-specific criteria. This increases the validity and the policy utility of the COD diagnoses.

III. Possibility of data collection using electronic devices. This enables additional functions for the interviewers, such as easier navigation of skip patterns and automated error checks. The ability to directly upload data to an appropriate server is also enabled.

IV. Ability to undergo automated diagnosis. This enables the provision of timely outputs even in a system with capacity and human resources challenges.

V. Inclusion of an open-narrative section. This better enables the spontaneous recall of symptoms, which carries more diagnostic weight than when recalling with prompts.

Even though a number of informal VA instruments are available, the fulfilment of the above criteria is not always easily achieved, and few have been scientifically validated. Among the range of existing VA instruments, two meet these qualities and have been rigorously tested: 1) SmartVA instrument (i.e. PHMRC-shortened version) and 2) WHO-2016 VA instrument.

Development of the WHO-2016 verbal autopsy instrument

In 2005, WHO conducted a systematic review on VA instruments. Based on its recommendations, the first WHO VA instrument was released in 2007. This was primarily used for small-scale research and in surveillance settings. In an attempt to facilitate its routine use, the WHO published the next version in 2012. By and large, the 2012 instrument was simplified, the number of questions reduced, and the response patterns revised. An iterative process of modifications was initiated and as a result, the WHO-2014 version was introduced. It was decided that the WHO instrument should be compatible with the three main analytical methods, and a global meeting of VA experts in 2016 resulted in the harmonisation of both WHO and SmartVA to accommodate the three algorithms, Tariff 2.0, Inter-VA and InSilico-VA,[23] with an increase in the number of questions to accommodate these analytical methods.

Development of the SmartVA instrument

In 2005, the PHMRC conducted a VA validation study with 12 542 VA interviews done in different countries and languages.[24] Confirmed causes of deaths, applying reliable clinico-pathological diagnostic criteria, were used in this study as the gold standard, with VA interviews conducted on these deaths. The PHMRC full questionnaire was developed as an output of the study. With VAs collected using the PHMRC-full instrument, as a further extension of this process, the Tariff method (the specific VA-analytical method of PHMRC questionnaire) was introduced and evaluated.[25] Later, the original Tariff method (Tariff 1.0) was tested using community VAs collected in PHMRC and National Health and Medical Research Council

22 The University of Melbourne. Introducing verbal autopsies into civil registration and vital statistics systems: *Guiding principles*. CRVS best-practice and advocacy. Melbourne, Australia; 2020.

23 Nichols EK, Byass P, Chandramohan D, Clark SJ, Flaxman AD, Jakob R, et al. The WHO 2016 verbal autopsy instrument: An international standard suitable for automated analysis by InterVA, InSilicoVA, and Tariff 2.0. *PLoS Med*. 2018;15(1):e1002486.

24 Murray CJ, Lopez AD, Black R, Ahuja R, Ali SM, Baqui A, et al. Population Health Metrics Research Consortium gold standard verbal autopsy validation study: design, implementation, and development of analysis datasets. *Popul Health Metr*. 2011;9:27

25 James SL, Flaxman AD, Murray CJ, Population Health Metrics Research C. Performance of the Tariff Method: validation of a simple additive algorithm for analysis of verbal autopsies. *Popul Health Metr.* 2011;9:31.

(NHMRC) studies. With the subsequent improvements in the original analytic model, the Tariff 2.0 analytical method came into existence,[26] followed by an item reduction exercise to limit the number of questions in the PHMRC-full instrument. This was done by establishing a rank order of the questions according to their impact on predicting the COD. Importantly, this reduction in the number of questions was achieved without a significant drop in performance. This led to the development of the PHMRC-shortened instrument (which is also known as the SmartVA instrument).[27]

In a recent development, SmartVA for Physicians was created to allow physicians to generate a probable COD in real time, in situations where completion of a timely death certificate is required. This is particularly useful for community physicians who need to arrive at COD decisions in situations where the deceased is not their patient, and where there is no access to the body or patient's medical records. SmartVA for Physicians was first piloted in the Philippines in 2017, and has been rolled out in countries including the Philippines, Brazil and Colombia.[28] SmartVA for Physicians produces up to three potential causes of death with a likelihood of dying from each cause. A summary of the endorsed symptoms for each death is also produced, further assisting the certifying physician to arrive at the final COD.

Comparison of WHO-2016 and SmartVA instruments

The following table (Table 1) compares selected characteristics of the WHO-2016 and the SmartVA instruments.

