Determining the Cause of Death: Mortality Surveillance Using Verbal Autopsy in Indonesia

Abdul Wahab,^{1,2,3*} Ifta Choiriyah,^{1,3} and Siswanto Agus Wilopo^{1,2,3}

¹Purworejo HDSS, Indonesia; ²INDEPTH Network, Accra, Ghana; ³Department of Biostatistics, Epidemiology and Population Health, Faculty of Medicine, Universitas Gadjah Mada, Yogyakarta, Indonesia

Abstract. In the absence of a vital registration and health information systems, Indonesia does not have complete, accurate, and continuous data to summarize the mortality statistics of the population, nor determine the exact cause of death. Verbal autopsies performed in a community-based mortality surveillance have been used to provide information on the cause of deaths in such context. However, physician review of verbal autopsy can be expensive, time-consuming, and give inconsistent results, raising concern about its reliability. We used the Purworejo Health and Demographic Surveillance System's (HDSS) mortality data collected between 2000 and 2002 and assigned causes of death for all age groups using Interpreting Verbal Autopsy-4, analytic software that applies a probabilistic model. A total of 1,999 deaths were identified among 55,581 individuals surveyed in 14,409 households; 830 deaths were able to be recorded using the standardized World Health Organization (WHO) verbal autopsy questionnaire. We calculated the proportion of different causes of death and its incidence rate (IR) ratios with 95% confidence interval (CI) to compare the IR per person-years-observation (PYO). The IR of stroke was 126.7 per 100,000 PYO (95% CI: 109.7, 143.7); acute respiratory infection including pneumonia was 70.8 per 100,000 PYO (95% CI: 58.1, 83.5); and the IR of other and unspecified cardiac diseases was 57.7 per 100,000 PYO (95% CI: 46.2, 69.2). Stroke was indicated as the leading cause of death among elderly people aged 50 years and above. Meanwhile, pneumonia as a communicable disease was found to be the most common cause of death among both 0–14-year-old children and elderly people.

INTRODUCTION

Mortality data are very important to assess the community health status and needs to track the changes in mortality measures over time, help formulate policies and programs to reduce premature mortality, and monitor the implementation of health programs. Civil registration and the vital registration system are the preferred source of continuous, timely, and accurate mortality data. However, data on the cause of death in Indonesia are not collected through the national vital statistics system. When available, it may be unreliable because it is not based on medical autopsy reports nor collected using a standardized method.¹ Worldwide Demographic Surveillance Systems (DSS) have been an important source of international health data for estimating global burden of disease in settings where vital registration or facility-based information systems are not available.² DSS data, although expensive and labor intensive, have been used to generate life tables and key demographic indicators including mortality rates.

Verbal autopsy (VA) is a systematic approach commonly used for determining causes of death in populations without routine medical certification. It has mainly been used in research contexts and involves relatively lengthy interviews.² Different approaches for determining the cause of death from VA interview information exist, including physician review, algorithms, and computerized coding of VA which can either be algorithmic or probabilistic in approach. However, the optimal approach for determining causes of death from VA data has been the subject of debate. Physician review is the most widely used method, and despite concerns about repeatability, it has been extensively evaluated and shown to

perform well in many settings. Analysis to determine causes of death is usually performed manually by physicians. Physician review yields high specificity but its sensitivity seems to depend on the cause of death. For example, sensitivity for injuries and direct maternal causes are very high (> 90%) yet are low (~40–50%) for cardiovascular system disorders.³ In addition, physician review can be very time consuming, expensive, and the subjective approach potentially provides poor repeatability.⁴ Expert-driven and data-driven algorithmic or probabilistic methods are developed to provide alternative approaches for settings where physician review is not feasible. Although evaluation consistently shows that physician review generates more accurate classification of causes of death,^{4,5} algorithmic or probabilistic methods may offer cost-effective alternatives to monitor large number of deaths in settings with limited resources.

This study used mortality data collected in the Health and Demographic Surveillance System's (HDSS) site in Purworejo

TABLE 1
Distribution of deaths by age and gender

Characteristic	Weighted		Unweighted	
	n	%	n	%
Age group				
Neonate	60	7.2	13	1.6
Infant	52	6.3	15	1.8
1–4 yrs	33	4.0	12	1.5
5–14 yrs	30	3.7	15	1.8
15–49 yrs	108	13.0	93	11.2
50–64 yrs	168	20.3	170	20.5
65+ yrs	378	45.6	512	61.7
Age category				
Children (0–14 yrs)	175	21.1	55	6.6
Adults (15–49 yrs)	108	13.0	93	11.2
Elderly (50+ yrs)	546	65.9	682	82.2
Gender				
Male	437	52.6	399	48.1
Female	393	47.4	431	51.9

* Address correspondence to Abdul Wahab, Department of Biostatistics, Epidemiology and Population Health (BEPH), Faculty of Medicine, Universitas Gadjah Mada, IKM Building 1st floor, Jl. Farmako 1 Sekip Utara, Yogyakarta 55281, Indonesia. E-mail: awahab@ugm.ac.id

