Original article

Estimating deaths due to other infectious diseases in Thailand 1996-2009 based on 2005 Verbal Autopsy data

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Background Vital registries in Thailand lack credibility because they often contain errors in deaths reported to be due to infectious disease. In this study, the term other infectious diseases excludes tuberculosis, septicemia and HIV

Objective The objective of this study was to model other infectious disease deaths based on 2005 Verbal Autopsy (VA) data and then to use that model to estimate other infectious disease deaths in Thailand from 1996 to 2009.

Methods Logistic regression models were used to model other infectious disease deaths from the 2005 VA dataset. The full model comprises province, gender-age group, and death certificate cause location group as factors. This model was then used to predict other infectious disease deaths from the vital registration database of the province in which the Verbal Autopsy was conducted. Proportions in the remaining provinces were predicted from spatial interpolation based on province coefficients.

Results The model without demographic covariates was preferred for comparison to full models by the area under the ROC curve and AIC. The most misclassified other infectious diseases deaths were those registered as septicemia and digestive. The confidence intervals from a statistical full model provided the estimates and their degree of precision.

Conclusion Demographic covariates are not essential to this study for accurately correcting causes of other infectious disease deaths. The model in this study can be used to more accurately estimate mortality data where their national vital registration data are of poor quality. **Chiang Mai Medical Journal 2017;56(1):9-19.**

Keywords: other infectious diseases, Verbal Autopsy (VA), logistic regression models, vital registries (VR)

Introduction

Infectious diseases are an important component of the morbidity and mortality rates of a population (1). Caused by pathogenic microorganisms such as bacteria, viruses, parasites and fungi, infectious diseases can spread, directly or indirectly, from one person to another, e.g., malaria, dengue, TB, septicemia, pneumonia, HIV/AIDS, etc. “Other infectious diseases” is here defined as all infectious diseases

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exclusive of TB, sepsis or septicemia and AIDS. There is a need to correctly classify other infectious diseases because they are leading causes of death among middle income countries.

Verbal Autopsy (VA) surveys have been widely used in several countries, including Ethiopia (2), India (3), Uganda (4), Tanzania (5), Malawi (6) and Thailand to provide more accurate information about causes of death than that available in civil registries.

The cause of death may be assigned incorrectly and statistical mortality data can contain errors of fact. The misclassification of the cause of death can affect policy formulation and planning for public health related to control and prevention of diseases and can interfere with the ability to address the real health problems of a country. For those reasons, VA surveys have become a source of cause-of-death statistics that meet the standards for reliable population-level disease-burden estimates that can be used in policy, planning, priority setting and benchmarking (7).

There are three methods of establishing cause of death in Thailand: (1) the gold standard, diagnosis by a medical specialist; (2) Verbal Autopsy (VA), a technique whereby public health personnel establish the cause of death through interviews with the deceased's close family members; and (3) the local registrar's report of the cause of death as recorded on the death certificate (8).

The epidemiological evidence used in planning national public health policy is based on statistics on the exact cause of death by gender and age group. Statistics based on local registries of death certificates, however, are limited by the fact that about 40% do not specify a clear cause of death (Ill-Defined). Presently, the accuracy and reliability of the vital registration (VR) database of causes of death in Thailand is poor. In response to that situation, Public Health academics have developed a tool to improve the quality of mortality data: an investigation of the cause of death known as Verbal Autopsy (VA).

The current Verbal Autopsy system used to investigate the cause of death was carried out as a SPICE project (Setting Priorities using Information on Cost-Effectiveness) and was developed from a series of questionnaires from the World Health Organization (WHO). The questionnaires include the deceased's history of treated disease until death, or as much event-dating as possible of both disease symptoms and the duration of treatment. Samples are divided into two groups: those who died in a hospital and those who died outside a hospital. For the population that died in a hospital, the information from medical records is used as the starting point for investigating the cause of death. For the segment of the population that died outside a hospital, the Verbal Autopsy by interview method is the starting point of the investigation of cause of death. This more complete and more accurate information on those who died in and outside a hospital was used in the statistical model to estimate the causes of deaths in Thailand (9).

