Verifying causes of death in Thailand: rationale & methods for empirical investigation

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Abstract

Background

Cause-specific mortality statistics by age and sex are primary evidence for epidemiological research and health policy. Annual mortality statistics from vital registration systems in Thailand are of limited utility on account of high proportions of deaths (~40%) registered with unknown or non-specific causes. This paper reports the rationale, methods and broad results from a comprehensive study to verify registered causes in Thailand.

Methods

A nationally representative sample of 11984 deaths was selected using a multistage stratified cluster sampling approach, distributed across 28 districts located in 9 provinces of Thailand. Registered causes were verified through medical record review for deaths in hospitals, and standard verbal autopsy procedures for deaths outside hospitals, the results of which were used to measure validity and reliability of registration data. Study findings were used to develop descriptive estimates of cause-specific mortality by age and sex in Thailand.

Results

Causes of death were verified for a total of 9644 deaths in the study sample, comprising of 3316 deaths in hospitals, and 6328 deaths outside hospitals. Field studies yielded specific diagnoses in almost all deaths in the sample originally assigned an ill-defined cause at registration. Study findings suggest that the leading causes of death in Thailand among males are stroke (9.4%), transport accidents (8.1%), HIV/AIDS (7.9%), ischaemic heart diseases (6.4%) and chronic obstructive lung diseases (5.7%). Among females, the leading causes are stroke (11.3%), diabetes (8%), ischaemic heart disease (7.5%), HIV/AIDS (5.7%), and renal diseases (4%).

Conclusions

Empirical investigation of registered causes of death in the study sample yielded adequate information to enable estimation of cause-specific mortality patterns in Thailand. These findings will inform burden of disease estimation and economic evaluation of health policy choices in the country. The development and implementation of research methods in this study will contribute to improvements in the quality of annual mortality statistics in Thailand. Similar research is recommended for other countries where the quality of mortality statistics is poor.
Introduction

Reliable information on levels of mortality and leading causes of death is essential to guide priorities for resource allocation within the health sector in order to increase longevity and improve quality of life. In combination with measures of disease or condition- specific morbidity, these data are also useful in monitoring the epidemiological impact of specific health interventions or broader health programs, as well as their cost-effectiveness, applying the burden of disease approach.[1] However, such evidence-based health development strategies are feasible only when reliable and timely epidemiological data are available for countries at national and sub-national levels. Mortality statistics are fundamental to such priority setting approaches to public health policy and planning. Recent assessments of global health statistics have suggested that only about a third of all countries have functional national civil registration systems, which are the optimal source for mortality data. [2] Much needs to be done to rectify this situation through strategic approaches to improve the availability and quality of mortality statistics. [3]

Thailand is among a group comprising another one third of the world’s countries that produce population level mortality statistics from civil registration, but which are of limited utility owing to problems with data quality.[4] These limitations severely hinder the potential use of these data for epidemiological assessments or health development strategies. Over the past two decades, Thailand has introduced several reforms to improve the national civil registration and vital statistics systems, which have been described in detail elsewhere. [5] This paper is the first in a series of articles based on a comprehensive field research project conducted in Thailand during 2005-2008 to verify and evaluate the quality of cause of death attribution in a nationally representative sample of nearly 10,000 deaths that occurred in 2005. The
study was designed to investigate the reliability of cause attribution within two broad categories; deaths that occurred in hospitals, and deaths that occurred at home or elsewhere.

Starting with an overview of the background, rationale and objectives of the project, this first paper goes on to describe the overall project design, sampling strategy, and the broad data collection methods employed in the two arms of study. The next two articles describe the findings and their implications, with supporting information on specific methodological issues that govern cause of death attribution in the two different settings. A fourth article applies the results from the field studies to adjust identified biases in registration data and derive an overall estimate of cause-specific mortality for Thailand in 2005. These adjusted mortality statistics form the primary evidence base for burden of disease assessment, economic evaluation, and the identification of national health policy priorities in Thailand.

A guiding principle for the study was to align its goals and methods with ongoing and planned reforms to data collection systems designed to improve the quality of cause of death statistics in Thailand, such that its implementation and findings would catalyse such developments. To our knowledge, no comparable study of cause of death reliability has been attempted in a developing country. This research could serve as a model for similar investigations into the quality of mortality statistics in other developing countries.