District, Central Java Province, Indonesia. One of the surveillance system components was the identification of mortality events in the surveillance area. In 2004, based on mortality identification through a 6-month surveillance, we performed VA for deaths in all age groups using the standardized instrument developed by World Health Organization (WHO).^{6,7} This article aimed to determine the causes of death using a program called Interpreting Verbal Autopsy (InterVA), which applies a probabilistic model based on Bayes' theorem to determine the cause of death by processing successive indicators to generate up to three likely causes of death for each case.⁸

MATERIALS AND METHODS

The study was conducted at the Purworejo HDSS site in Central Java, located between longitudes 109°E and 110°E and latitude 7°S, covering an area of 1,082 km², and is inhabited by a population of 708,483. About 65% of population were in the economically productive age group, with 19% of those aged > 10 years old and graduated from high school. Most of the population live in rural areas. The annual parasite incidence (API) of malaria dramatically increased from 4.6 cases per 1,000 residents in 1997 to be 44.5 cases per 1,000 residents in 2000.⁹ However, the malaria elimination

TABLE 2
Weighted and unweighted frequency distribution and IR per 100,000 PYO with 95% CI of the causes of death (all ages)

Cause of death	Weighted			Unweighted				
	%	95% CI		n	%	IR*	95% CI of IR	
		Lower	Upper				Lower	Upper
01.01 Sepsis (nonobstetric)	0.4	0.1	1.1	3	0.4	1.8	-0.2	3.8
01.02 Acute respiratory infection including pneumonia	15.7	12.8	19.0	119	14.3	70.8	58.1	83.5
01.03 HIV/AIDS-related death	0.9	0.4	2.0	7	0.8	4.2	1.1	7.2
01.04 Diarrheal diseases	1.6	0.9	2.7	14	1.7	8.3	4.0	12.7
01.05 Malaria	6.0	4.1	8.7	37	4.5	22.0	14.9	29.1
01.07 Meningitis and encephalitis	1.8	0.8	3.7	9	1.1	5.4	1.9	8.9
01.09 Pulmonary tuberculosis	5.9	4.5	7.7	55	6.6	32.7	24.1	41.4
01.99 Other and unspecified infectious diseases	2.3	1.4	3.6	20	2.4	11.9	6.7	17.1
02.01 Oral neoplasms	0.1	0.0	0.9	1	0.1	0.6	-0.6	1.8
02.02 Digestive neoplasms	1.0	0.5	2.0	8	1.0	4.8	1.5	8.1
02.03 Respiratory neoplasms	0.4	0.1	1.1	4	0.5	2.4	0.0	4.7
02.04 Breast neoplasms	0.7	0.3	1.6	5	0.6	3.0	0.4	5.6
02.05 and 02.06 Reproductive neoplasms MF	0.3	0.1	1.1	3	0.4	1.8	-0.2	3.8
02.99 Other and unspecified neoplasms	1.3	0.7	2.3	12	1.4	7.1	3.1	11.2
03.01 Severe anemia	1.0	0.6	1.9	11	1.3	6.5	2.7	10.4
03.02 Severe malnutrition	1.6	0.8	2.9	12	1.4	7.1	3.1	11.2
03.03 Diabetes mellitus	1.3	0.7	2.3	12	1.4	7.1	3.1	11.2
04.01 Acute cardiac disease	1.0	0.5	1.9	9	1.1	5.4	1.9	8.9
04.02 Stroke	20.6	18.0	23.5	213	25.7	126.7	109.7	143.7
04.99 Other and unspecified cardiac diseases	9.8	8.0	11.9	97	11.7	57.7	46.2	69.2
05.01 Chronic obstructive pulmonary disorder	3.1	2.2	4.4	32	3.9	19.0	12.4	25.6
05.02 Asthma	0.2	0.1	1.0	2	0.2	1.2	-0.5	2.8
06.01 Acute abdomen	2.5	1.7	3.7	26	3.1	15.5	9.5	21.4
06.02 Liver cirrhosis	1.0	0.6	2.0	10	1.2	6.0	2.3	9.6
07.01 Renal failure	1.1	0.6	2.1	11	1.3	6.5	2.7	10.4
08.01 Epilepsy	0.3	0.1	1.0	3	0.4	1.8	-0.2	3.8
09.02 Abortion-related death	0.1	0.0	1.0	1	0.1	0.6	-0.6	1.8
09.08 Ruptured uterus	0.1	0.0	1.0	1	0.1	0.6	-0.6	1.8
10.01 Prematurity	1.0	0.3	4.0	2	0.2	1.2	-0.5	2.8
10.03 Neonatal pneumonia	1.0	0.3	4.0	2	0.2	1.2	-0.5	2.8
10.06 Congenital malformation	1.8	0.7	4.8	4	0.5	2.4	0.0	4.7
10.99 Other and unspecified neonatal Complications	1.6	0.5	5.0	3	0.4	1.8	-0.2	3.8
12.01 Road traffic accident	1.0	0.5	2.2	7	0.8	4.2	1.1	7.2
12.02 Other transport accident	1.4	0.7	2.6	9	1.1	5.4	1.9	8.9
12.03 Accidental fall	0.4	0.1	1.1	3	0.4	1.8	-0.2	3.8
12.04 Accidental drowning and submersion	0.8	0.3	2.0	5	0.6	3.0	0.4	5.6
12.05 Accidental exposure to smoke fire and flame	0.1	0.0	1.0	1	0.1	0.6	-0.6	1.8
12.08 Intentional self-harm	0.1	0.0	0.6	1	0.1	0.6	-0.6	1.8
12.09 Assault	0.6	0.3	1.6	5	0.6	3.0	0.4	5.6
12.99 Other and unspecified external Co	0.1	0.0	0.9	1	0.1	0.6	-0.6	1.8
98 Other and unspecified NCD	0.9	0.5	1.8	9	1.1	5.4	1.9	8.9
99 Indeterminate	7.0	4.6	10.4	41	4.9	24.4	16.9	31.9