The past two decades have seen a proliferation of interest, as well as research and development, in all aspects of the Verbal Autopsy process. These include data-collection systems where Verbal Autopsy is applied; questionnaire content and format; application to different age groups; the cause-of-death assignment process; coding and tabulation of causes of death according to the ICD-10 rules; and the vexing issue of validation (10).

Vital registry (VR) or national vital registration data in Thailand provided by the Ministry of Interior through the Bureau of Policy and Strategy, Ministry of Public Health, are of poor quality, not only lacking completeness but also providing an inaccurate picture of causes of death (11-16).

Aungkulanon S et al. (2012) found that from 1958 to the mid-1990s, the rate of infectious-disease–associated deaths declined five-fold (from 163.4 deaths/100,000 population in 1958 to 29.5/100,000 in 1997). This average annual reduction of 3.2 deaths/100,000 population was largely attributed to a decline in deaths related to malaria, tuberculosis, pneumonia, and gastrointestinal infections (17). Although deaths from infectious diseases decreased overall, HIV/AIDS deaths continued to increase

during that period (18). Strategies for reducing infectious diseases mortality in Thailand, however, are complicated by the fact that most death certificates do not accurately report the cause of death.

To address this problem, this study attempted to model other infectious disease deaths based on 2005 Verbal Autopsy data, to examine under-reporting and misclassification of other infectious disease deaths and to estimate the number of other infectious disease deaths in Thailand from 1996 to 2009.

Methods

Data Sources and Management

This study used secondary data from the 2005 VA survey and was confined to deaths of people aged five years and older. VR data from 1996-2009 were obtained from the Bureau of Policy and Strategy database, Ministry of Public Health.

The 2005 VA was designed to verify causes of death for a nationality-specific, representative sample of deaths, using a multistage stratified cluster sampling technique. The sample was drawn from the VR database and the sampling unit was a registered death of a Thai citizen who was a permanent resident in Thailand. The 2005 VA study included a sample of 9,644 deaths (3,316 in-hospital and 6,328 outside-hospital), in nine provinces and 28 districts of four regions, of which 9,495 were deaths of people age five years and older. These data produced a table with five fields: (a) the deceased person's province; (b) the person's gender and age; (c) the ICD-10 code reported on the death certificate; (d) the location of death (in or outside hospital); (e) the VA-assessed ICD-10 code.

The cause of death based on 2005 VA data was then summarized as the chapter-block classifications of ICD-10 codes to group causes of death (19). We studied 149 child deaths (under age 5) separately, and created 21 major cause groups for deaths from age 5 and older (9,495 deaths) with VA counts (Table 1). To ensure statistical accuracy, we aimed to have close to 200 in each group, except for septicemia (over-reported), which deserved special attention. The proportion of all deaths represented by category varied from 0.8% for septicemia to 11.3% for stroke and 2.3% for other infectious disease (ICD 10 code A*, B *).

Province, Gender and Age-group, Reported ICD 10 Cause group and Location (in/outside hospital) were selected as variable determinants, whereas death from other infectious diseases was the outcomes variable. The determinants separate naturally into regional, demographic, and medical components.

Table 1. Cause of Death per 2005 VA count

Cause group	VA Count (%)
01: TB (A15-19)	195 (2.1)
02: Septicemia (A40-41)	77 (0.8)
03: HIV (B20-24)	512 (5.4)
04: Other Infectious Disease (A*,B*)	219 (2.3)
05: Liver Cancer (C22)	500 (5.3)
06: Lung Cancer+ C30-39)	320 (3.4)
07: Other Digestive (C15-26-)	290 (3.1)
08: Other Cancer (C-, D0-48)	697 (7.3)
09: Endocrine (E)	647 (6.8)
10: Mental+Nervous (F, G)	223 (2.3)
11: IHD (I20-25)	617 (6.5)
12: Stroke (I60-69)	1,076 (11.3)
13: Other CVD (I-)	540 (5.7)
14: Respiratory (J)	801 (8.4)
15: Digestive (K)	489 (5.2)
16: Genitourinary (N)	412 (4.3)
17: Ill-defined (R)	501 (5.3)
18: Transport Accident (V)	536 (5.6)
19: Other Injury (W, X0-59)	327 (3.4)
20: Suicide (X60-84)	158 (1.7)
21: All Other	358 (3.8)
Total	9,495 (100.0)