Civil registration and vital statistics in Thailand

Birth and death registration in Thailand commenced in 1916, supplemented by the introduction of the household register in 1956, a copy of which is issued to the
household as proof of civil status. [6] In 1991, a revised Civil Registration Act nominated the Bureau of Registration Administration, Ministry of Interior as the central agency responsible for civil registration through a network of offices at local, district, municipality and provincial level, and stipulated the requirement for death notification within 24 hours.[7] Causes of deaths in hospitals are notified using a Thai version of the standard International Form of Medical Certificate of Causes of Death, with an additional column in which the certifying physician records one cause in Thai language to be used for registration purposes. It is this cause which is entered in the national registration electronic database. For unnatural (ie. injury) deaths, causes are certified following forensic investigation by a physician, using a similar process. For deaths outside hospitals (about 65% of all deaths), local registrars enquire about the cause of death from family members, supported wherever possible by documentary evidence from previous hospitalization or medical attention during the illness preceding death. Local registrars then record the reported cause of death in Thai. After computerization, a complete extract of the database (with a single cause in Thai for each death) is transferred to the Ministry of Public Health, where the causes are coded according to ICD-10, and tabulated by age, sex and cause for subsequent dissemination and analysis. [5]

**Characteristics of Thai death registration data**

Thailand is one of the few Asian countries that has been submitting data on a regular basis to the World Health Organization since 1950. [2] A recent assessment of mortality statistics in Thailand identified that the sound legal framework and institutional capacity for implementation are strengths that result in regular and timely data. [5] Computerization of civil registration over the past two decades has vastly
improved efficiency of registration services as well as compilation of statistics. However, mortality data are limited by the incompleteness of death registration, and more so by the high proportion of ill-defined causes of death.[5] These limitations also preclude the application of detailed technical criteria to assess additional aspects of data quality, in terms of validity and reliability.[8]

In recent years, a gradual increase in the number of registered deaths has been noted, from 264,350 in 1991 to 395,374 in 2005.[9] This increase is attributable to various factors, including the 1991 revisions to the legal framework, administrative reforms to registration procedures, and computerised compilation of data, all of which came into effect over the period up to 1996. [7] However, the current level of completeness of adult death registration remains a subject of ongoing research, with the application of different demographic methods yielding completeness estimates ranging from 80-95%.[10-12] While there is general consensus regarding the extent (approximately 50%) of under-registration of child deaths, [5,7,10,13] the overall completeness of death registration in Thailand remains uncertain.

In terms of recorded causes of death, about 40% are routinely coded to symptoms, signs and ill-defined conditions. [14] The bulk of these ill-defined deaths occur outside health facilities, although in-hospital cause of death attribution is also problematic, arising from the process for recording the single cause for registration in Thai language. Hence, the validity of registered causes of death is questionable, greatly limiting their public health utility. A study conducted by Boonthai et al found low validity of diagnoses on death certificates issued in a sample of hospital deaths during the period 1967-1984. [15] Choprapawon and colleagues later conducted a detailed verification of 47,632 deaths that occurred in 15 provinces in Thailand during
1997-1999, using a combination of verbal autopsy interviews and medical record review, as applicable.[7] Their findings indicated poor validity of registered causes for deaths in hospitals as well as for deaths occurring at home.

**Rationale for current research**

In view of the existing problems with cause of death ascertainment, further reforms to the Thai death registration system were pilot tested in 18 provinces during 2001-2003. Direct support from the medical profession was sought to certify causes for non-hospital deaths, using information from previous contact with health services and/or limited verbal autopsy interviews.[7] However, potential medico-legal implications from attributing causes without having attended to the deceased restricted the implementation of this reform by the medical profession.[5]

Given these circumstances, the Thai Ministry of Public Health proposed a long term strategy to improve cause of death statistics using two approaches. [6] For deaths in hospitals, capacity should be strengthened to improve accuracy of medical certification of cause of death, and selection and coding of underlying causes of death according to ICD principles. For home deaths, local health personnel should be trained in the use of available medical records and verbal autopsy procedures to improve accuracy in the recording of causes of death at registration. As an interim measure, the Thai Ministry of Health identified the need to conduct research studies to verify causes in a national sample of registered deaths every five years, and to use this research to derive periodic estimates of cause-specific mortality patterns in order to monitor health status and inform health policy and planning in Thailand. [5,16] This series of four papers describes the findings of the first such comprehensive investigation of causes of death in Thailand. At the same time, the research team has
been collaborating on a broader study to estimate the relative cost effectiveness of various intervention choices in Thailand, for which corrected age-sex-cause-specific death rates were required to more reliably estimate the burden of disease applicable to each intervention.[18]

