Appendix 1

Manuscript I:

A Statistical Method for Forecasting Demographic Time Series Counts, with Application to HIV/AIDS and Other Infectious Disease Mortality in Southern Thailand

A STATISTICAL METHOD FOR FORECASTING DEMOGRAPHIC TIME SERIES COUNTS, WITH APPLICATION TO HIV/AIDS AND OTHER INFECTIOUS DISEASE MORTALITY IN SOUTHERN THAILAND

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Abstract. This study investigated regional and temporal patterns of death reported from infectious diseases (including HIV/AIDS) in 14 provinces of southern Thailand over the period 1999-2004, using data obtained from the Thailand Bureau of Policy and Strategy, Ministry of Public Health. Causes of deaths were identified using the International Classification of Diseases 10th revision (ICD-10), and mortality incidence rates were then calculated using populations obtained from the 2000 population census. Poisson and negative binomial lagged observation-driven regression models for mortality incidence were fitted to the data separately for HIV/AIDS and other infectious diseases. Overall, the hospital mortality rates started to increase sharply in 2003 - 2004. The in-hospital mortality for HIV/AIDS showed peaks in urban districts and decreased from north to south with mortality for males approximately double that of females. For other infectious diseases, an upward trend in hospital mortality age 40 and over started in 2003-2004, particularly among persons reported as dying from septicemia, while showing a slightly increasing trend for other infectious diseases. Identifying the real cause of hospital deaths recorded as septicemia would substantially improve hospital mortality data quality.

INTRODUCTION

Accuracy and complete mortality data are important for sound health planning and policy making (Prasartkul and Vapattanawong, 2006). The prevailing perception in society is that the most reliable mortality data are those with cause of death certified in a hospital by medical professionals. However, such information is available for less than 30% of the estimated 50.5 million deaths occurring in the world each year (Murray and Lopez, 1997). In addition, hospital statistics tend to under-estimate the prevalence of mortality in underdeveloped countries, such as Ethiopia (Reniers *et al,* 2005). In Thailand, inaccurately recorded causes of death are still a major problem. Approximately 70% of deaths occur outside the hospital (Chuprapawan *et al,* 2003) and a substantial proportion of these deaths have "senility (senescence)" (ICD10 code R54) recorded as the cause. A study of the completeness of death registration in Kanchanaburi Province in Thailand estimated 12.5% of deaths were not registered (Prasartkul and Vapattanawong, 2006).

Infectious diseases account for over a quarter of all global deaths (National Intelligence Council, 2000). The trend in infectious disease mortality has declined in developed countries due to better living conditions and health care (Gage, 1994; Dore *et al,* 1998;

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Wolleswinkel-van den Bosch *et al,* 2001; Bi *et al,* 2003; Serraino *et al,* 2004) but some developing countries have reemerging infectious diseases (Chow *et al*, 2003). Infectious diseases are still a leading cause of death in Thailand (Rumakom *et al,* 2002; Rukumnuaykit, 2006). HIV and its complications was the leading cause of mortality among those age 25-44 years (Bureau of Policy and Strategy, 2002). Therefore, looking at HIV/AIDS separately from other infectious diseases should be useful in investigating disease trends.

Although causes of death are more accurately recorded in hospitals, there is still substantial room for improvement. For example, for persons living in southern Thailand over the six year period 1999-2004, of 6,885 deaths in hospitals from infectious disease excluding HIV/AIDS, 61.2% had a principal diagnosis recorded as "septicemia, unspecified" (ICD10: A41.9), which says little about the actual cause.

With this lack of information about the real causes of death both inside and outside hospitals, the aim of our study was to investigate and forecast regional and temporal patterns of deaths reported as infectious disease (including HIV/AIDS) in the 14 provinces of southern Thailand over the period 1999-2004. Using statistical models for time series counts in spatial regions to highlight unexplained data variation and deficiencies, such a study can assist health planners to improve the accuracy of the causes of death statistics.

MATERIALS AND METHODS

Mortality data from 1999 to 2004 in 14 provinces of southern Thailand were obtained from the Bureau of Policy and Strategy, Ministry of Public Health. For these data, the principal diagnosis and demographic information are given on death certificates that include sex, age, occupation, marital status, place of residence, and date, place, diagnosing officer and principal diagnosis. The principal diagnosis is coded using the International Classification of Diseases in its 10th revision (ICD10). Population denominators were obtained from the Population and Housing Census of Thailand in the year 2000 undertaken by the National Statistics Office of Thailand.

