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Survey of Knowledge, Attitude and Practice Initiated by an Investigation of a Human Rabies Death in Chanthaburi Province, Thailand, 2015

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Abstract

In October 2015, one confirmed human rabies case with many human and animal contacts were reported in a subdistrict of Chanthaburi Province. A joint human and animal health team conducted an investigation, including a survey on knowledge, attitude and practice (KAP) in two villages with confirmed animal rabies cases. The human case was scratched at the wrist and bitten at the calf by a stray dog. The wounds were merely washed with rice whisky. However, 77 days later, the case developed myalgia and rash, and thus, visited the subdistrict health promoting hospital. He later died in the provincial hospital. While 22 dogs were suspected for rabies, three dogs were tested positive. Members of 149 households and 79 close contacts from the two villages were interviewed. Respondents from both villages had low scores of knowledge, attitude and practice on rabies as well as wound care. Prior to the outbreak, vaccine coverage resulted as 14.8% for owned dogs and 4.2% for cats. The phylogenetic lineage of the rabies virus found in the case was in a group commonly found in Thailand. Poor practice by the case and low KAP scores of the villagers indicated inadequate knowledge about rabies and post-exposure management. The coverage of rabies vaccine among domestic animals in the community was much lower than the requirement of 80%.

Keywords: rabies, knowledge, attitude, practice, investigation, Thailand

Introduction

Rabies is a vaccine preventable viral disease. Globally, it causes about 60,000 human deaths, 3.7 million disability-adjusted life year lost and 8.6 billion USD of economic loss every year.[1] Cooperation among animal and human health sectors, and local administrations plays a key for effective rabies prevention and control in humans. This includes public relations to promote knowledge and awareness, training for medical personnel, rabies surveillance in humans and animals, and mass immunization of animals of at least 80% coverage. In addition, the public must be educated to inform local authorities, by telephone or otherwise, about suspected rabid animals in the area.[2]

The number of human rabies cases in Thailand declined over the past few decades, from 370 deaths reported in 1980 to less than 10 deaths per year during 2011-2014. In 2015, out of six human deaths reported, all of them lacked to receive or continue post-exposure prophylaxis.[3] A low level of knowledge and awareness of rabies, lack of animal vaccination, and scarcity of vaccination campaigns are the main challenges of human rabies prevention.[4-6]

On 20 Oct 2015, the Bureau of Epidemiology was notified about a confirmed human rabies death in Klong Yai Subdistrict, Pong Nam Ron District, Chanthaburi Province. A joint investigation was conducted by Bureau of Epidemiology, district health office, district hospital, and livestock development offices from 22 Oct 2015 to 5 Nov 2015, aiming to identify source of the outbreak and magnitude of contact exposure, and assess knowledge, attitude and practice toward rabies control and prevention among villagers in the affected communities.

Methods

This investigation was carried out in Klong Yai Subdistrict, Pong Nam Ron District, Chanthaburi Province, Thailand, where the confirmed human rabies case was reported. Areas of the investigation included three villages: Village A (where the index case lived), Village B (where the index case was bitten), and Village C (where a local dog was bitten by a stray dog) (Figure 1). Dogs suspected of rabies were also reported to be observed in these villages.

Figure 1. Geographical location of 3 villages with suspected rabid dogs in Klong Yai Subdistrict, Pong Nam Ron District, Chanthaburi Province, Thailand, 2015

Descriptive Study

The rabies situation in Thailand was reviewed from the database in the Bureau of Epidemiology[3,7] under the Ministry of Public Health and the Department of Livestock Development (Thai Rabies Net)[8]. Information on voluntary rabies post-exposure prophylaxis from the surveillance database reported from hospitals was used to determine the number of people who had received post-exposure prophylaxis.

Officers from provincial health office, provincial livestock office and district livestock office were interviewed to obtain information about rabies situation in the province, and current prevention and control measures. The possible source of infection was identified by interviewing district livestock officers whether any dogs in the district had tested positive for rabies infection between 1 Jul to 28 Oct 2015, had a history of contact with the index rabid dog on 27 July 2015, or was known to have at least one of the following symptoms: aggression, excitation, self-mutilation, excessive salivation, depression, difficulty swallowing, ataxia and paralysis.

In addition, conveniently selected villagers were interviewed in two (Villages A and B) of the three villages for the possible source of the disease. The deceased's friends and neighbors were also interviewed to ascertain wound management and subsequent behavior after he was scratched and bitten by a stray dog. The case's medical record was also reviewed for clinical signs and symptoms. The phylogenetic linkage was determined to identify the strain of rabies virus.

From 1 Jul to 28 Oct 2015, active finding of contacts was performed by looking for any persons who lived in Village A or B and, within 10 days of the exposure period, had come into contact with any dogs having rabies symptoms in the village. Reports on laboratory-confirmed rabid animals by direct fluorescent antibody test at the Center of Veterinary Research and Development and the National Institute of Animal Health, Department of Livestock Development were assessed and examined as well.

Community Survey

A door-to-door community survey was conducted to determine pet raising behaviors, accessibility to broadcasts and media, ability to identify rabies surveillance stickers, and knowledge, attitude and practice (KAP) concerning rabies prevention and control measures. Afterwards, these scores were compared between two villages: one with a human rabies case (Village B) and one without (Village A). One representative from each randomly selected household was interviewed using a questionnaire that had been reviewed by experts and had been pretested in the community. Household members who aged under 15 or over 75 were excluded.