**Study objectives**

The overall goal of the study was to derive the best estimate of cause specific mortality patterns in Thailand for 2005. Specific objectives were to:

1. ascertain, certify and code underlying causes of death according to ICD-10 principles for a sample of deaths that had occurred in hospital, through medical record review;
2. develop, test and implement standard verbal autopsy procedures (adapted to the Thai setting) for ascertainment of the probable underlying cause for deaths in the study sample that had occurred outside hospitals;
3. utilise findings from this research to adjust vital registration data, and derive ‘best’ estimates of age-sex-cause-specific mortality rates in Thailand for 2005; and
4. build capacity among Thai health professionals (physicians, paramedical staff, biostatisticians and epidemiologists) to critically assess vital statistics data and improve the quality of causes of death recorded at registration in Thailand.

**Methods**

**Study design**

A cross-sectional study was designed to verify causes for a nationally representative multi-stage stratified cluster sample of deaths that occurred in Thailand during 2005.
The sample was drawn from the mortality database maintained by the Bureau of Policy and Strategy, Ministry of Public Health. [9] The sampling unit was a registered death of a Thai citizen, identified by assigned national identification numbers, who was a permanent resident in one of the sample provinces included in the study. The cause(s) for each study death were to be investigated through verbal autopsy (VA). For study deaths that had occurred in a hospital, relevant medical records were accessed and reviewed to derive reference diagnoses. These reference diagnoses were used to validate and correct registered causes in the study sample, as well as to assess the validation characteristics of VA procedures for individual causes of death. For deaths that had occurred at home, VA diagnoses were used to estimate cause-specific mortality patterns, with appropriate adjustments for biases for individual causes of death, as observed from the VA validation component. Proportionate mortality distributions for health facility deaths in the study sample were used to estimate mortality patterns for all deaths in hospitals in Thailand (about 140,000 deaths each year) (see Figure 3). Similarly, VA-based proportionate mortality distributions for deaths outside hospitals were used to estimate mortality patterns for such deaths for 2005 (about 254,000 deaths). The overall proportionate (by cause) mortality estimates from the two settings were then applied to the national estimate of total mortality derived from demographic analyses to obtain corrected national cause specific mortality estimates by age and sex for Thailand in 2005.

**Issues in determining sample size**

Several considerations influence sample size estimation for a study of this nature. While statistical considerations are paramount when computing sample size, the ultimate choice of such parameters is guided by available financial and human resources, as well as time constraints. Also, epidemiological considerations influence
the inclusion of important causes of death into the study. Such logistical and epidemiological considerations usually limit the number of causes of interest to a selection of leading causes of death.

In this study, generalizability of findings is essential to accomplish the overall objective to derive cause-specific mortality estimates for Thailand. Intuitively, a close fit between the proportionate distributions of causes of death in the registration data and the study sample would support generalizability. The twenty leading causes of death in the Thai registration data (based on the WHO Mortality Tabulation List 1 [17]) accounted for more than 85% of all deaths, including 38.2% from the leading registered cause of death, ‘Symptoms, signs and ill-defined conditions’. Therefore, we chose a sample of deaths that matched the proportionate distribution for the twenty leading causes in the registration data.

The proportion of deaths from the twenty-first leading cause of death in the Thai registration data was 0.0118. We assumed that the proportionate distribution by cause in a random sample of deaths adequate to measure the proportion of deaths from this twenty-first leading cause (within defined statistical parameters of error and significance) is likely to match the proportionate distribution for the twenty leading causes of death in the sampling frame. Therefore, we used this proportion for the twenty-first leading cause to compute the study sample size (n) as follows:

\[ n = \frac{Z_{\alpha/2}^2 \pi(1 - \pi)}{d^2}, \]

where \( \pi = 0.0118 \), within a selected margin of error \( d = 0.0025\% \), at the 95% level of confidence. This suggested that a random sample of 7168 deaths would be required to
accurately measure the proportion of the twenty-first leading cause in registration data within the given margin of error and level of confidence, based on prior information as to the proportion of interest. Further, since this sample was designed to be implemented in clusters for logistical and operational reasons, a design effect of 1.4 was applied, yielding an overall sample size of just over 10,000 deaths (10,035). [19-20]