To simplify the effect of location of residence when calculating death rates, one or more contiguous districts in each province were grouped together to form "super-districts" containing populations of 200,000 on average (Table 1), where they are listed in order of geographical location from the northernmost to the southernmost in the region (keeping super-districts within the same province) with their 2000 census populations.

Since age was included as a demographic determinant, it was divided into three groups: below 5 years of age, 5 to 39 years and 40 and over. The number of deaths in each demographic group defined by age and/or gender and super-district of residence of the deceased was aggregated in intervals of two months: January-February, March-April, etc, giving six annual seasonal periods.

Incidence death rates per 1,000 persons for causes of death categories and per 100,000 persons for HIV/AIDS deaths in the demographic group resident in each super-district were calculated to analyze the levels and patterns of mortality.

Poisson and negative binomial lagged observation-driven regression models (Venables and Ripley, 1999) for mortality incidence were fitted to the data. Correlations with death rates in preceding periods and other demographic groups were incorporated into these models using autoregressive terms. The simplest model is based on linear regression taking the outcome variable as the death rate in a cell indexed by super-district and a two-month period, with super-district, season, and autoregressive terms as categorical determi-

nants. More complex models included further demographic components separating in-hospital and outside-hospital deaths, age group, and gender, together with corresponding autoregressive terms.

Incidence rates generally have positively skewed distributions, so we transformed them by taking logarithms. To handle zero counts we defined the outcome as

$$y = \ln\left(1 + \frac{Kn}{P}\right), \quad (1)$$

where n is the number of disease cases in the cell, P is the population at risk, and K is a specified constant. Suppose that N_{ijt} is a random variable denoting the reported number of mortality cases in a demographic group i, super-district j and two-month period t and n_{ijt} is the corresponding number observed. An observation-driven linear regression model with m lagged variables may be defined by the equation

$$Y_{ijt} = \mu + \alpha_i + \beta_j + \eta_s + \sum_{k=1}^{m} \gamma_k y_{ij,t-k} + \rho\, y_{ij,t-1}^{(\alpha)} + \delta\, y_{ij,t-1}^{(\beta)} + \varepsilon_{ijt}, \quad (2)$$

where $y_{ijt}^{(\alpha)}$ and $y_{ijt}^{(\beta)}$ denote the observed (transformed) incidence rates in all demographic groups other than i and in all super-districts other than j, respectively; Y_{ijt} is the outcome variable specified in Equation (1) and y_{ijt} the corresponding number observed, ε_{ijt} is comprises a set of zero-mean independent Gaussian random variables, and s = mod (t, 6). We assume $\alpha_1 = 0$, $\beta_1 = 0$ and $\eta_1 = 0$.

Davis *et al* (2003) suggested observation-driven generalized linear models (GLMs) for time series counts N_t based on the Poisson distribution with mean λ_t, where $\ln(\lambda_t)$ is expressed as an additive function of determinants and lagged observations on N_t. These models are not appropriate for disease epidemics because they express the mean of the process at time t as an exponential function of lagged observations on the same process and are thus numerically unstable when substantial variations occur. However, they become stable when the lagged observations are log-transformed incidence rates using Equation (1), and a suitable generalized linear model based on the Poisson distribution is

$$\ln(\lambda_{ijt}) = \ln(p_{ij}) + \mu + \alpha_i + \beta_j + \eta_s + \sum_{k=1}^{m} \gamma_k y_{ij,t-k} + \rho\, y_{ij,t-1}^{(\alpha)} + \delta\, y_{ij,t-1}^{(\beta)}, \quad (3)$$

where λ_{ijt} is the mean of N_{ijt}.

Poisson models for disease counts are often over-dispersed due to spatial or temporal clustering of cases, in which case the negative binomial distribution is more appropriate. This distribution has an additional parameter γ and takes the form

$$\text{Prob}[N_t = n] = \frac{\Gamma(n+\gamma)}{\Gamma(n+1)\Gamma(\gamma)} \left(\frac{\gamma}{\gamma+\lambda_t}\right)^{\gamma} \left(\frac{\lambda_t}{\gamma+\lambda_t}\right)^{n}, \quad (4)$$

The conditional expected value of N_t is λ_t as in the Poisson model, but the conditional variance is now $\lambda_t + \lambda_t^2/\gamma$ (see for example, Venables and Ripley, 1999). The parameter γ is inversely related to the over-dispersion, with the Poisson model being the limit as $\gamma \to \infty$.

We used maximum likelihood estimation to fit these GLMs. Deviance residuals (Venables and Ripley, 1999) can be plotted against normal scores with points close to a line with unit slope indicating that the fit is satisfactory.