AIDS = acquired immunodeficiency syndrome; CI = confidence interval; HIV = human immunodeficiency virus; IR = incidence rate; MF = male and female; NCD = non-communicable diseases; PYO = person years observation.

* IR = incidence rate per 100,000 PYO.

project successfully reduced API to be 0.77 per 1,000 resident in 2004 and it has been kept low since then.¹⁰ Purworejo HDSS, which is a member of the INDEPTH Network consisting of 38 HDSS sites in Africa, Asia, and Oceania, was established since 1994 and covers a population of 55,000 living in 13,443 households in 128 enumeration areas. This HDSS was founded by the Government of Indonesia and supported by the World Bank DSS project. It was initially developed as a Community Health and Nutrition Research Laboratory, which was later expanded to aim for broader goals of a worldwide health surveillance system and covered diverse research topics including the Study on Population Ageing.¹¹ This study was based on our 2004 cycle data collection on the mortality for all age groups. Although our data are more than 10 years old, there are no recent data from VA or similar mortality data available in Indonesia, because of limited resources. Most of the recent Indonesian mortality data are from hospital-based studies which are biased toward those who use tertiary health facilities and do not include deaths that occur at home, and thus do not represent the general population.

At the beginning of the study, 14,627 households accommodating 58,667 people were covered by the surveillance system. The 2002 surveillance data show that the total population was 55,581; crude birth rate and crude death rate were 11.8 and 11.6, respectively.¹² Causes of death were never collected before the 2004 cycle. Sample households were selected using proportionate population to estimate size with two-stage cluster sampling. We selected 148 clusters (census block) and approximately 101 households from each cluster using systematic random sampling. Trained field workers systematically identified and registered deaths—including infant and under-five mortality—using structured questionnaires and household member control cards.

Based on the mortality list, VA was performed using the standard verbal autopsy instrument developed by WHO. Data

were entered into a microcomputer using dSURVEY program that has built-in checks against erroneous data entry. Subsequently, the data were converted into InterVA-4 format using STATA program and saved into the file "batchin.csv" in the same folder with InterVA-4 software. The output of calculation was stored in "valog.txt" and then could be read and saved using STATA software program version 12.

Between 2000 and 2002, 1,999 mortalities were identified, consisting of 1,000 male and 999 female deaths in all age groups. In total, 865 mortality cases were randomly sampled and selected to be interviewed using the VA questionnaire; only 830 (95.9%) interviews were completed due to limited of time, funding and staff. Forty-six children died before reaching the age of 5 years and 43 of those were successfully interviewed with the parents as respondents. The causes of death in six cases (13.9%) of under-five mortality could not be determined by InterVA program because of incomplete information. Applying Bayes' theorem, this program can determine the cause of death by processing successive indicators to generate up to three likely causes of death for each case. In this report, the main cause was used to identify the cause of death. Causes of death were coded according to ICD-10. According to WHO classifications, the age groups were coded into three age categories: children (0–14 years), adults (15–49 years), and elderly (50 years or more). Sex-adjusted, weighted attributed causes of death were presented by age group.