The target population was all reported Thai deaths from January 1996 through December 2009. The sample was Verbal Autopsies assessing the true cause of death for 9,495 selected residents aged five and older from nine provinces (Bangkok, Nakon Nayok, Ubon Ratchatani, Loei, Payao, Chiang Rai, Supan Buri, Chumpon and Songkla) who died in 2005. Age was divided into eight groups (5-19, 20-29, 30-39, 40-49, 50-59, 60-69, 70-79, 80 and above). The report ICD 10 causes of death included other Infectious disease, Ill-Defined, Septicemia, Digestive, Genitourinary, Respiratory, Mental and Nervous, and Other.

Statistical Methods

There have been many published reports using this method of estimating infectious disease mortality, e.g., Sriwattanapongse W. et al. (2012), which studied the mortality rate due to malaria in Thailand which followed and forecast mortality from malaria in the VR database using death certificate reports (20).

Waeto S et al. (2014) did a study that modeled liver cancer deaths based on VA data in 2005 to provide more accurate estimates of liver cancer deaths than those reported. The results were used to estimate number of liver cancer deaths during 2000-2009 (21).

The outcome variable was other infectious disease death (yes/no) and the determinants variables

were province, gender-age group and VR cause and location. A logistic regression model was used for describing the relation between the outcome and determinants variable (22). This model formulates the logic of the probability P that a person died from Other Infectious Disease as an additive linear function of the determinant factors of four models as follows:

$$\log it\left(\frac{P_{ijk}}{1-P_{ijk}}\right)=\mu+\alpha_i+\beta_j+\gamma_k \qquad (A)$$

$$\log it\left(\frac{P_{ik}}{1-P_{ik}}\right)=\mu+\alpha_i+\gamma_k \qquad (B)$$

$$\log it\left(\frac{P_{jk}}{1-P_{jk}}\right)=\mu+\beta_j+\gamma_k \qquad (C)$$

$$\log it\left(\frac{P_{k}}{1-P_{k}}\right)=\mu+\gamma_k \qquad (D)$$

In this model is the probability of death due to other infections disease in province , gender-age group is, VR cause-location is and is a constant. , and are individual parameters relating VR to a province, gender-age group and VR cause-location, respectively.

Sum Contrasts

The "sum contrasts" approach developed by Tongkumchum and McNeil (23) is an alternative to the conventional "treatment contrasts" in which the first level was left out of the model to be used as a reference. This method allows the computation of the estimate and the 95% confidence interval of deaths for each of the covariate levels in the VA and the VR datasets.

For the nine provinces studied, fitting the complete logistic regression model to the 2005 VA dataset resulted in nine province coefficients, 16 gender-age group coefficients, and 16 VR cause-location coefficients. The model was used to estimate other infectious disease deaths and 95% confidence intervals as well.

Area Under the Curve

To assess the accuracy of model prediction, the Receiver Operating Characteristic (ROC) curve from logistic regression was drawn based on a concept described by Chongsuvivatwong (24) and Fan et al. (25). Area under the ROC curve measures the performance of a model and represents model accuracy (26,27). A cut-off point in the curve, where the predicted number of other infectious disease deaths equals the observed value in the VA dataset (219 cases), was used to report the sensitivity and the false positive rate of the model. Furthermore, the ROC curve shows how well a model predicts a binary outcome by the area under the ROC curve (the larger the area under the curve, the more accurate the model is).

Triangulation method

For the remaining 67 provinces of Thailand, we used a simple and easily implemented spatial "triangulation method" (28,29) to interpolate province coefficients. This was preferred to the "kriging" method because it uses fewer points than kriging, and because there were insufficient sample provinces (nine) to provide a basis for kriging (30). Triangles were drawn linking the nine provinces in the 2005 VA study. Values of province coefficients in each triangle were assigned the average value of coefficients from nearby provinces in the model.