It should be noted that, as in all time series regression models that include lagged observations, the regression coefficients reflect the effects of the predictor variables on the outcomes after these outcomes have been adjusted for the autocorrelations, rather than the direct effects of the predictors on the outcomes.

All analyses in this study were undertaken using R software (R Development Core Team, 2007).

RESULTS

According to records from death certificates, 250,175 deaths were recorded among

Table 1
Populations (2000 census) of super-districts in southern Thailand.

Super-district	Code	Population
Chumphon North	1	246,279
Chumphon South	2	199,927
Ranong	3	161,210
Surat Thani Northwest	4	243,238
Surat Thani City	5	241,373
Surat Thani East	6	168,801
Surat Thani South	7	215,998
Phang-nga	8	234,188
Nakhon Si Thammarat North	9	176,496
Nakhon Si Thammarat Northwest	10	163,187
Nakhon Si Thammarat North Coast	11	212,903
Nakhon Si Thammarat Central	12	164,324
Nakhon Si Thammarat City	13	267,560
Nakhon Si Thammarat South Coast	14	238,059
Nakhon Si Thammarat Southwest	15	297,282
Krabi North	16	130,564
Krabi South	17	205,646
Phuket	18	249,446
Trang North	19	184,815
Trang City	20	190,340
Trang South	21	219,955
Pattalung City	22	251,029
Pattalung West	23	247,442
Songkhla North Coast	24	149,706
Songkhla West	25	205,607
Songkhla City	26	162,700
Hat Yai	27	324,596
Songkhla Southeast Coast	28	177,396
Songkhla South	29	235,657
Satun	30	247,875
Pattani City-West	31	253,567
Pattani Central	32	219,932
Pattani East	33	122,486
Yala City	34	228,042
Yala South	35	187,495
Narathiwat Coast	36	250,997
Narathiwat Central	37	234,441
Narathiwat Southwest	38	176,912

residents of 14 southern Thai provinces for the calendar years 1999 to 2004, corresponding to an average annual death rate of 5.16 per 1000 based the total population of 8.087 million residents according to the 2000 Population and Housing Census. Table 2 shows the proportions of deaths in hospitals by year, where it can be seen that a jump in the percentage of hospital deaths occurred in 2003.

Table 2
Percentages of hospital deaths in southern Thailand by year.

Year	Total	In hospital	Percent
1999	37,817	8,160	21.6
2000	41,111	7,607	18.5
2001	41,136	8,211	20.0
2002	42,114	9,266	22.0
2003	43,580	12,163	27.9
2004	44,417	13,648	30.7
Total	250,175	59,055	23.6

Based on the ICD10 disease classification system and WHO recommendations (Mathers *et al,* 2002), we grouped causes of death into eight categories: (1) heart diseases (I00-I99), (2) infectious diseases other than HIV/AIDS (A00-A19, A25-B99, G00, G03-G04, N70-N73), (3) respiratory diseases (J00-J98), (4) HIV/AIDS (A20-A24), (5) cancer (C00-C97), (6) injuries (V00-X99), (7) digestive system diseases (K00-92), and (8) other causes. Note that since 1999 pneumonia has been classified as a respiratory disease rather than an infectious disease.

Table 3 shows the percentages of in-hospital deaths for each of the eight groups of diseases. The percentages of hospital deaths attributed to the digestive system, respiratory, heart, and infectious diseases other than HIV/AIDS were all between 40 and 50%, and were around 30% for HIV/AIDS and cancer, and less than 20% of deaths were from injuries and other causes.

For 59,619 (53.3%) of the non-hospital deaths from other causes, the cause of death given on the death certificate was “senility (senescence)”. This compares with only 2.5% of hospital deaths from other causes.

For hospital deaths only, Fig 1 shows the

Table 3
Percentages of hospital deaths in southern Thailand by reported cause.

Cause of death	Total	In hospital	Percent
Heart disease	27,168	11,672	43.0
Infectious diseases	15,007	6,885	45.9
Respiratory diseases	16,021	6,445	40.2
HIV/AIDS	7,546	2,392	31.7
Cancer	20,850	5,969	28.6
Injuries	47,180	8,371	17.7
Digestive system diseases	4,582	2,196	47.9
All other causes	111,821	15,125	13.5
Total	250,175	59,055	23.6

distribution of the causes of mortality by super-district. The chart shows a broad trend of decreasing in-hospital mortality with increasing distance south (away from Bangkok). The peaks in the chart correspond to the super-districts containing urban districts, notably the island of Phuket (18) and the districts of Songkhla City (26) and Hat Yai (27) in Songkhla Province. The lower troughs correspond to the central districts of Pattani Province (comprising many rural villages) and most of Narathiwat Province.