RESULTS

Unweighted and weighted frequency distribution of the deaths by age and gender are presented in Table 1. Almost half of the deaths (66%) occurred among the elderly population; whereas 13% and 21% occurred among 15–49-year-old and 0–14-year-old children, respectively. Eighteen percent

TABLE 3

Weighted and unweighted frequency distribution and IR per 100,000 PYO with 95% CI of the causes of death among children (0–14 years old)

Cause of death	Weighted			Unweighted				
	%	95% CI		n	%	IR*	95% CI of IR	
		Lower	Upper				Lower	Upper
01.01 Sepsis (nonobstetric)	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0
01.02 Acute respiratory infection including pneumonia	25.8	15.8	39.0	15	27.3	36.0	17.8	54.2
01.03 HIV/AIDS-related death	1.1	0.2	7.7	1	1.8	2.4	–2.3	7.1
01.04 Diarrheal diseases	1.2	0.2	7.9	1	1.8	2.4	–2.3	7.1
01.05 Malaria	14.6	7.6	26.3	9	16.4	21.6	7.5	35.7
01.07 Meningitis and encephalitis	5.7	2.0	15.0	4	7.3	9.6	0.2	19.0
01.99 Other and unspecified infectious diseases	1.2	0.2	7.8	1	1.8	2.4	–2.3	7.1
03.02 Severe malnutrition	2.6	0.6	10.1	2	3.6	4.8	–1.9	11.4
04.99 Other and unspecified cardiac diseases	1.2	0.2	7.9	1	1.8	2.4	–2.3	7.1
10.01 Prematurity	4.8	1.2	17.5	2	3.6	4.8	–1.9	11.4
10.03 Neonatal pneumonia	4.8	1.2	17.5	2	3.6	4.8	–1.9	11.4
10.06 Congenital malformation	8.7	3.3	21.1	4	7.3	9.6	0.2	19.0
10.99 Other and unspecified neonatal Complications	7.7	2.5	21.4	3	5.5	7.2	–0.9	15.3
12.01 Road traffic accident	1.1	0.2	7.5	1	1.8	2.4	–2.3	7.1
12.02 Other transport accident	1.2	0.2	7.8	1	1.8	2.4	–2.3	7.1
12.04 Accidental drowning and submersion	1.2	0.2	7.8	1	1.8	2.4	–2.3	7.1
99 Indeterminate	17.2	8.4	32.1	7	12.7	16.8	4.4	29.2

AIDS = acquired immunodeficiency syndrome; CI = confidence interval; HIV = human immunodeficiency virus; IR = incidence rate; PYO = person years observation.

* IR = incidence rate per 100,000 PYO.

of the deaths occurred among under-five children—77% of which among neonates and infants. The deaths were 53% male and 47% female.

Table 2 presents the unweighted and weighted frequency distribution of specific causes of death and its incidence rates (IRs) per 100,000 person-years-observation (PYO) with 95% confidence interval (CI) for all ages. In general, stroke was found to be the leading cause of death with the proportion of 20.6%, followed by acute respiratory infections (ARIs) including pneumonia, other and unspecified cardiovascular diseases, malaria, and tuberculosis at 15.7%, 9.8%, 6%, and 5.9%, respectively. Combined, neoplasms caused 3.2% of the deaths in the sample population. The IR of stroke was 126.7 per 100,000 PYO (95% CI: 109.7, 143.7), ARI including pneumonia was 70.8 per 100,000 PYO (95% CI: 58.1, 83.5), other and unspecified cardiac diseases was 57.7 per 100,000 PYO (95% CI: 46.2, 69.2). These IRs suggested that for every 100,000 persons observed for a year, there are 126 deaths caused by stroke, 70 deaths caused by pneumonia, and 57 deaths caused by other and unspecified cardiac diseases. Other significant causes of death identified in the study area

were pulmonary tuberculosis, malaria, chronic obstructive pulmonary diseases, and acute abdomen, with IR 32.7, 22, 19, and 15.5 per 100,000 PYO, respectively.

The limited sample size only allows estimation of IRs by the three age groups (children, adult, and elderly); each are presented in Tables 3–5. Different patterns of cause of deaths can be observed in the three age groups. Among children of 0–14 years old, the most common cause of death was communicable diseases with proportion of 49.6% (95% CI: 36, 63.1) and IR of 74.3 per 100,000 PYO (95% CI: 61.3, 87.4). For 12.7% of the death, their cause could not be determined. Among adults of 15–49 years old, both communicable and noncommunicable diseases contribute to similar proportion of deaths; with proportion of 31.9% (95% CI: 23.2, 42.0) and IR of 36.6 per 100,000 PYO (95% CI: 27.5, 45.7) and proportion of 30.2% (95% CI: 21.7, 40.3) and IR of 34.2 per 100,000 PYO (95% CI: 25.3, 43.0), respectively. Specifically, ARI including pneumonia, pulmonary tuberculosis, and stroke are the three top causes of death in the 15–49 years age group. Unlike the other age groups, trauma contributes a large proportion (19.7%) of deaths among adults. Neoplasms are responsible

TABLE 4

Weighted and unweighted frequency distribution and IR per 100,000 PYO with 95% CI of the causes of death among adult (15–49 years old)