Table 1: Comparison of characteristics of the WHO-2016 and SmartVA questionnaires

	WHO-2016[29,30,31,32]	**SmartVA**[33,34,35,36]
Development	A result of over 15 years of evidence-based revisions and improvements of an initial instrument.	Has a history of similar duration. Parallel to the improvements in the instrument, developments of the specific analytical method (i.e. Tariff) and other applications (e.g. SmartVA for physicians) have also occurred.
Global usage	The WHO-2007 version has been translated/ adapted and modified for use in multiple settings, with literature also available on the utilisation of WHO-2016.	The current (shortened version) has been used in multiple settings, including Bangladesh, China. Philippines, Myanmar and Sri Lanka.
Time of administration	Typically conducted from the end of the mourning period (e.g. from six weeks after death but varies upon the context) up to one year following death.[37]	Recommended period is similar to that of WHO-2016. Literature has shown that 'the probability of a correct diagnosis in VAs collected three to 11 months after death will, on average, be 95.9 per cent of that in VAs collected within three months of death.[38]
Administration method	Administered primarily through electronic data collection methods. A set of paper forms are also available.	Same as WHO-2016.

26 Serina P, Riley I, Stewart A, James SL, Flaxman AD, Lozano R, et al. Improving performance of the Tariff Method for assigning causes of death to verbal autopsies. *BMC Med*. 2015;13:291.

27 Serina P, Riley I, Stewart A, Flaxman AD, Lozano R, Mooney MD, et al. A shortened verbal autopsy instrument for use in routine mortality surveillance systems. *BMC Med*. 2015;13:302.

28 University of Melbourne. *Introduction to SmartVA for Physicians*. Melbourne; Australia; 2020.

29 Nichols EK, Byass P, Chandramohan D, Clark SJ, Flaxman AD, Jakob R, et al. The WHO 2016 verbal autopsy instrument: An international standard suitable for automated analysis by InterVA, InSilicoVA, and Tariff 2.0. *PLoS Med.* 2018;15(1):e1002486.

30 World Health Organization. Verbal autopsy standards: *The 2016 WHO verbal autopsy instrument- V1.5.3*. WHO; 2016.

31 World Health Organization. *Verbal autopsy standards: ascertaining and attributing causes of death*. WHO; 2020 [Available from: https://www.who.int/healthinfo/statistics/verbalautopsystandards/en/]

32 World Health Organization. *Manual for the Training of Interviewers on the use of the 2016 WHO VA Instrument*. WHO; 2017.

33 Murray CJ, Lopez AD, Black R, Ahuja R, Ali SM, Baqui A, et al. Population Health Metrics Research Consortium gold standard verbal autopsy validation study: design, implementation, and development of analysis datasets. *Popul Health Metr*. 2011;9:27.

34 Serina P, Riley I, Stewart A, Flaxman AD, Lozano R, Mooney MD, et al. A shortened verbal autopsy instrument for use in routine mortality surveillance systems. *BMC Med. 2015;13:302.*

35 Hazard RH, Buddhika MPK, Hart JD, Chowdhury HR, Firth S, Joshi R, et al. Automated verbal autopsy: from research to routine use in civil registration and vital statistics systems. *BMC Med*. 2020;18(1):60.

36 D4H Technical Working Group. *Guidelines for interpreting verbal autopsy data. CRVS technical guides.* The University of Melbourne, Melbourne, Australia; 2020.

37 World Health Organization. *Manual for the Training of Interviewers on the use of the 2016 WHO VA Instrument.* WHO; 2017.

38 Serina P, Riley I, Hernandez B, Flaxman AD, Praveen D, Tallo V, et al. What is the optimal recall period for verbal autopsies? Validation study based on repeat interviews in three populations. *Popul Health Metr.* 2016;14:40.