For each triangle, values a, b and c were obtained by solving three equations using linear algebra based on latitude and longitude as follows.

$$a+longP_j \times b + latP_j \times c = \beta_{PJ},\ j=1,2,3 \qquad (1)$$

(Note: P = Province, β = coefficient)

The coefficient for any province j within a triangle was then

$$\beta_{PJ} = a+longP_j \times b + latP_j \times c \qquad (2)$$

The coefficients for provinces outside the triangles were obtained similarly by extrapolation from nearby provinces and the magnitude of other infectious disease deaths was estimated. R program version 3.3.2 (31) was used for all statistical analysis and graphical displays.

Results

Of the 9,495 cases in the VA study, it was assessed that 219 deaths were due to other infectious disease. Of those 219 VA other infectious disease deaths, the most likely VR reported causes were other infectious disease (28), ill-defined (106), septicemia (27), digestive (12), genitourinary (12), respiratory (11), TB (4), HIV (1), liver cancer (3), other cancer (3), mental and nervous (4), IHD (1), stroke (2), other CVD (3) and all others (2).

Table 2 shows the crude percentages of other infectious disease deaths (among all deaths) for thenine provinces, 16 gender-age groups, and 16 VR cause-location groups plus the adjusted values with 95% confidence intervals. The values derived from the direct VA assessment and from the full logistics regression model were similar, indicating some variation among groups but with no substantial confounding. The plotted values above the average line reflect the groups that were more likely to die from other infectious disease.

Table 2. Estimated percentage of other infectious disease-related deaths out of all deaths based on the full logistics regression model

Province	0:other	1:othInfDis	Sum	%	provCILB	provCIUB
Bangkok	845	12	857	1.40	0.710	2.112
Nkn.Nayok	632	8	640	1.25	0.605	2.186
UbonRat.	2,299	74	2,373	3.12	2.396	4.101
Loei	846	20	866	2.31	1.582	3.713
Payao	575	13	588	2.21	1.372	3.829
ChiangRai	1,408	29	1,437	2.02	1.452	3.037
SupanBuri	1,558	42	1,600	2.63	1.904	3.609
Chumphon	301	9	310	2.90	1.470	5.055
Songkla	812	12	824	1.46	0.804	2.353
Sex age gr					SagCILB	SagCIUB
01:m0-19	181	5	186	2.69	1.568	9.525
02:m20-29	304	1	305	0.33	0.077	3.174
03:m30-39	545	15	560	2.68	1.361	4.129
04:m40-49	600	15	615	2.44	1.510	4.460
05:m50-59	692	18	710	2.54	1.779	4.846
06:m60-69	941	16	957	1.67	1.153	3.259
07:m70-79	1,121	18	1,139	1.58	0.964	2.631
08:m80+	875	33	908	3.63	2.138	4.936
09:f0-19	69	2	71	2.82	0.903	14.405
10:f20-29	118	3	121	2.48	0.608	5.966
11:f30-39	229	2	231	0.87	0.175	2.677
12:f40-49	286	5	291	1.72	0.813	4.647
13:f50-59	414	6	420	1.43	3.605	3.605
14:f60-69	672	12	684	1.75	3.451	3.451
15:f70-79	1,004	30	1,034	2.90	3.999	3.999
16:f80+	1,225	38	1,263	3.01	1.778	4.059
Cause-location					vrhCILB	vrhCIUB
01:othInf.oh	32	14	46	30.43	19.190	47.567
02:illDef.oh	3,269	97	3,366	2.88	1.877	3.627
03:sept.oh	51	3	54	5.56	1.883	15.435
04:diges.oh	133	6	139	4.32	1.891	8.826
05:GU.oh	212	7	219	3.20	1.386	5.948
06:resp.oh	245	5	250	2.00	0.902	4.862
07:ment&nerv.oh	116	3	119	2.52	0.905	7.632
08:othGrps.oh	2,082	8	2,090	0.38	0.196	0.778
09:othInf.ih	54	14	68	20.59	13.249	34.250
10:illDef.ih	426	9	435	2.07	1.149	4.186
11:sept.ih	441	24	465	5.16	3.923	9.261
12:diges.ih	156	6	162	3.70	1.825	8.487
13:GU.ih	155	5	160	3.13	1.449	7.749
14:resp.ih	347	6	353	1.70	0.856	4.055
15:ment&nerv.ih	31	1	32	3.13	0.510	18.514
16:othGrps	1,526	11	1,537	0.72	0.445	1.472
	9,276	219	94,95			