**Sampling plan**

The nationally representative study sample was selected from the national death registration database using a multi-stage stratified clustered approach. At the first stage, Thailand was stratified into four broad regions – North-east, North, Central, and South - as well as Bangkok, with the total sample of 10,000 deaths being distributed across regions according to the proportion of deaths from each region in the national death registration data. Each of the four regional samples were inflated by 15%, and by 50% for Bangkok, to account for potential losses to follow up as suggested by the pilot study for this research, and earlier research in Bangkok.[7] Subsequently, in each of the four broad regions, provinces were ordered according to numbers of registered deaths in 2005, and divided into two strata at the 50th percentile. One province was randomly selected from each stratum, leading to two study provinces from each of the four broad regions. The adjusted (inflated) regional sample was then distributed between the two provinces proportionate to the number of deaths registered in 2005. Figure 1 shows the geographical distribution of the study provinces in Thailand.

[Figure 1 here]

In each study province, districts were ranked according to the number of registered deaths in 2005, and similarly divided into two strata at the 50th percentile. In order to
ensure representation of predominantly urban or rural communities as well as differential access to health facilities, districts within the provincial study sample were selected according to probability proportionate to size. In each stratum, a district was randomly selected at first, and the stratum specific sample was proportionately allocated to the selected district according to probability proportionate to number of deaths registered in 2005. Additional districts were selected one at a time with similar allocation of the study sample, cumulating the sample across selected districts until the province-stratum sample was attained. Within each selected district, the study deaths were randomly selected without replacement from all deaths registered during 2005.

For Bangkok, the study sample was distributed across the inner, middle and outer concentric zones of the Bangkok Metropolitan Area, and one district was randomly selected from each zone for inclusion in the study. The district specific samples were determined according to probability proportionate to size, and within each district, the study sample was selected without replacement. Based on this strategy, a total of 11,984 deaths were selected into the study, distributed across 25 districts located in eight provinces from among the four broad regions of Thailand, and 3 districts from Bangkok.

**Data collection and processing**

For each sampled death, relevant information on the age, sex and identity of the deceased, date of death, as well as the address and the cause of death recorded at registration (the VR cause of death) was extracted from the national death registration database for 2005. Subsequently, an initial visit was undertaken to the households of each of the deceased, to

- confirm the address and the place of death of the deceased;
• set up an appointment for a verbal autopsy enquiry into the cause of death; and
• in case the death had occurred in a health facility, obtain informed consent to
  access medical records for ascertaining the cause of death

Subsequent data collection proceeded as follows:

1. for deaths in health facilities, cause of death ascertainment was based on a
   review of medical records (the MR cause of death), as well as a second,
   independent cause of death ascertainment based on verbal autopsy
   procedures (the VA cause of death)\textsuperscript{1}, and

2. for deaths at home, cause of death ascertainment was based on verbal
   autopsy (VA cause of death).

Detailed data collection procedures, relevant training support, data processing and
management protocols are described in the separate articles for each arm of the study,
along with key findings and their implications.\textsuperscript{[21-23]} A detailed quality control
mechanism was implemented to ensure accuracy in the process of selection and
coding of underlying causes of death (see Figure 2). Measures were instituted to
detect and correct errors in this process from a range of potential sources, and
summary indices were developed to assess the overall quality of cause of death
certification and ICD coding from either medical records review or verbal autopsy
questionnaires.

[Figure 2 here]

Underlying causes of death were derived for each death in the sample, and classified
according to the Tenth Revision of the International Classification of Diseases and
Health Related Problems (ICD-10).\textsuperscript{[17]} For deaths in health facilities, underlying

\textsuperscript{1} In a sub sample of 2232 hospital deaths, a detailed audit procedure was also carried out to assess the
quality of information recorded on medical certificates of cause of death. This information will be used
subsequently to improve certification practices in Thailand.
causes of death were available from three sources: the vital registration (VR) diagnosis, the medical record (MR) diagnosis, and the verbal autopsy (VA) diagnosis. For deaths outside health facilities, two sources were available; the VR and the VA diagnoses. Underlying causes were then aggregated to the Mortality Tabulation List 1 of ICD-10, consisting of 103 categories. All subsequent descriptive and comparative analyses were conducted using these aggregated data.