	WHO-2016[39,40,41,42]	SmartVA[43,44,45,46]
Data collection platform for electronic versions	Generally, "Open Data Kit (ODK)". Hence the selection of translations is possible in non-English populations.	Same as WHO-2016.
Designed for Age groups categorisations	All groups including maternal deaths, perinatal deaths and injuries. • Under four weeks (termed "neonatal" age group) • Four weeks to 11 years (termed "children" age group) • 12 years and above (termed "adult" age group).	Same as WHO-2016.
Pre-set questions	Includes three questions on HIV-malaria mortality and season.[47]	Not included as pre-set questions in the questionnaire. However, selection can be done in subsequent automated analysis through the SmartVA-Analyze software.
Details on background/ deceased/respondent/ vital registration*	Includes 36 questions for adults, 35 questions for children and 31 questions for neonates.[48]	Includes 23 questions. The number of questions vary slightly according to the geographical classifications of each setting. As an example, one country may prefer to enter the province followed by district and another health unit to specify a geographical location (i.e. three responses altogether for a location) whereas in another country, two levels may be used.
History of injury/ accidents*	Includes 24 questions for adults and 22 questions for neonates and children. Questions appear for the presence/absence of each type of injury. Questions include details about road traffic accidents (e.g. the role and the counterpart).[49]	Includes four questions for adults, three for children, none for neonates. Fewer questions in this instrument as the option is given to select from a list appearing on a single screen, rather than asking details about each injury/accident type. Same pattern of responses can be printed for this section if paper format is used.
Health history*	Includes 210 for adults, 187 for children, 160 for neonates.[50]	Includes 103 for adults, 59 for children and 62 for neonates.
Open narrative (text field)	Includes space for typing the narrative and then selection of conditions from a given list.	Includes the selection of conditions from a given list and a verification question if none were selected.

39 Nichols EK, Byass P, Chandramohan D, Clark SJ, Flaxman AD, Jakob R, et al. The WHO 2016 verbal autopsy instrument: An international standard suitable for automated analysis by InterVA, InSilicoVA, and Tariff 2.0. *PLoS Med.* 2018;15(1):e1002486.

40 World Health Organization. Verbal autopsy standards: *The 2016 WHO verbal autopsy instrument- V1.5.3*. WHO; 2016.

41 World Health Organization. *Verbal autopsy standards: ascertaining and attributing causes of death*. WHO; 2020 [Available from: https://www.who.int/healthinfo/statistics/verbalautopsystandards/en/]

42 World Health Organization. *Manual for the Training of Interviewers on the use of the 2016 WHO VA Instrument*. WHO; 2017.

43 Murray CJ, Lopez AD, Black R, Ahuja R, Ali SM, Baqui A, et al. Population Health Metrics Research Consortium gold standard verbal autopsy validation study: design, implementation, and development of analysis datasets. *Popul Health Metr*. 2011;9:27.

44 Serina P, Riley I, Stewart A, Flaxman AD, Lozano R, Mooney MD, et al. A shortened verbal autopsy instrument for use in routine mortality surveillance systems. *BMC Med. 2015;13:302.*

45 Hazard RH, Buddhika MPK, Hart JD, Chowdhury HR, Firth S, Joshi R, et al. Automated verbal autopsy: from research to routine use in civil registration and vital statistics systems. *BMC Med*. 2020;18(1):60.

46 D4H Technical Working Group. *Guidelines for interpreting verbal autopsy data. CRVS technical guides.* The University of Melbourne, Melbourne, Australia; 2020.

47 World Health Organization. *Verbal autopsy standards: The 2016 WHO verbal autopsy instrument- V1.5.3*. WHO; 2016.

48 Ibid.

49 Ibid.

50 Ibid.

	WHO-2016[51,52,53,54]	SmartVA[55,56,57,58]
Additional sections	• Health care treatment and experience before death (termed as "background and context"). These questions explore aspects such as access to the health institutions, financial impacts, encountered problems in receiving care (etc.) and are not included in the COD assignment. • Additional questions on COVID-19, however these are yet to be validated.[59]	As at June 2021, the process of adding COVID-19 related questions has commenced and the validation of questions in a large research study is underway.
Total number of questions*	Includes 296 questions for adults, 270 for children and 252 for neonates at "entry level or level 2".[60]	Includes 132 questions for adults, 87 for children and 87 for neonates.
Response types	• Dichotomous responses • Multiple choice • Durations of some instances • Free text fields.	Generally, similar patterns are used to WHO-2016, however, the type of the response may not be identical for each question. An example is given under the accidents/ injuries row above.
Skip patterns	Included	Included
Time – duration of interview	Estimated to be on average, 30 to 60 minutes.	On average, 20 to 22 minutes with an additional three to five minutes for the open narrative section.[61]
Use of free-text and narrative checklist in the analysis	This function is only available if the Tariff method is used.	Currently, the Tariff method can use these in the analysis when entered in English.
Analysis	The data in completed questionnaires can be processed with automated analysis through the Tariff, InterVA and InSilicoVA analytical methods.	The data are processed through the Tariff method.
Facility of applying re-distribution techniques where output is uncertain or has a high confidence interval	Only available if the Tariff method is used.	Cases with undetermined or uncertain causes in the first analysis undergo re-distribution. As a result, CSMFs can be obtained with and without undetermined diagnoses.