Cause of death	Weighted			Unweighted				
	%	95% CI		n	%	IR*	95% CI of IR	
		Lower	Upper				Lower	Upper
01.01 Sepsis (nonobstetric)	1.1	0.2	7.4	1	1.1	1.2	–1.2	3.6
01.02 Acute respiratory infection including pneumonia	9.6	5.1	17.5	9	9.7	11.0	3.8	18.2
01.04 Diarrheal diseases	2.1	0.5	7.9	2	2.2	2.4	–0.9	5.8
01.05 Malaria	5.3	2.2	12.0	5	5.4	6.1	0.8	11.4
01.07 Meningitis and encephalitis	2.1	0.5	8.2	2	2.2	2.4	–0.9	5.8
01.09 Pulmonary tuberculosis	8.5	4.3	16.1	8	8.6	9.8	3.0	16.5
01.99 Other and unspecified infectious diseases	3.2	1.0	9.5	3	3.2	3.7	–0.5	7.8
02.02 Digestive neoplasms	4.5	1.7	11.3	4	4.3	4.9	0.1	9.7
02.04 Breast neoplasms	4.2	1.6	10.7	4	4.3	4.9	0.1	9.7
02.05 & 02.06 Reproductive neoplasms MF	1.1	0.2	7.5	1	1.1	1.2	–1.2	3.6
02.99 Other and unspecified neoplasms	3.3	1.1	9.7	3	3.2	3.7	–0.5	7.8
03.02 Severe malnutrition	1.1	0.2	7.5	1	1.1	1.2	–1.2	3.6
03.03 Diabetes mellitus	2.2	0.6	8.5	2	2.2	2.4	–0.9	5.8
04.01 Acute cardiac disease	1.1	0.2	7.4	1	1.1	1.2	–1.2	3.6
04.02 Stroke	7.5	3.6	14.9	7	7.5	8.5	2.2	14.9
04.99 Other and unspecified cardiac disorders	6.4	2.9	13.6	6	6.5	7.3	1.5	13.2
05.01 Chronic obstructive pulmonary disorder	1.1	0.2	7.4	1	1.1	1.2	–1.2	3.6
05.02 Asthma	1.1	0.2	7.4	1	1.1	1.2	–1.2	3.6
06.01 Acute abdomen	1.1	0.2	7.6	1	1.1	1.2	–1.2	3.6
06.02 Liver cirrhosis	2.1	0.5	8.2	2	2.2	2.4	–0.9	5.8
07.01 Renal failure	3.2	1.0	9.6	3	3.2	3.7	–0.5	7.8
08.01 Epilepsy	1.1	0.2	7.5	1	1.1	1.2	–1.2	3.6
09.02 Abortion-related death	1.0	0.1	7.0	1	1.1	1.2	–1.2	3.6
09.08 Ruptured uterus	1.1	0.1	7.2	1	1.1	1.2	–1.2	3.6
12.01 Road traffic accident	3.3	1.1	9.8	3	3.2	3.7	–0.5	7.8
12.02 Other transport accident	6.6	3.0	14.0	6	6.5	7.3	1.5	13.2
12.03 Accidental fall	1.1	0.2	7.4	1	1.1	1.2	–1.2	3.6
12.04 Accidental drowning and submersion	4.3	1.6	10.9	4	4.3	4.9	0.1	9.7
12.05 Accidental exposure to smoke fire and flame	1.0	0.1	7.1	1	1.1	1.2	–1.2	3.6
12.09 Assault	3.3	1.1	9.8	3	3.2	3.7	–0.5	7.8
98 Other and unspecified NCD	2.1	0.5	8.0	2	2.2	2.4	–0.9	5.8
99 Indeterminate	3.1	1.0	9.3	3	3.2	3.7	–0.5	7.8

CI = confidence interval; IR = incidence rate; MF = male and female; NCD = non-communicable diseases; PYO = person years observation.

* IR = incidence rate per 100,000 PYO.

TABLE 5

Weighted and unweighted frequency distribution and IR per 100,000 PYO with 95% CI of the causes of death among elderly (50+ years old)