The causes of death due to infectious disease were divided into 2 groups: deaths due to HIV/AIDS and deaths due to infectious diseases other than HIV/AIDS.

The first group comprises of HIV/AIDS deaths both in and outside the hospital. The principal diagnosis was specific in each case. We excluded persons below aged 15 and separated the data cells by gender, but not by age group.

For the second group, comprising infectious disease deaths excluding HIV/AIDS, we separated the data cells according to whether or not the principal diagnosis was unspecified septicemia, but only considered in-hospital deaths, given that the percentage of deaths so diagnosed outside hospital was less than 30%, compared with more than 60% in the hospital. In this analysis we also separated the data by gender, but restricted analysis to those age 40 or older, because the number of deaths due to "unspecified septicemia" was much less frequent in persons in younger age groups.

HIV/AIDS mortality

Fig 2 shows the HIV/AIDS mortality rate per 100,000 residents in super-districts inside hospitals (inner bands) and outside hospitals (outer bands) for males (right panel) and females (left panel). The rates for males are approximately double those for females. The pattern for hospital mortality for HIV/AIDS was similar to that shown for all disease groups in Fig 1, namely, decreased mortality as one moves south with peaks in Phuket and Songkhla City (but not Hat Yai). Nakhon Si Thammarat had a particularly high outside-hospital mortality rate for this disease.

Table 4 (super-district effects) and Fig 3 (other effects and residuals plot) show the results of fitting a negative binomial GLM. The model is defined by equations (1), (3) and (4) with $m = 3$ autoregressive lag terms, and taking gender as the demographic group with a minor modification, namely that we allow different parameters ρ_1 and ρ_2 for each gender. We separated cells according to whether the death occurred inside or outside the hospital

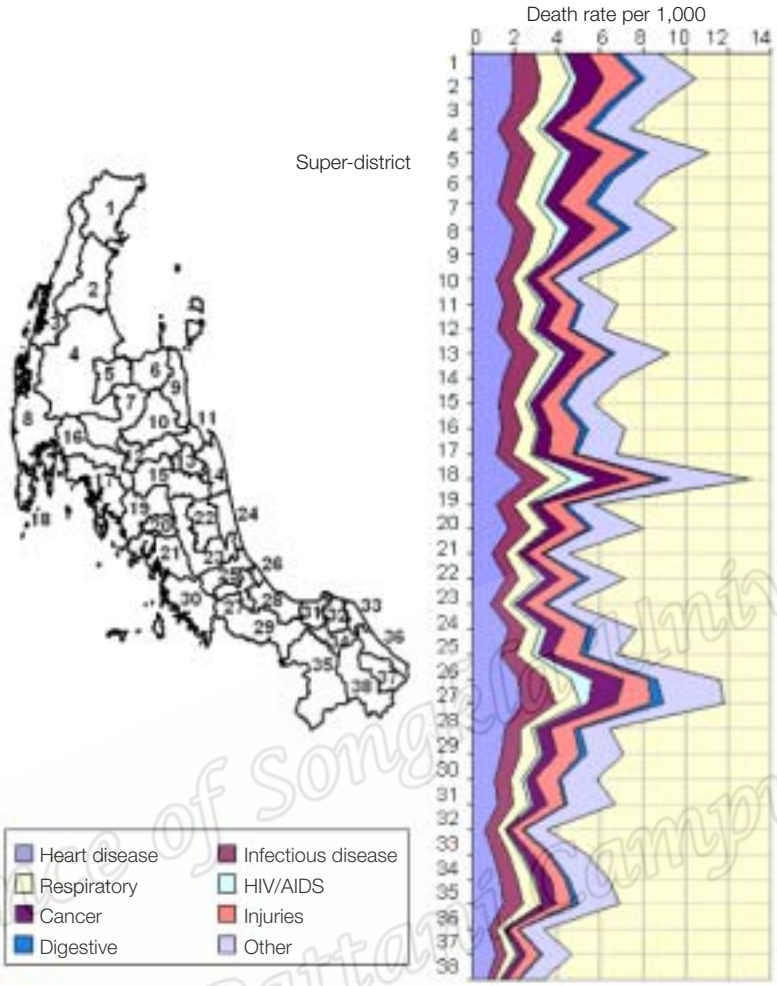


Fig 1–Distribution of hospital death rates by residence location of deceased.

and included an additional parameter in the model for this effect. We also chose K = 500,000, because substantially lower values for K give autoregressive coefficients that have a sum greater than 1 (unstable models).