51 Nichols EK, Byass P, Chandramohan D, Clark SJ, Flaxman AD, Jakob R, et al. The WHO 2016 verbal autopsy instrument: An international standard suitable for automated analysis by InterVA, InSilicoVA, and Tariff 2.0. *PLoS Med.* 2018;15(1):e1002486.

52 World Health Organization. Verbal autopsy standards: *The 2016 WHO verbal autopsy instrument- V1.5.3*. WHO; 2016.

53 World Health Organization. *Verbal autopsy standards: ascertaining and attributing causes of death*. WHO; 2020 [Available from: https://www.who.int/healthinfo/statistics/verbalautopsystandards/en/]

54 World Health Organization. *Manual for the Training of Interviewers on the use of the 2016 WHO VA Instrument*. WHO; 2017.

55 Murray CJ, Lopez AD, Black R, Ahuja R, Ali SM, Baqui A, et al. Population Health Metrics Research Consortium gold standard verbal autopsy validation study: design, implementation, and development of analysis datasets. *Popul Health Metr*. 2011;9:27.

56 Serina P, Riley I, Stewart A, Flaxman AD, Lozano R, Mooney MD, et al. A shortened verbal autopsy instrument for use in routine mortality surveillance systems. *BMC Med. 2015;13:302.*

57 Hazard RH, Buddhika MPK, Hart JD, Chowdhury HR, Firth S, Joshi R, et al. Automated verbal autopsy: from research to routine use in civil registration and vital statistics systems. *BMC Med*. 2020;18(1):60.

58 D4H Technical Working Group. *Guidelines for interpreting verbal autopsy data. CRVS technical guides.* The University of Melbourne, Melbourne, Australia; 2020.

59 World Health Organization. *VA Field Interviewer Manual for the 2016 WHO VA Instrument.* WHO.

60 World Health Organization. *Verbal autopsy standards: The 2016 WHO verbal autopsy instrument- V1.5.3.* WHO; 2016.

61 Hazard RH, Buddhika MPK, Hart JD, Chowdhury HR, Firth S, Joshi R, et al. Automated verbal autopsy: from research to routine use in civil registration and vital statistics systems. *BMC Med.* 2020;18(1):60.

	WHO-2016[62,63,64,65]	SmartVA[66,67,68,69]
Number of target causes	63 in total, distributed as:[70] • Infections and parasitic diseases (14) • Non-communicable diseases (20) • External (11) • Maternal (9) • Neonatal (7) • Stillbirths (2)	46 in total distributed as:[71] • Communicable diseases (11) • Non-communicable diseases (19) • External (9) • Maternal (1)# • Neonatal (5) • Stillbirths (1)
Extensions	The application of 'SmartVA for Physicians' is only available if the Tariff method is used.	'SmartVA for physicians' application is used in helping physicians to come to a diagnosis. All VAs done with the SmartVA questionnaire can be processed through this software.
Guidance documents	Available through the WHO website.	Available through the CRVS Knowledge Gateway.[72]

*For WHO-2016, questions at "Entry level and level-2" have been mentioned as published in the Manual. Entry level questions must always be answered.
The identification of specific causes of maternal deaths with VAs in routine practice is not reliable.[73]

62 Nichols EK, Byass P, Chandramohan D, Clark SJ, Flaxman AD, Jakob R, et al. The WHO 2016 verbal autopsy instrument: An international standard suitable for automated analysis by InterVA, InSilicoVA, and Tariff 2.0. *PLoS Med.* 2018;15(1):e1002486.

63 World Health Organization. Verbal autopsy standards: *The 2016 WHO verbal autopsy instrument- V1.5.3*. WHO; 2016.

64 World Health Organization. *Verbal autopsy standards: ascertaining and attributing causes of death*. WHO; 2020 [Available from: https://www.who.int/healthinfo/statistics/verbalautopsystandards/en/]

65 World Health Organization. *Manual for the Training of Interviewers on the use of the 2016 WHO VA Instrument*. WHO; 2017.

66 Murray CJ, Lopez AD, Black R, Ahuja R, Ali SM, Baqui A, et al. Population Health Metrics Research Consortium gold standard verbal autopsy validation study: design, implementation, and development of analysis datasets. *Popul Health Metr*. 2011;9:27.