Cause of death	Weighted			Unweighted				
	%	95% CI		n	%	IR*	95% CI of IR	
		Lower	Upper				Lower	Upper
01.01 Sepsis (nonobstetric)	0.3	0.1	1.3	2	0.3	4.5	-1.7	10.7
01.02 Acute respiratory infection including pneumonia	13.6	11.2	16.4	95	13.9	213.9	171.0	256.9
01.03 HIV/AIDS-related death	1.0	0.4	2.2	6	0.9	13.5	2.7	24.3
01.04 Diarrheal diseases	1.6	0.9	2.8	11	1.6	24.8	10.1	39.4
01.05 Malaria	3.4	2.2	5.1	23	3.4	51.8	30.6	73.0
01.07 Meningitis and encephalitis	0.4	0.1	1.4	3	0.4	6.8	-0.9	14.4
01.09 Pulmonary tuberculosis	7.3	5.5	9.5	47	6.9	105.8	75.6	136.1
01.99 Other and unspecified infect dis	2.4	1.5	3.9	16	2.3	36.0	18.4	53.7
02.01 Oral neoplasms	0.2	0.0	1.3	1	0.1	2.3	-2.2	6.7
02.02 Digestive neoplasms	0.6	0.2	1.7	4	0.6	9.0	0.2	17.8
02.03 Respiratory neoplasms	0.6	0.2	1.6	4	0.6	9.0	0.2	17.8
02.04 Breast neoplasms	0.2	0.0	1.2	1	0.1	2.3	-2.2	6.7
02.05 & 02.06 Reproductive neoplasms MF	0.3	0.1	1.2	2	0.3	4.5	-1.7	10.7
02.99 Other and unspecified neoplasms	1.3	0.7	2.5	9	1.3	20.3	7.0	33.5
03.01 Severe anemia	1.6	0.9	2.8	11	1.6	24.8	10.1	39.4
03.02 Severe malnutrition	1.3	0.7	2.5	9	1.3	20.3	7.0	33.5
03.03 Diabetes mellitus	1.6	0.8	2.9	10	1.5	22.5	8.6	36.5
04.01 Acute cardiac disease	1.2	0.6	2.5	8	1.2	18.0	5.5	30.5
04.02 Stroke	29.9	26.5	33.4	206	30.2	463.9	400.7	527.1
04.99 Other and unspecified cardiac disorders	13.2	10.8	16.0	90	13.2	202.7	160.8	244.5
05.01 Chronic obstructive pulmonary disorder	4.5	3.2	6.3	31	4.5	69.8	45.2	94.4
05.02 Asthma	0.1	0.0	1.0	1	0.1	2.3	-2.2	6.7
06.01 Acute abdomen	3.6	2.4	5.3	25	3.7	56.3	34.2	78.4
06.02 Liver cirrhosis	1.2	0.6	2.3	8	1.2	18.0	5.5	30.5
07.01 Renal failure	1.1	0.5	2.2	8	1.2	18.0	5.5	30.5
08.01 Epilepsy	0.3	0.1	1.1	2	0.3	4.5	-1.7	10.7
12.01 Road traffic accident	0.5	0.2	1.7	3	0.4	6.8	-0.9	14.4
12.02 Other transport accident	0.4	0.1	1.5	2	0.3	4.5	-1.7	10.7
12.03 Accidental fall	0.3	0.1	1.3	2	0.3	4.5	-1.7	10.7
12.08 Intentional self-harm	0.1	0.0	0.9	1	0.1	2.3	-2.2	6.7
12.09 Assault	0.3	0.1	1.3	2	0.3	4.5	-1.7	10.7
12.99 Other and unspecified external complications	0.2	0.0	1.3	1	0.1	2.3	-2.2	6.7
98 Other and unspecified NCD	1.0	0.5	2.1	7	1.0	15.8	4.1	27.4
99 Indeterminate	4.4	3.1	6.3	31	4.5	69.8	45.2	94.4

AIDS = acquired immunodeficiency syndrome; CI = confidence interval; HIV = human immunodeficiency virus; IR = incidence rate; MF = male and female; NCD = non-communicable diseases; PYO = person years observation.

* IR = incidence rate per 100,000 PYO.

for 13% of the deaths. Meanwhile, among elderly people aged 50 years old or above, noncommunicable diseases is the most common cause of death with the proportion of 61% (95% CI: 56.7, 64.1) and IR of 936.8 per 100,000 PYO (95% CI: 890.7, 982.8). Stroke is the leading cause of death among the elderly people (30%), followed by ARI including pneumonia and other and unspecified cardiac diseases with the proportion of 13.6% and 13.2%, respectively. Three percent of the deaths among elderly are caused by neoplasms, and this proportion is lower than the proportion among adults.

Overall, the proportion of noncommunicable disease-related deaths was 44.5% whereas the proportion of deaths from communicable diseases was 34.4%; with an IR of 265.9 (95% CI: 241.3, 290.6) and 157.1 (95% CI: 138.1, 176), respectively (Table 6).

The incidence rate ratios (IRRs) are presented in Table 7. There was no significant difference in the IR of all causes of death between male and female, except for trauma with IRR 3.3 (95% CI: 1.47, 7.35) for male. Children were more likely to die of communicable diseases compared with adults with IRR 14.4 (95% CI: 8.7, 23.8). Meanwhile, the elderly had higher mortality rates from communicable and

noncommunicable diseases compared with adults with IRR 5.5 (95% CI: 3.75, 8.07) and IRR 11.9 (95% CI: 8.13, 17.49), respectively.