The residuals plot indicates that the model fits extremely well. Although the coefficients for the lagged terms relating the death rate in a super-district to the rates in preceding periods in the same super-district low (0.15, 0.14 and 0.09 for lags 1, 2 and 3, respectively) the coefficient of the lagged term from other super-districts was more substantial (0.49), and their sum was 0.98, with the result that the correlation-adjusted outcome is close to the relative increase in mortality rather than its absolute level. The largest coefficient corresponds to the gender effect, thus indicating that female death rates were not only substantially lower than male rates (as seen in Fig 2) but also increased to a lesser extent than male rates.

Table 5 shows the results after fitting negative binomial GLMs to the same data with the autoregressive terms excluded. These results may be used to compare the absolute (rather than autocorrelation-adjusted) HIV/AIDS death rates with respect to the risk factors. Since negative binomial GLMs are not hierarchical, in the sense that the residual de-

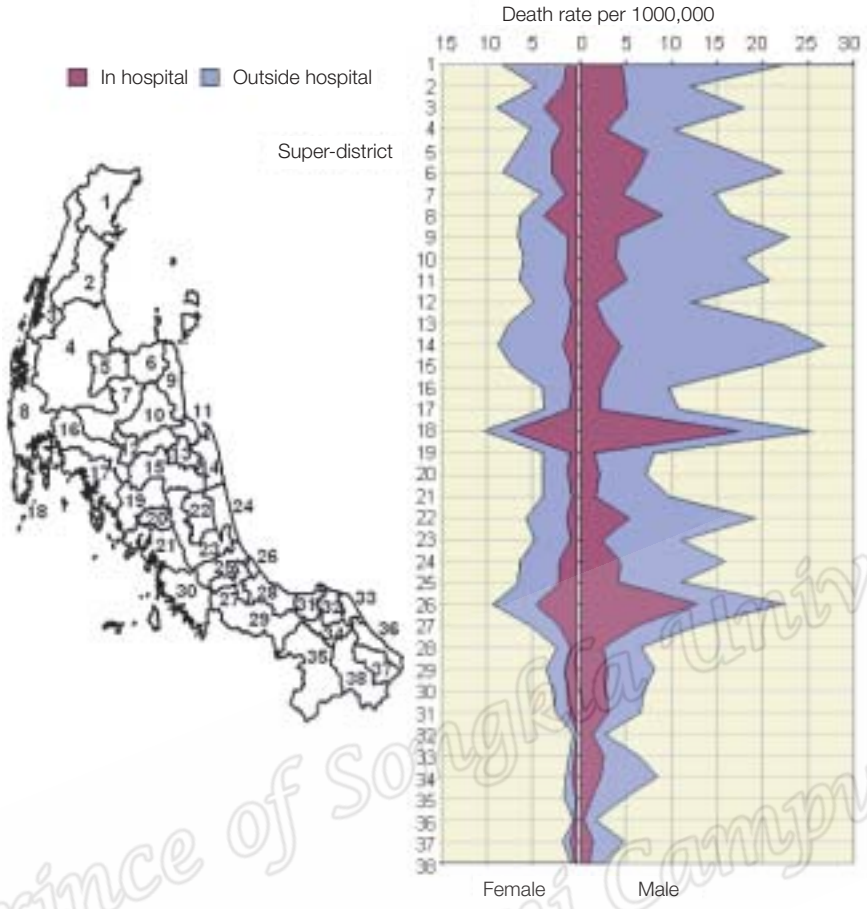


Fig 2–Distribution of death rates for HIV/AIDS by gender, place of death (in or outside hospital) and residence location.

viance decreases when additional parameters are included, unless the dispersion parameter is held constant, Table 5 also includes the results obtained by fixing the dispersion parameter at its value estimated by the model containing all the auto-regressive parameters. It shows that the fitted coefficients change only slightly, but the residual deviance is increased substantially, as expected.

Fig 4 shows the forecasts based on the full model (Table 4 and Fig 3).The inclusion of the autoregressive time series parameters enables the forecasts to make use of the most recent available information, and thus these forecasts can track the paths of the epidemic reasonably well. The graph clearly shows that reported HIV/AIDS mortality outside the hospital declined after peaking around the middle of 2003, with a similar but less pronounced pattern for in-hospital mortality among males.

Given that overall in-hospital death rates continued to increase in 2004 (Table 2) we examined trends for other disease groups.