67 Serina P, Riley I, Stewart A, Flaxman AD, Lozano R, Mooney MD, et al. A shortened verbal autopsy instrument for use in routine mortality surveillance systems. *BMC Med. 2015;13:302.*

68 Hazard RH, Buddhika MPK, Hart JD, Chowdhury HR, Firth S, Joshi R, et al. Automated verbal autopsy: from research to routine use in civil registration and vital statistics systems. *BMC Med*. 2020;18(1):60.

69 D4H Technical Working Group. *Guidelines for interpreting verbal autopsy data. CRVS technical guides.* The University of Melbourne, Melbourne, Australia; 2020.

70 World Health Organization. *Verbal autopsy standards: The 2016 WHO verbal autopsy instrument- V1.5.3*. WHO; 2016.

71 D4H Technical Working Group. *Guidelines for interpreting verbal autopsy data.* CRVS technical guides. The University of Melbourne, Melbourne, Australia; 2020.

72 https://crvsgateway.info/

73 Riley ID, Hazard RH, Joshi R, Chowdhury HR, Lopez AD. Monitoring progress in reducing maternal mortality using verbal autopsy methods in vital registration systems: what can we conclude about specific causes of maternal death? *BMC Med.* 2019;17(1):104.

Verbal autopsy instrument selection: Policy implications

Both the WHO-2016 and SmartVA instruments fulfill many of the basic requirements of a valid and reliable VA instrument. One major difference is the shorter time period required to complete a VA using the SmartVA instrument, which is important to some countries where VAs are conducted in routine practice as opposed to use for research purposes. It is possible that reducing the time spent per VA interview may decrease the workload of data collectors, as well as improve the compliance of respondents, lower non-response rates and minimise selection bias. Furthermore, VA interviewers in a routine setting often have workloads which include competing tasks, so a reduction in the time taken to conduct the interview is preferable. A shorter interview also minimises respondent 'fatigue' and frees up time for associated activities, such as counselling or health promotion with the family of the deceased.

In a multi-country validation study among more than 12 000 death records, the Tariff analytical method was shown to perform 'as well or better than' many other analytical methods such as InterVA-4, Random Forest, Simplified Symptom Pattern, King-Lu and PCVA.[74] The subsequent re-distribution techniques (based on the globally used Global Burden of Disease [GBD] country estimates as well as gold standard data in the PHMRC dataset), ensures the assignment of specific causes for all deaths even when adequate evidence is not available to assign a specific cause in the first round of analysis. In addition, there is a paucity of data comparing the cause-specific mortality fractions (CSMFs) derived from the three different analytical methods (i.e. InterVA, InsilicoVA and Tariff) applied to the WHO-2016 instrument. Given any potential variation (even to a minor degree) between the three automated algorithms, countries must initiate an additional dialogue when deciding which output to prioritise. This issue is not encountered with SmartVA as different sets of CSMFs are not generated.

Furthermore, additional utilities are associated with SmartVA such as SmartVA for Physicians, which provides information to assist physicians in arriving at an informed final COD for each death.

In some situations, the best option for a country in the process of deciding which VA instrument to use may involve trialling different methods and evaluating the findings. This evaluation would explore and compare the performance of these tools in relation to the validity, reliability and feasibility of the VA process.

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Supplementary section 1: Common analysis methods for generating verbal autopsy results

InterVA: InterVA works on the Bayes' rule for conditional probabilities and yields the propensity of each cause for each death. Thus, for each death, three causes are suggested based on the magnitude of the propensity. When the propensities are not above a defined threshold, the cause is classified as "indeterminate". The population-level fractions are derived by summing across the largest propensities for each cause.[75,76]

InSilicoVA: InsilicoVA is based on the Bayesian hierarchical model fit. It is based on probabilities of causes per death and joint probability-distributions for a set of deaths. This analytical method does not produce any "indeterminate" diagnoses, but yields "credible intervals", the width of which reflects the confidence of the assigned cause.[77,78]

Tariff: Tariff works by generating a set of tariff-scores for each disease-symptom pair. These scores reflect the "relatedness" of each symptom with each cause, which is termed the "signal-to-noise" ratio. For deaths that do not get a specific cause assigned, as they have not met the pre-defined "tariff-thresholds", redistribution techniques are applied with reference to the gold standard database and the GBD estimates for the country.[79,80] Hence, for all deaths, a specific cause can be assigned.

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