**Data analysis**

Figure 3 describes the different elements of data analyses pertaining to each arm of the study, and the process used to derive cause-specific mortality estimates for Thailand, using the study findings. For deaths in hospitals, the validation characteristics (concordance, sensitivity, and positive predictive value) of registration diagnoses were derived for leading causes of death, using the MR diagnoses as the reference standard. The study findings were subsequently applied to estimate cause-specific mortality patterns for all hospital deaths in the registration data. In a sub sample of hospital deaths for which a VA diagnosis was also available, validation characteristics were derived for VA methods (the VA validation study). [21-22] [Figure 3 here]

A verbal autopsy (VA) was able to be completed for 6328 deaths outside health facilities. These VA diagnoses were compared with VR diagnoses for the same deaths. Patterns of misclassification between registration (VR) and VA diagnoses were assessed, and *kappa* measures of agreement were used to determine reliability of registration diagnoses, since no reference diagnoses (“gold standards”) are available to measure validity for these deaths. The VA diagnoses were then used to estimate cause-specific mortality proportions in the study sample, in view of the more rigorous methods applied compared to registration diagnoses. Subsequently, findings from the
VA validation study conducted on hospital deaths were used to adjust the VA-based cause-specific mortality proportions for these 6328 deaths, assuming that the validation characteristics of VA for hospital deaths would be the same for deaths outside hospitals. These adjusted VA diagnostic distributions were then used to estimate cause-specific mortality patterns for deaths outside health facilities in Thailand.

Finally, mortality estimates from the two arms of the study were summed, and adjusted to fit the overall numbers of deaths by age and sex estimated from demographic analysis, to derive detailed cause-specific mortality estimates for Thailand in 2005. [23]

Results

Table 1 shows the distribution of the study sample across provinces, as well as the results from data collection for the two broad categories of deaths in hospitals and deaths elsewhere. Losses to follow up were higher for deaths in hospitals including deaths for which households could not be traced to obtain consent for participation in the study, (397 deaths), as well as deaths for which consent was obtained but adequate medical records were not available (931 deaths). While the loss of some of the latter deaths with inadequate medical records could have been due to the limited time period between admission and death, these findings suggest that urgent measures are needed to improve the quality of medical records in hospitals in Thailand. Overall, about 29% of hospital deaths in the sample were lost to follow up.

About half as many (1012 cases, or 14%) of home deaths were lost to follow up. Household contact and VA response rates were particularly high in the study provinces located in the north east region, but only around 50% in Bangkok, with loss
to follow up arising roughly equally from inability to trace households and from refusal to participate in VA interviews. While these findings suggest the broad acceptance of VA by the community, they nonetheless indicate the need for more adequate sensitization about its public health utility, particularly in urban areas.

[Table 1 here]

It is important to consider the extent to which such losses to follow up, for whatever reason, might lead to serious distortions in the proportionate distribution by cause of the sample, and hence affect the generalizability of the results. Table 2 shows the proportionate distributions by registered cause as derived from:

a) the sampling frame (i.e. national death registration data);

b) the sample drawn for the study; and

c) the sample of deaths eventually recruited and used for mortality estimation, comprising of 3316 hospital deaths and 6328 deaths outside hospitals.

There is clearly a very close approximation of the proportionate distributions by cause across the three sources, indicating that any effects resulting from the sampling procedure or from losses to follow up are unlikely to greatly affect the generalizability of study findings.

[Table 2 here]

The primary purpose of this study was to verify (or not) registered causes of death in a nationally representative sample of deaths in Thailand during 2005, using detailed cause of death ascertainment procedures, and to use the findings to derive an estimate of mortality by age, sex and cause for Thailand in 2005. Figures 3 and 4 provide an overview of estimated proportionate mortality from leading causes of death in males and females respectively. The reassessment of causes of death via medical records
review or verbal autopsy resulted in a substantially different broad cause of death distribution to that suggested by the vital registration system. In particular, these methods led to a massive reduction in the percent of deaths assigned to ill-defined causes for both males and females, declining from 33-45% of all deaths in vital registration to 4-6%, with the vast majority of these deaths being attributed to specific causes of death from our methods. Adjustment for systematic undercount or overcount of specific causes by the VA procedure (shown in the bar titled ‘adjusted’ in Figures 4 and 5) resulted in important changes to estimated proportionate mortality, notably from HIV/AIDS, ischaemic heart disease, and diabetes.