Slightly higher percentages of other infectious disease deaths occurred in Ubon Ratchathani province (3.12%), and in males aged 80 and older (3.63%), with 20.59% and 30.43% of reported other infectious disease deaths in and outside hospital, respectively. Deaths reported as septicemia accounted for 5.16% and 5.56% of deaths in and outside hospital respectively; digestive reported deaths accounted for 3.70% and 4.32% deaths in and outside the hospital, respectively.

The logistic regression model for estimating other infectious disease deaths in the VA study gave the following p-values when fitted to case-by-case records.

Both VR cause-location and province are highly statistically significant (p<0.01), but there is no evidence of gender-age group variation. This means that the model could be reduced to exclude demographic factors.

This study compared four models, one of which (Model A) contained all the predictor groups under consideration and the others contained a subset of these predictor groups each of which included the VR cause-location (Models B, C and D).

The full model (A) was assessed using the ROC curve and then compared to the reduced models (B), (C) and (D). Figure 2 shows the ROC curves of the full model (A) and reduced models (B), (C) and (D) that included the VR cause-location factor. The ROC curve of the full model (A) included the three factors of province, gender-age group and VR-cause location. The cut-off point gives a total predicted number agreement of the number of VA-assessed other infectious disease deaths (219) in the model. The ROC curve of logistic regression of the full model (A), by choosing c=0.073, represents the area under the curve (area under the ROC curve measures the performance of a model and represents model accuracy) of 0.9550 (95.50%), 17.6% sensitivity, and 1.94% false positive rate, whereas the reduced models (B), (C) and (D) represent an area under the curve of 0.9694, 16.4% sensitivity, and 1.93% false positive rate for model (B); 0.9606, 14.16% sensitivity, and 1.35% false positive rate for model (C) and 0.9749, 12.84% sensitivity, and 0.93% false positive rate for model (D). Note that using the reported cause to predict the true cause has a sensitivity of 0.25, but only 28 cases out of 114 other infectious disease deaths (or about 24.56%) were correctly reported. These were compared with results from four models as shown in Figure 1.

Table 3. Results from logistic regression model

Factor	Deviance reduction	df	p-value
VR cause-location	2035.5	15	< 2.2e-16
Sex-age group	1874.2	15	0.190894
Province	1875.2	8	0.008455
Error	1854.6	9,456	
Total		9,494	

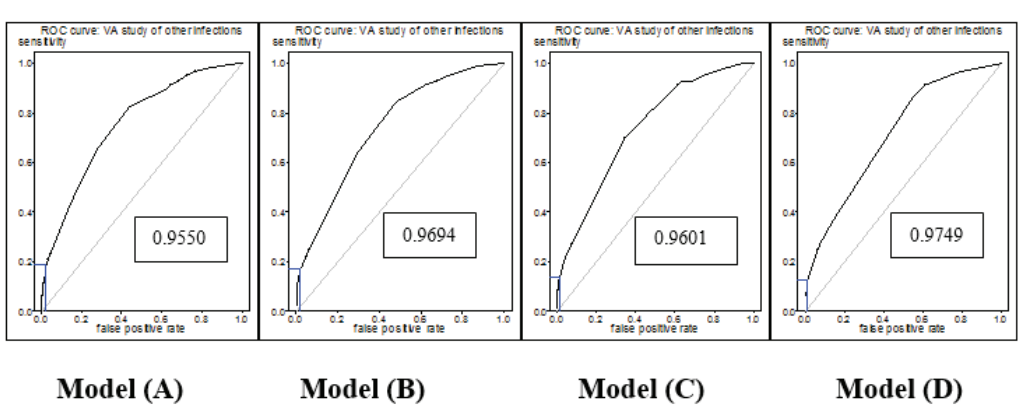

Figure 1. ROC curve of the logistic regression model with and without demographic covariates