Infectious disease mortality (excluding HIV/AIDS)

We fitted the negative binomial GLM specified in Equations (1), (3) and (4) to non-HIV/AIDS infectious disease hospital death data, with m = 3 lags, with no demographic subgroups. We separated cells according to whether or not the death had "unspecified septicemia" as its principal cause and included an additional parameter in the model for this effect. We also chose K to be

Table 4
Regression coefficients and standard errors for super-district effects in negative binomial GLM fitted to HIV/AIDS mortality in southern Thailand.

Code	Coefficient	SE	Code	Coefficient	SE	Code	Coefficient	SE	Code	Coefficient	SE
1	0	-	11	-0.122	0.103	21	-0.491	0.138	31	-0.722	0.129
2	-0.383	0.143	12	-0.333	0.214	22	-0.170	0.105	32	-1.467	0.222
3	-0.046	0.205	13	-0.013	0.209	23	-0.394	0.114	33	-0.823	0.353
4	-0.430	0.113	14	-0.014	0.102	24	-0.230	0.226	34	-0.758	0.143
5	-0.193	0.102	15	-0.127	0.112	25	-0.272	0.140	35	-0.955	0.232
6	-0.025	0.182	16	-0.464	0.308	26	0.045	0.182	36	-1.826	0.223
7	-0.348	0.130	17	-0.511	0.157	27	-0.373	0.153	37	-0.910	0.160
8	-0.142	0.106	18	0.163	0.096	28	-0.753	0.209	38	-1.361	0.275
9	-0.081	0.125	19	-0.523	0.188	29	-0.598	0.128			
10	-0.172	0.177	20	-0.598	0.168	30	-0.676	0.130	*K*	500,000	

Predictor		Coeff.	SE
Constant		-0.848	0.965
Season:	Jan - Feb	0	-
	Mar - Apr	0.021	0.053
	May - Jun	0.079	0.053
	Jul - Aug	-0.030	0.052
	Sep - Oct	-0.063	0.052
	Nov - Dec	-0.184	0.053
Female gender		-0.583	0.317
Inside hospital		-0.105	0.040
Autoregressive	Lag 1	0.152	0.014
	Lag 2	0.143	0.014
	Lag 3	0.086	0.014
Other districts Lag 1		0.490	0.433
Female to male Lag 1		0.010	0.397
Male to female Lag 1		0.102	0.351
Dispersion parameter		5.041	0.473

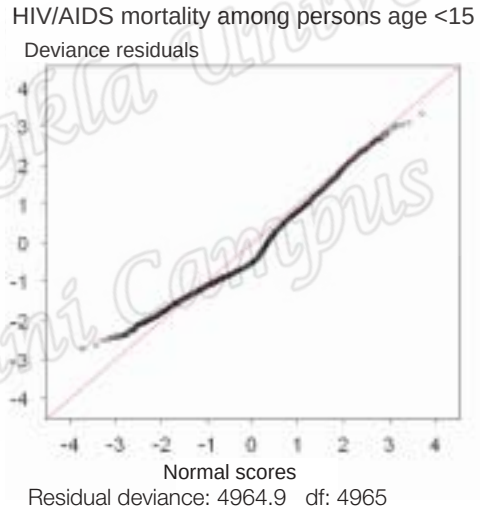


Fig 3–Regression coefficients for other parameters and deviance residuals plot for HIV/AIDS mortality.

1,000,000 because substantially lower values of *K* give autoregressive coefficients that add up to more than 1. The results are shown in Table 6 and Fig 5.

The model fit well. It showed that neither unspecified septicemia reported causes nor season of the year were related to infectious disease mortality. The highest outlier in the residuals plot was 5.4 for just 7 deaths from septicemia in southwest Surat Thani Province in November - December 2000. Fig 5 shows the forecasts based on the model for aggregated hospital deaths in this age group from infectious diseases from all 14 provinces.

Fig 6 shows the forecasts based on the full model (Table 6 and Fig 5) applied to aggregated data for hospital septicemia deaths among those age 40 or over. The graph shows that unspecified septicemia as a cause of death sharply increased at the end of 2002, whereas mortality from other hospital infectious diseases remained relatively stable.

Table 5
Regression coefficients for season, gender and in-hospital location after fitting models with super-districts also included but autoregressive terms excluded.

Model	Dispersion parameter estimated		Dispersion parameter fixed at 5.041	
Predictor	Coefficient	SE	Coefficient	SE
Constant	1.729	0.095	1.750	0.080
Season: Jan - Feb	0	-	0	-
Mar - Apr	0.056	0.061	0.050	0.059
May - Jun	0.176	0.060	0.170	0.058
Jul - Aug	0.072	0.058	0.062	0.056
Sep - Oct	0.052	0.059	0.042	0.057
Nov - Dec	-0.089	0.060	-0.096	0.058
Female gender	-1.028	0.035	-1.023	0.035
Inside hospital	-0.815	0.035	-0.800	0.034
Dispersion parameter	2.105	0.120	5.041	-
Residual deviance	4897.3		6054.8	
df	4971		4971	

Table 6
Regression coefficients and standard errors for super-district effects in negative binomial GLM fitted to age <40 hospital infectious disease deaths in southern Thailand.