[Figures 4 and 5 here]

Interestingly, in addition to cardiovascular diseases and cancers, the study identified diabetes, renal diseases and chronic obstructive pulmonary disease as important non-communicable diseases, the magnitude of mortality from which was substantially less evident from registration data. Further, many injury deaths in the study sample with non-specific causes were reallocated to specific external causes upon verification, highlighting suicide, assault, and drowning as external causes of public health importance among males in particular, in addition to transport accidents.

Conclusions

Despite the fundamental importance of cause of death information for health planning, few countries regularly evaluate the quality of their cause of death statistics, or the functioning of the civil registration system that routinely generates them. This study has conducted a systematic evaluation of registration data, the results of which have yielded corrected estimates of the true underlying cause of death pattern. The study design and research methods employed here could serve as a template for
similar research that might be carried out in other populations where the vital registration system is performing poorly, or where it’s performance is unknown.

Our sampling methods, and the use of standard verbal autopsy and medical records review procedures, have been widely applied elsewhere [24-26] and provide some basis for the generalization of our findings to the population of Thailand. In the absence of widespread autopsy, we believe that careful medical records review provides a reasonable basis for ascertaining the true underlying cause of death in hospitals. The application of the findings from verbal autopsy validation to adjust for systematic biases resulting from the use of VA strengthens the empirical basis for estimating population level cause-specific mortality patterns from the study. More importantly, we conclude that rigorous and careful application of VA methods can drastically improve the information content of cause of death data at comparatively low cost.

We further explore these research questions, methods and results in companion papers that provide more detailed insights into the validity and reliability of cause of death statistics in Thailand, and the likely pattern of age-cause-specific mortality rates, taking into account estimated levels of underreporting of deaths and the misclassification patterns that this study has identified. Collectively, this research will greatly strengthen the evidence base for health policy in Thailand. The collateral benefits of this project lie in the development of scientific methods for such research, as well as the strengthening of technical capacity within the Thai Ministry of Public Health for the conduct of evaluation research and its integration into routine cause of death data collection systems.
References


### Table 1: Distribution of study sample and results of data collection by province and place of death in Thailand, 2005

<table>
<thead>
<tr>
<th>Region (% deaths)</th>
<th>Province</th>
<th>Study districts</th>
<th>Study sample</th>
<th>Data collection</th>
<th>Home deaths</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Only medical records</td>
<td>Hospital deaths</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Medical records &amp; VA</td>
<td>Only VA</td>
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<tr>
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<td></td>
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<tr>
<td>North east</td>
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<td>7</td>
<td>2699</td>
<td>81</td>
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<td>(32.4%)</td>
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<td>22</td>
<td>165</td>
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<tr>
<td></td>
<td>Chiang Rai</td>
<td>3</td>
<td>1849</td>
<td>73</td>
<td>404</td>
</tr>
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<td></td>
<td>Payow</td>
<td>3</td>
<td>751</td>
<td>20</td>
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<tr>
<td>North</td>
<td>Supanburi</td>
<td>3</td>
<td>1970</td>
<td>68</td>
<td>472</td>
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<tr>
<td>(22.5%)</td>
<td>Nakhon Nayok</td>
<td>2</td>
<td>866</td>
<td>9</td>
<td>188</td>
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<tr>
<td>Central</td>
<td>Songkhla</td>
<td>2</td>
<td>1059</td>
<td>140</td>
<td>277</td>
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<tr>
<td>(24.5%)</td>
<td>Chumpon</td>
<td>2</td>
<td>400</td>
<td>5</td>
<td>111</td>
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<td>South</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>(12.6%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bangkok Metropolitan Area</td>
<td></td>
<td>3</td>
<td>1350</td>
<td>340</td>
<td>280</td>
</tr>
</tbody>
</table>

| Total              |                  | 28              | 11984        | 758             | 2558         | 931           | 397   | 4644          | 6328  |

\footnote{Sampling plan included 15\% oversampling for outer regions and 50\% for Bangkok}

\footnote{Deaths for which adequate medical records traced but refused VA (verbal autopsy)}