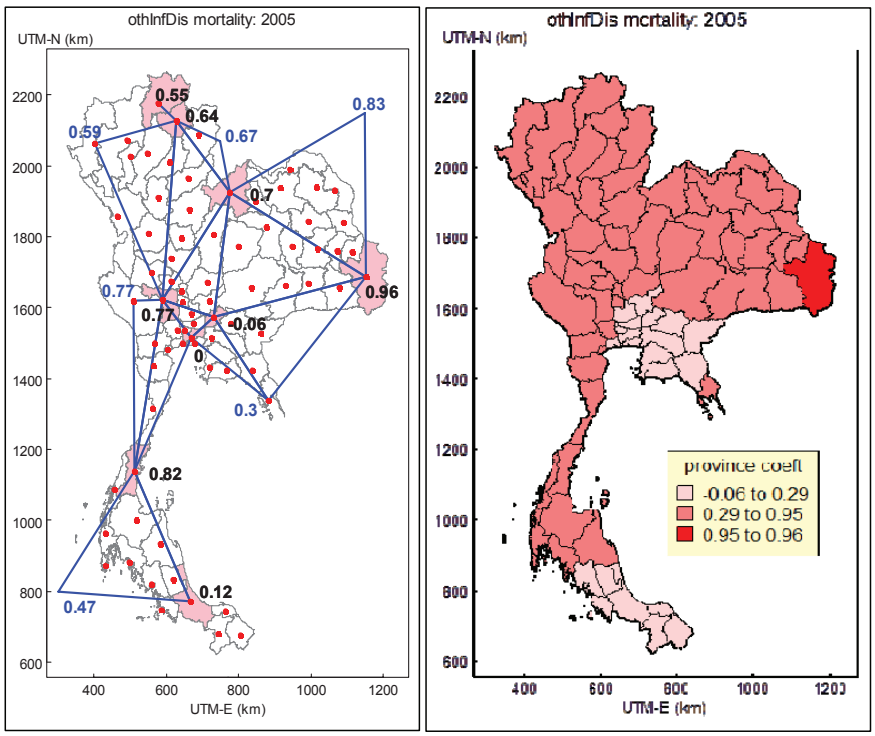

Figure 2. Triangulation to interpolate coefficients for all provinces

Based on the area under the curve, models B and D were selected, but from Table 2 and the calculated AIC of models B and C were 1922.1 and 1926.3, respectively. The reduced model (Model B) was preferred.

Figure 2 shows the study's nine province coefficients from the logistic regression model in black; values in blue are averages of coefficients from nearby provinces in each triangle using the triangulation method. The right panel classifies coefficients of provinces into three levels. The lowest were found in the Central (Nakhon Nayok, Samut Prakan, Saraburi, Nonthaburi, Samut Sakhon and Phra Nakhon Si Ayutthaya), the East (Chachoengsao, Prachin-Buri, Chon Buri and Sa Kaeo), Northeast (Sa Kaeo) and the lower South (Songkhla, Pattani, Yala, Narathiwat, Satun, Phatthalung and Trang). The coefficients of the provinces were highest in the Northeast (Ubon Ratchathani).

The model was then used to show the VR data for male and for female deaths in 1996-2009. The difference between the number of other infectious disease deaths estimated by VA and the number of reported deaths due to other infectious disease was compared using area plots (Figure 3). The area of each color strip denotes the number of other infectious disease deaths in each age group. The total number of VA-estimated other infectious disease deaths were modeled using logistic regression by inflation factors for males and females of 1.29 and 1.75, respectively. Over the period 1996-2009, this gives the estimated number of other infectious disease deaths as 55,848 (males) and 43,126.5 (females). These are 29% (male) and 75% (female) higher than the reported totals of 43,164 and 24,669, respectively.