DISCUSSION

Our analysis shows that stroke and other noncommunicable diseases have become the leading cause of death among adults and elderly people in Indonesia. The findings are consistent with results from an Indonesian mortality registration system strengthening project conducted in an urban municipality and a predominantly rural district in Central Java in 2006–2007 that combined data from death certificates for hospital deaths and verbal autopsies reviewed by trained physicians for home deaths, which reported stroke, ischemic heart disease, and chronic respiratory disease as the leading causes of death. Stroke caused most of the death in both urban and rural areas covered by the project, accounting for 27% and 19.9% of deaths, respectively.¹³ The study also found that the death rates from stroke in the project areas were higher compared with the Global Burden of Disease Study

TABLE 6

Weighted and unweighted frequency distribution and IR per 100,000 PYO with 95% CI cause of death category and stratified by age group

Cause of death (all age)	Weighted			Unweighted				
	%	95% CI		n	%	IR*	95% CI of IR	
		Lower	Upper				Lower	Upper
Communicable	34.4	30.6	38.4	264	31.8	157.1	138.1	176.0
Neoplasms	3.8	2.7	5.4	33	4.0	19.6	12.9	26.3
Noncommunicable	44.5	40.7	48.5	447	53.9	265.9	241.3	290.6
Maternal	0.3	0.1	1.1	2	0.2	1.2	-0.5	2.8
Neonatal	5.5	3.1	9.6	11	1.3	6.5	2.7	10.4
Trauma	4.5	3.2	6.4	32	3.9	19.0	12.4	25.6
Indeterminate	7.0	4.6	10.4	41	4.9	24.4	16.9	31.9
Child (0–14 years old)								
Communicable	49.6	36.0	63.1	31	56.4	74.3	61.3	87.4
Noncommunicable	3.8	1.2	11.3	3	5.5	7.2	3.1	11.2
Neonatal	26.0	15.2	40.9	11	20.0	26.4	18.6	34.1
Trauma	3.4	1.1	10.2	3	5.5	7.2	3.1	11.2
Indeterminate	17.2	8.4	32.1	7	12.7	16.8	10.6	23.0
Adult (15–49 years old)								
Communicable	31.9	23.2	42.0	30	32.3	36.6	27.5	45.7
Neoplasms	13.0	7.5	21.6	12	12.9	14.6	8.9	20.4
Noncommunicable	30.2	21.7	40.3	28	30.1	34.2	25.3	43.0
Maternal	2.1	0.5	8.0	2	2.2	2.4	0.1	4.8
Trauma	19.7	12.7	29.1	18	19.4	22.0	14.9	29.0
Indeterminate	3.1	1.0	9.3	3	3.2	3.7	0.8	6.6
Elderly (50 + years old)								
Communicable	30.0	26.6	33.6	203	29.8	457.1	424.9	489.4
Neoplasms	3.2	2.1	4.9	21	3.1	47.3	36.9	57.7
Noncommunicable	60.5	56.7	64.1	416	61.0	936.8	890.7	982.8
Trauma	1.9	1.0	3.4	11	1.6	24.8	17.2	32.3
Indeterminate	4.4	3.1	6.3	31	4.5	69.8	57.2	82.4

CI = confidence interval; IR = incidence rate; PYO = person years observation.

* IR = incidence rate per 100,000 PYO.

estimates for Indonesia in 2004, whereas the death rates from pneumonia and ischemic heart diseases were lower than the national estimates, suggesting major regional variations of cause-specific mortality in Indonesia. The study did not calculate the death rates by age group; thus, we could not compare the age-specific death rates. Other national study estimates suggested that 242,800 deaths due to ischemic heart diseases occurred in 2008, higher than the Purworejo district's rate.¹⁴ Those findings are consistent with the increasing prevalence of stroke and other noncommunicable diseases, suggesting that epidemiological transition from communicable to noncommunicable diseases is well underway in Central Java.

Southeast Asia is facing an epidemic of chronic noncommunicable diseases, responsible for 60% of deaths in the region. The problem stems from environmental factors that promote tobacco use, unhealthy diet, and inadequate physical activity.¹⁵ IDHS 2012 reported that 63.8% of households were exposed to daily smoking and 72% of married men smoked tobacco.¹⁶ Concerning physical activity, men reported spending more time in doing vigorous and moderate activities compared with women. In nine rural health and demographic surveillance sites, older people tended to do less vigorous and moderate activities in their daily life.¹⁷ This pattern suggests the need to prioritize noncommunicable diseases through health care provision, disease prevention, and health promotion. Adequate regulation and control are needed to reduce the prevalence of adult tobacco smoking. Thus, a death registration system is also essential to monitor the mortality statistics associated with exposure to smoking and other risk factors.