\footnote{Deaths for which medical records either not traced or of inadequate quality to derive causes of death}

\footnote{Households not located due to incorrect address in registration records, or migration}

\footnote{Deaths for which household not located or refused VA}
<table>
<thead>
<tr>
<th>Cause</th>
<th>ICD codes</th>
<th>Registration data</th>
<th>Study sample</th>
<th>Recruited sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptoms signs and ill defined conditions</td>
<td>R00-R99</td>
<td>38.2</td>
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<td>All other external causes</td>
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<td>4.7</td>
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<td>2.7</td>
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</tr>
<tr>
<td>Diseases of the liver</td>
<td>K70-K76</td>
<td>2.1</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Lung cancer</td>
<td>C33-C34</td>
<td>2.0</td>
<td>2.1</td>
<td>2.1</td>
</tr>
<tr>
<td>HIV/AIDS</td>
<td>B20-B24</td>
<td>2.0</td>
<td>2.0</td>
<td>1.8</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>E10-E14</td>
<td>1.9</td>
<td>1.9</td>
<td>1.9</td>
</tr>
<tr>
<td>Other respiratory diseases</td>
<td>J00-J06, J30-J39, J60-J98</td>
<td>1.8</td>
<td>1.9</td>
<td>1.9</td>
</tr>
<tr>
<td>Other heart diseases</td>
<td>I26-I51</td>
<td>1.5</td>
<td>1.6</td>
<td>1.5</td>
</tr>
<tr>
<td>Chronic lower respiratory diseases</td>
<td>J40-J47</td>
<td>1.4</td>
<td>1.7</td>
<td>1.6</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>A15-A16</td>
<td>1.3</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Other diseases of the nervous system</td>
<td>G04-G25, G31-G98</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>Other digestive disorders</td>
<td>K00-K22, K28-K66, K80-K92</td>
<td>1.2</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>All other causes</td>
<td>All other codes</td>
<td>11.5</td>
<td>11.8</td>
<td>11.4</td>
</tr>
<tr>
<td>Total deaths (100%)</td>
<td></td>
<td>395374</td>
<td>11984</td>
<td>9644</td>
</tr>
</tbody>
</table>

* C17, C23-C24, C26-C31, C37-C41, C44-C49, C51-C52, C57-C60, C62-C66, C68-C69, C73-C81, C88, C96-C97
Figure 1: Distribution of study provinces in Thailand

Bangkok and 2 provinces from each region
Figure 2: Data processing and quality control measures for selection and coding of underlying causes of death in the study sample

Provincial level

- MR review by trained internal medicine specialists
- VA review by trained general practitioners
- Standard medical certificate of cause of death
- ICD coding of all listed causes by coders
- Selection of underlying cause of death by certifying physicians

Central level

- 100% review by central team of expert coders
  - DECISION
    - Underlying cause accepted
    - Underlying cause / code changed
      - Final adjudication by study team expert
        - Agreement
        - Incorrect
        - Disagreement
          - FINAL VERDICT

Potential sources of error
- Incorrect cause(s) of death / disease sequence
- Incorrect code(s)
- Incorrect application of rules for selecting underlying cause

Incorrect = Change in ICD code at 3 or 4 character level, but no change at Mortality Tabulation List 1 level of aggregation
Disagreement = Change in ICD code resulting in change at Mortality Tabulation List 1 level of aggregation
Figure 3: Analytical plan for estimating cause-specific mortality in Thailand, 2005

Study sample
11984 deaths

Hospital deaths
4644

Home deaths
7340

No medical records
1328

Lost to follow up
1012

Only MR
758

MR and VA
(VA VALIDATION)
2558

MR diagnoses
3316

Corrected cause profile for hospital deaths
140,531

Corrected cause profile for home deaths
254,843

Corrected mortality envelope
437,000

ESTIMATES OF DEATHS BY
AGE, SEX AND CAUSE
FOR THAILAND, 2005
Figure 4: Proportionate mortality (in %) for selected leading causes of death based on study findings, FEMALES, Thailand, 2005.
Figure 5: Proportionate mortality (in %) for selected leading causes of death based on study findings, MALES, Thailand, 2005

![Bar chart showing proportionate mortality for selected causes of death based on study findings, MALES, Thailand, 2005.](chart_image)