Discussion and conclusions

The logistic regression full model shows that VA-assessed other infectious disease deaths were more likely in elderly men age 80 and older compared to death registrations, but many of those deaths were VR-registered as deaths from septicemia or from digestive. The misclassification of deaths from septicemia and from other infectious diseases can make an important difference in terms of priority setting. Other infectious diseases occur when germs

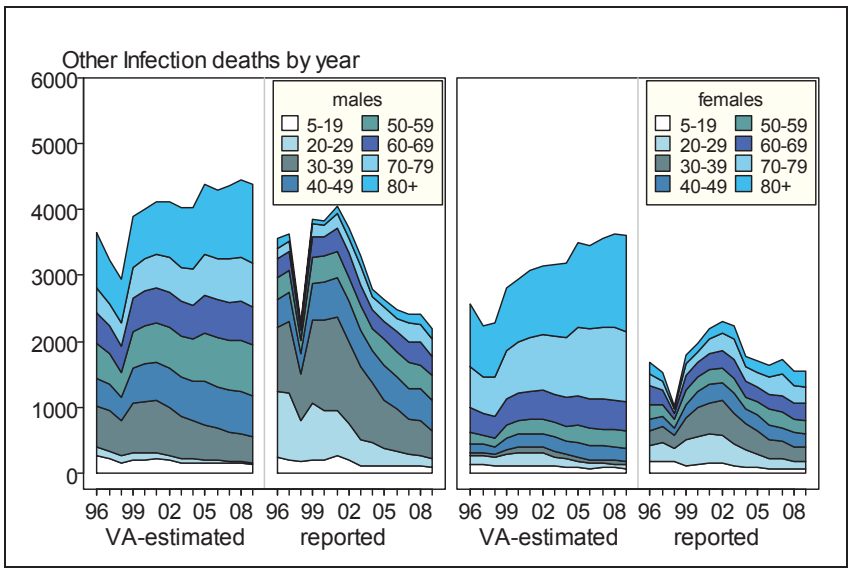

Figure 3. Area plots for number of VA-estimated and reported other infectious disease deaths, 1996-2009

enter a person's body and multiply, causing illness, organ and tissue damage and infection which can turn serious, or even deadly, very rapidly. In addition, sepsis is a complication caused by the body's overwhelming and life-threatening response to infection which can lead to tissue damage, organ failure, and death. It is not very different from deaths from septicemia and from other infectious diseases. Moreover, the difference in the percentage of correct classifications of cause of death in a hospital (20.59% against 30.43% out of hospital) is low. It is possible that a deceased person could have had an infectious disease in an organ and that the cause of death was recorded as diseases of that organ by the clinician but as "other infectious disease" by the Verbal Autopsy Researchers.

The model could be reduced to exclude gender-age group as a factor without significantly affecting the results. The reduced model (Model B) was preferred; however, Chutinantakul A et al. (2014) (32) examined that same model and found that the full model had greater ability to predict the correct cause in cases of HIV than the simple cross-reference model. VR reporting using the full model was most common in the northeast and the lower south of the country. VR under-reported other infection disease deaths by a factor of three, which could lead to what Gavazzi G. et al. (2004) (33) predicted: infectious disease in elderly patients will have an increasing impact on the public health and economy of developing countries.

This study showed that other infectious disease mortality does not vary with gender or age. González-González C et al. (2014) (34) indicated that a mixed epidemiological regime (the presence of both chronic and infectious disease) adds to the mortality health burden experienced by older people, therefore, when estimating the number of other infectious disease deaths it is not necessary to take demographic factors into account. In addition, mortality varies by geographic location. The south had the lowest overall mortality which is in agreement with Faramnuayphol P et al. (2008) (35), which concluded that geographical variation of mortality exists and should be used in targeting efforts to reduce the mortality gap across geographical areas. The other infectious disease deaths were proportionally lowest among all deaths in the central and lower south areas. The estimated numbers of other infectious disease deaths over the years 1996-2009 were 29% (male) and 75% (female) higher than the reported totals.