Our results also confirmed the rise of premature deaths caused by neoplasms and trauma among adults in developing

countries. Indonesia's basic health survey (Riskesdas) in 2013 estimated that there are 1.4 cancer deaths per 1,000 population, placing cancer as the seventh most common cause of death with the proportion of 5.7%. As neoplasms increasingly become the prominent cause of deaths in Indonesia, hospital-based cancer registry may provide essential data in the absence of population-based registry. More than 90% of trauma deaths occur in low and middle-income countries; yet in those countries where preventive programs are often nonexistent and health care performance are inadequate, the epidemic is neglected. The Global Burden of Disease Study 2010 put road injury in the third rank with the proportion of 6% of total years of life lost in Indonesia. In our study, the proportion of deaths due to trauma was 3.9%, and it was more similar to the mortality registration system strengthening the project's result which was 3.7%.¹³

Meanwhile, mortality among children aged 0 to 14 years old was mostly caused by ARI or pneumonia as well as other communicable diseases. ARI including pneumonia and pulmonary tuberculosis are still significant causes of death among adults as well, suggesting that communicable diseases remain an important health problem and pose a double burden of disease in Indonesia. The finding is also consistent with studies on causes of death among children in other developing countries.

Our experience in determining causes of death in a community-based survey using verbal autopsy demonstrated that asking family members to recall events surrounding the death is often prone to distress and recall inability. Several cases in our study had incomplete information where we could not determine the cause of deaths. Although physician's manual review is the standard in many research settings and

TABLE 7
Poisson regression of the cause of death categories by gender and age

	Communicable	Neoplasms	NCD	Trauma
	IRR	IRR	IRR	IRR
	[95% CI]	[95% CI]	[95% CI]	[95% CI]
Gender				
Male	1.25 [0.98, 1.59]	1.70 [0.85, 3.40]	1.05 [0.87, 1.26]	3.29** [1.47, 7.35]
Female (ref.)	1 [1, 1]	1 [1, 1]	1 [1, 1]	1 [1, 1]
Age category				
Children	14.40*** [8.70, 23.83]	— —	1.544 [0.47, 5.08]	1.998 [0.586, 6.81]
Adults (ref.)	1 [1, 1]	1 [1, 1]	1 [1, 1]	1 [1, 1]
Elderly	5.49*** [3.75, 8.07]	1.45 [0.71, 2.96]	11.93*** [8.13, 17.49]	0.53 [0.25, 1.12]
N	830	830	830	830
pseudo R ²	0.117	0.02	0.195	0.071
AIC	1,155.4	267.4	1,400	222.8

CI = confidence interval; IRR = incidence rate ratio.

Exponentiated coefficients; 95% CIs in brackets; * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

thus is preferred, the process is time consuming, expensive, and agreement can be low. Physician review of hundreds of verbal autopsies was not feasible for our study resource. The Bayesian approach used by InterVA software allows the automation of coding and may improve the reliability of the verbal autopsy instrument. Although the InterVA software is based on an updated WHO standard verbal autopsy instrument, we used the older version in our study. Before analysis, we had to update our data field to adjust to the available field in the software. However, once the data were entered, the program was properly executed to provide a reliable and accurate result.

Even with complete information and professional expertise, assigning a cause to a death can be challenging. Given the limited resources and data, studies in developing countries often have to resort to less than ideal setup that involves uncertainties. By using probabilistic methods, it is very possible that we misclassified a number of deaths. Probabilistic methods lack the more nuanced approach to detailed cause(s) of death (and any comorbidities) of physician review and will not be able to determine complex or unusual causes of death.¹⁸ Studies that compare the performance of physician review and probabilistic modeling show inconsistent results, some found high level of agreement between the two methods over diverse population settings^{19–21} but another found low level of agreement.²² The cause-specific mortality fractions by the two approaches can be very different for particular causes of death, and there are regional and age-group variations in the level of agreement, for example, the level of agreement is the lowest for deaths among newborns aged 0–28 days.²⁰ Probabilistic modeling also tends to misclassify causes of death that share many clinical features and yield higher proportion of indeterminate death.^{19,22} However, Byass et al.²⁰ argued that the two methods generate good public health equivalence, meaning that taking public health planning measures on the basis of either source would lead to similar conclusions. With such complexities and uncertainties involved, InterVA would not generate the true estimates of the causes of death. The search for improved methods for assigning causes of death in limited resource

settings continues. For the time being, InterVA provides for resource poor settings, a direly needed major advance for public health measurement in areas that otherwise would not be available.

CONCLUSION

In summary, stroke was indicated as the leading cause of death among adults and elderly. Meanwhile, pneumonia as a communicable disease was indicated as the most common cause of death among both children and elderly people. The findings provide important information to further monitor the burden of stroke and other noncommunicable diseases and design appropriate public health policy and health care strategies to tackle the rapidly growing burden of noncommunicable diseases, particularly in developing countries such as Indonesia.

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Authors' addresses: Abdul Wahab, Department of Biostatistics, Epidemiology and Population Health (BEPH), Faculty of Medicine, Universitas Gadjah Mada, Yogyakarta, Indonesia, E-mails: abiwahab@yahoo.com and awahab@ugm.ac.id. Ifta Choiriyah and Siswanto Agus Wilopo, Faculty of Medicine, Universitas Gadjah Mada, Yogyakarta, Indonesia, E-mails: ifta.choiriyah@gmail.com and sawilopo@yahoo.com.

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