Code	Coefficient	SE	Code	Coefficient	SE	Code	Coefficient	SE	Code	Coefficient	SE
1	0	-	11	0.192	0.127	21	-0.368	0.156	31	-0.293	0.149
2	0.247	0.131	12	-0.273	0.161	22	-0.652	0.151	32	-0.376	0.163
3	0.296	0.140	13	-0.167	0.154	23	-0.543	0.159	33	-0.279	0.180
4	-0.112	0.138	14	-0.129	0.135	24	-0.218	0.153	34	-0.069	0.143
5	0.161	0.131	15	-0.408	0.144	25	-0.248	0.150	35	0.050	0.149
6	-0.004	0.147	16	0.006	0.168	26	0.187	0.139	36	-1.167	0.210
7	-0.131	0.145	17	-0.134	0.156	27	0.457	0.121	37	-0.674	0.178
8	-0.084	0.138	18	0.262	0.130	28	-0.138	0.152	38	-0.983	0.233
9	-0.237	0.146	19	-0.086	0.152	29	-0.020	0.139			
10	-0.052	0.145	20	-0.017	0.142	30	-0.245	0.149	*K*	1,000,000	

DISCUSSION

We found that the overall hospital mortality rate in southern Thailand remained stable during the four years from 1999 to 2002 at just over 20%, and then increased sharply in 2003 to 28%, with a further increase to 31% in 2004. This jump could be a consequence of the universal health coverage ("30 baht") system, which became fully operational in 2003 after its introduction in October 2001 (International Labour Office, 2004). In-hospital mortality had a specific geographical pattern in southern Thailand over this six-year period, decreasing from north to south, away from Bangkok, and with peaks in urban areas served by large district hospitals where people could access health care more easily than in rural areas.

The geographic distribution of HIV/AIDS

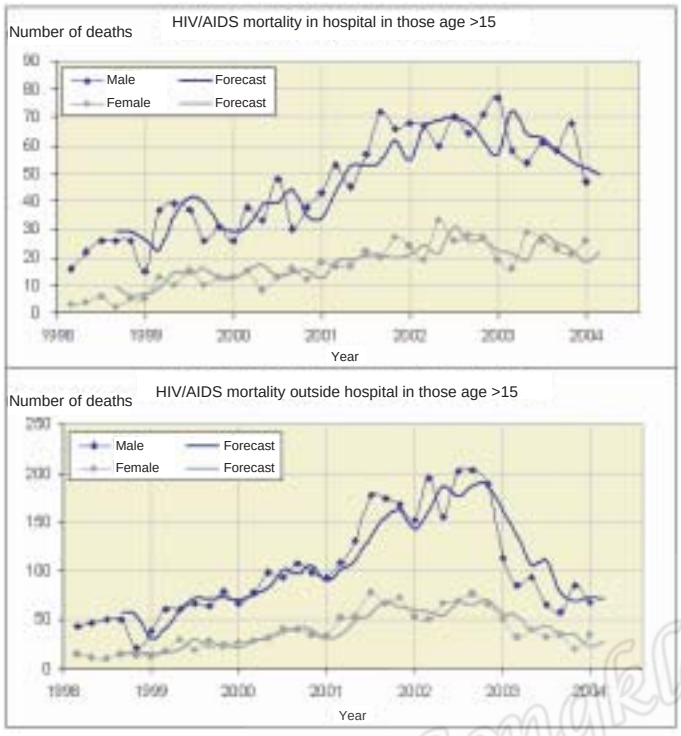
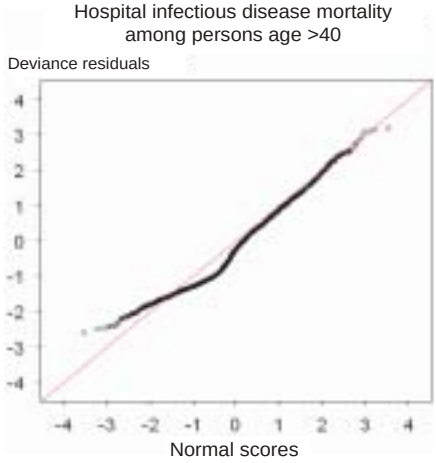


Fig 4–HIV/AIDS mortality forecasts based on past observations in two-month periods for persons age ≥15.

related mortality both inside and outside the hospital resembled the overall pattern with a decrease from the north to the south. In-hospital deaths showed peaks in urban districts (particularly Phuket Island and Songkhla City). The four border provinces (Satun, Pattani, Yala and Narathiwat) had the lowest overall HIV/AIDS mortality rates. These areas also had different demographics, being over 70% Muslim, whereas the other ten provinces were over 70% Buddhist (National Statistical Office, 2002).