The main strength of this study lies in the

methodologies used. Logistic regression is appropriate for use in public health research. There were, however, limitations in our analysis. First, the sample survey design did not stratify by strong predictors of the outcome such as reported cause and location of report. Second, only nine of Thailand's 76 provinces were included in the VA study. Third, we have assumed that the 2005 VA data can inform corrections in the years between 1996 and 2009. There could, therefore, be differences in misclassification of other infectious disease related deaths across the years which are not captured by our methods. Finally, VA itself has limitations in terms of the accuracy of the method used for data collection. Results, therefore, must be interpreted with care.

Assessments of data consistency and reliability are further constrained by lack of public availability of data sets (36), by the scarcity of rigorous validation studies and by the frequently encountered problem of small and non-representative samples.

The research methodology used in this study can be used with available mortality data in developing countries where national vital registration data are of poor quality and where reliable supplementary data are available.

Based on these findings, misclassification errors are likely to have very significant implications for health policy decision making as well as for clinical practice. Routine incorporation of validated Verbal Autopsy methods have the potential to significantly improve the quality of cause-of-death data in Thailand (Porapakkham Y et al., 2010). Clinicians, local registrars and Verbal Autopsy researchers should be aware of the importance of cause of death data. The Ministry of Public Health could benefit from that more accurate data to more effectively control and prevent diseases that are the leading cause of death in Thailand.

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การประมาณการตายเนื่องมาจากโรคติดต่ออื่นๆในประเทศไทย: 1996-2009 บนข้อมูลการสืบสวนหาสาเหตุการตาย ปี ค.ศ. 2005

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บทนำ สาเหตุการตายของประเทศไทยขาดความน่าเชื่อถือ ข้อมูลมีความคลาดเคลื่อนจากความเป็นจริง

วัตถุประสงค์ เพื่อสร้างตัวแบบการตายของโรคติดต่ออื่น ๆ บนข้อมูลการสืบสวนหาสาเหตุการตาย ปี ค.ศ. 2005 และประมาณการตายของโรคติดต่ออื่น ๆ ระหว่างปี ค.ศ. 2000-2009

วิธีการศึกษา ตัวแบบการถดถอยโลจิสติกถูกนำมาใช้กับชุดข้อมูลการสืบสวนหาสาเหตุการตาย ปี ค.ศ. 2005 ประกอบด้วยปัจจัย พื้นที่จังหวัด กลุ่มอายุเพศ และสถานที่เสียชีวิต (ในหรือนอกโรงพยาบาล) หลังจากนั้นใช้ตัวแบบนี้ทำนายการตายโรคติดต่ออื่นจากฐานข้อมูลลงทะเบียนการตายของจังหวัดที่ไปการสืบสวนหาสาเหตุการตาย สัดส่วนในจังหวัดที่เหลือถูกทำนายจากการประมาณค่าเชิงพื้นที่บนสัมประสิทธิ์จังหวัด

ผลการศึกษา ตัวแบบที่เลือกใช้เป็นตัวแบบที่ปราศจากตัวแปรร่วมทางระบาดวิทยาเมื่อเทียบกับตัวแบบเต็ม โดยพิจารณาจาก โค้ง ROCและ AIC การตายจากโรคติดเชื้ออื่นที่จัดผิดกลุ่มทีได้ลงทะเบียนการตายมากที่สุด คือโรคภาวะติดเชื่อในกระแสเลือด และโรคทางเดินอาหาร

สรุปผลการศึกษา ตัวแปรร่วมทางระบาดวิทยาไม่มีความจำเป็นในตัวแบบ เข้าถึงการปรับแก้ไขสาเหตุการตายจากโรคติดเชื่ออื่น ตัวแบบนี้สามารถใช้ปรับแก้สาเหตุการตายจากข้อมูลการลงทะเบียนการตายซึ่งมีคุณภาพไม่ดี
เชียงใหม่เวชสาร 2560;56(1):9-19.

คำสำคัญ: โรคติดเชื่ออื่น การสืบสวนหาสาเหตุการตาย ตัวแบบการถดถอยโลจิสติก การลงทะเบียนการตาย