Other studies have used statistical models for time series counts in spatial regions to account for unexplained data variation, spatial correlation and deficiencies (Rutaremwa, 2000; Congdon, 2006; Lix *et al,* 2006). Poisson models and Generalized Linear Models with Generalized Estimation Equations (GLM with GEE) have been described by Congdon (2000)

Predictor		Coefficent	SE
Constant		-1.891	0.146
Season: Jan - Feb		0	-
Mar - Apr		-0.022	0.067
May - Jun		-0.028	0.067
Jul - Aug		0.007	0.064
Sep - Oct		-0.263	0.067
Nov - Dec		-0.174	0.066
Diagnosis: Other cause		0	-
Unspecified septicemia		0.089	0.050
Autoregressive	Lag 1	0.077	0.014
	Lag 2	0.014	0.013
	Lag 3	0.038	0.013
Other districts	Lag 1	0.814	0.046
Dispersion parameter		8.300	1.400



Residual deviance: 2765.2 df: 2460

Fig 5–Coefficients for other model parameters and deviance residuals plot for hospital infectious disease mortality.

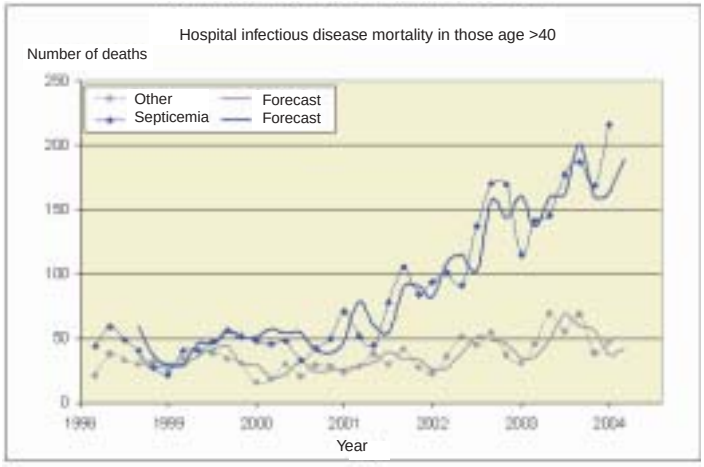


Fig 6–Hospital infectious disease mortality forecasts based on past observations in two-month periods for persons age ≥40.

and Lix *et al* (2006). In our study, the overdispersion violated the Poisson model assumption, so a negative binomial GLM was used instead. Spatial-time series modeling of the pattern of HIV/AIDS mortality revealed reported incidence rates for males were approximately double those for females and mortality more than doubled in the four years from 1999 to 2003, then declined almost as much in the next two years. This finding is similar to that reported by Rumakom *et al* (2002). Reported HIV/AIDS mortality outside hospitals declined after peaking in the middle of 2003 but less so for in-hospital mortality among males. The HIV/AIDS mortality trends agree with the projections for HIV/AIDS in Thailand 2000-2020 (Thai Working Group on HIV/AIDS Projection, 2001). Even though HIV/AIDS mortality rates are known to be underreported (Rumakom *et al,* 2002) this did not have an appreciable effect on overall mortality.

In regards to mortality due to other infectious diseases, we evaluated those who died in the hospital due to unspecified septicemia or other causes in those age 40 and over. Statistic regarding deaths from infectious disease outside the hospital in Thailand are known to be unreliable (Chuprapawan *et al,* 2003) so only in-hospital deaths were considered. Spatial-time series modeling revealed the reported incidence rate for each diagnostic class was stable from 1999 until the end of 2002, when a sharp increase occurred in septicemia mortality. Septicemia itself is not the cause of death, but a symptom. There are many causes of death leading to septicemia. A study of risk factors for septicemia mortality in older adults in the United States reported that septicemia mortality was associated with a history of diabetes or cancer (Salive *et al,* 1993).

Our study raises questions about the real causes of death attributed to unspecified septicemia and to HIV/AIDS in southern Thailand. Further studies are needed to answer these questions.

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