The KAP questionnaire consisted of items with short statements and answers either yes or no. Proportions of items answered correctly were calculated for each respondent with the formula of dividing the number of correct answers by total number of items in each category. As recommended by the experts, if the proportion of items answered correctly for each category was more than 80%, then that was deemed as a pass. The proportions of respondents who passed each of three KAP categories were compared between the two villages using Pearson's chi-square test. Epi-info version 7.1.5.2[9] was used for all data management and analysis.

Results

Descriptive Study

Reviewing the rabies situation in Thailand, the animals that were tested for confirmation and resulted positive for rabies were 30.2% (240/796) in 2014, 34.7% (320/921) in 2015 and 45.9% (462/1,007) in 2016. During 2015, there were six confirmed human rabies cases reported to the Bureau of Epidemiology.[3] Out of 330 (3.8%) animal specimens tested positive for rabies from the animal sentinel sites of the Department of Livestock Development, 93.3% were dogs[3,7,8,10]. Before 2015, the most recent human rabies death was reported in Chanthaburi Province during 2006[11]. In 2015, out of 1,512 humans exposed to animals suspected to have rabies in Chanthaburi Province, 349 (23.1%) discontinued the post-exposure prophylaxis[12]. The number of people received the post-exposure prophylaxis had been decreasing over the past three years while the rate of discontinuation had been increasing (Figure 2).

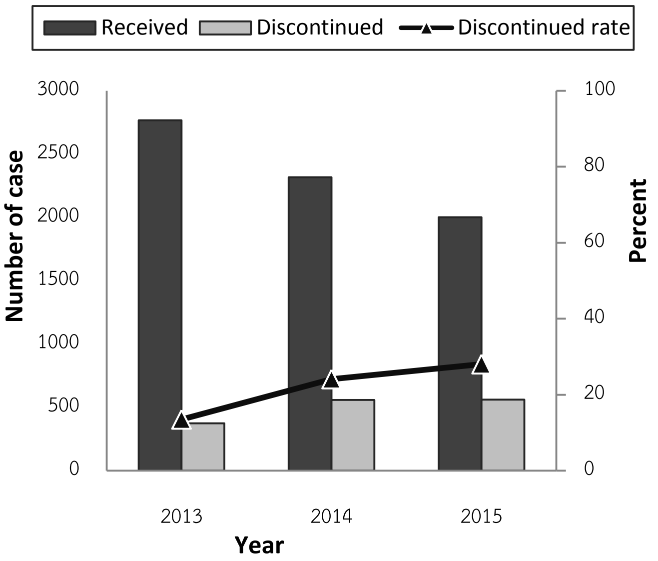

Figure 2. Number of people who received post-exposure prophylaxis (PEP) and discontinued rabies vaccination in Chanthaburi Province, Thailand, 2013-2015

The confirmed human index case was a 58-year old Thai male who drank alcohol regularly, had no underlying disease, and no history of rabies or pre- or post-exposure prophylaxis or travel outside of the area. He moved to Village A in Klong Yai Subdistrict to work as a gardener in 2000. On 27 Jul 2015, he was scratched at the wrist and bitten at the calf by a stray dog in Village B. He did not seek medical treatment and simply washed his wound with rice whisky. On 12 Oct 2015 (77 days later), he developed fever, vesicles at the site of the wound and severe itchiness. On 17 Oct 2015, further symptoms of restlessness, dysphagia, anxiousness and tightness in the chest prompted him to visit the provincial hospital where he was diagnosed with suspected rabies. He died one day later. The patient's brain biopsy was positive for rabies by immunofluorescence assay. Hair follicles and cornea were also found to have rabies virus by nested reverse transcription polymerase chain reaction. The phylogenetic lineage of the isolated rabies virus was related to a common strain of rabies virus found in Thailand (Figure 3).

During 1 Jul and 5 Nov 2015, three stray dogs were observed and attacked other dogs in Villages A, B and C. Among 22 contact dogs identified, eight (36.4%) were killed instantly or died later from injuries, and samples from three dogs tested to have rabies by immunofluorescence assay at the Veterinary Research and Development Center.

Order of Contacts

Village A: On 1 Jul 2015, a stray dog was observed by the residents. There were unknown number of contact persons, and among nine contact dogs reported, three died and all three out of five tested positive for rabies.

Village B: On 27 Jul 2015, a stray dog, possibly the same one from Village A, was observed by the residents. Out of 79 contact persons and 10 contact dogs reported, three dogs died. However, samples were not taken for rabies testing.

Village C: On 30 Oct 2015, a group of aggressive stray dogs was observed in the village. No human contact was observed or reported. Of three contact dogs, two died and both tested negative for rabies.

Community Survey

There are total seven villages in Khlong Yai Subdistrict and is part of Pong Nam Ron District in Chanthaburi Province which has a border crossing with Cambodia. As shown in the figure 1, Villages A, B and C are within four kilometers from each other. There were 345 households sheltering 1,122 residents in three villages. According to the survey, most of the villagers were longan farmers. There were no fences between houses, and some of the villagers had gardens nearby or close to their houses.

The survey was conducted in 151 (68.9%) randomly selected households from Villages A and B. Two households were excluded due to the age of interviewees. Out of total 149 respondents included in the community survey, 64 (43.0%) of the respondents were female and the median age was 45 years (range 15-75).

Majority (57.6%) of the respondents had attended primary school or pre-school only. There were 321

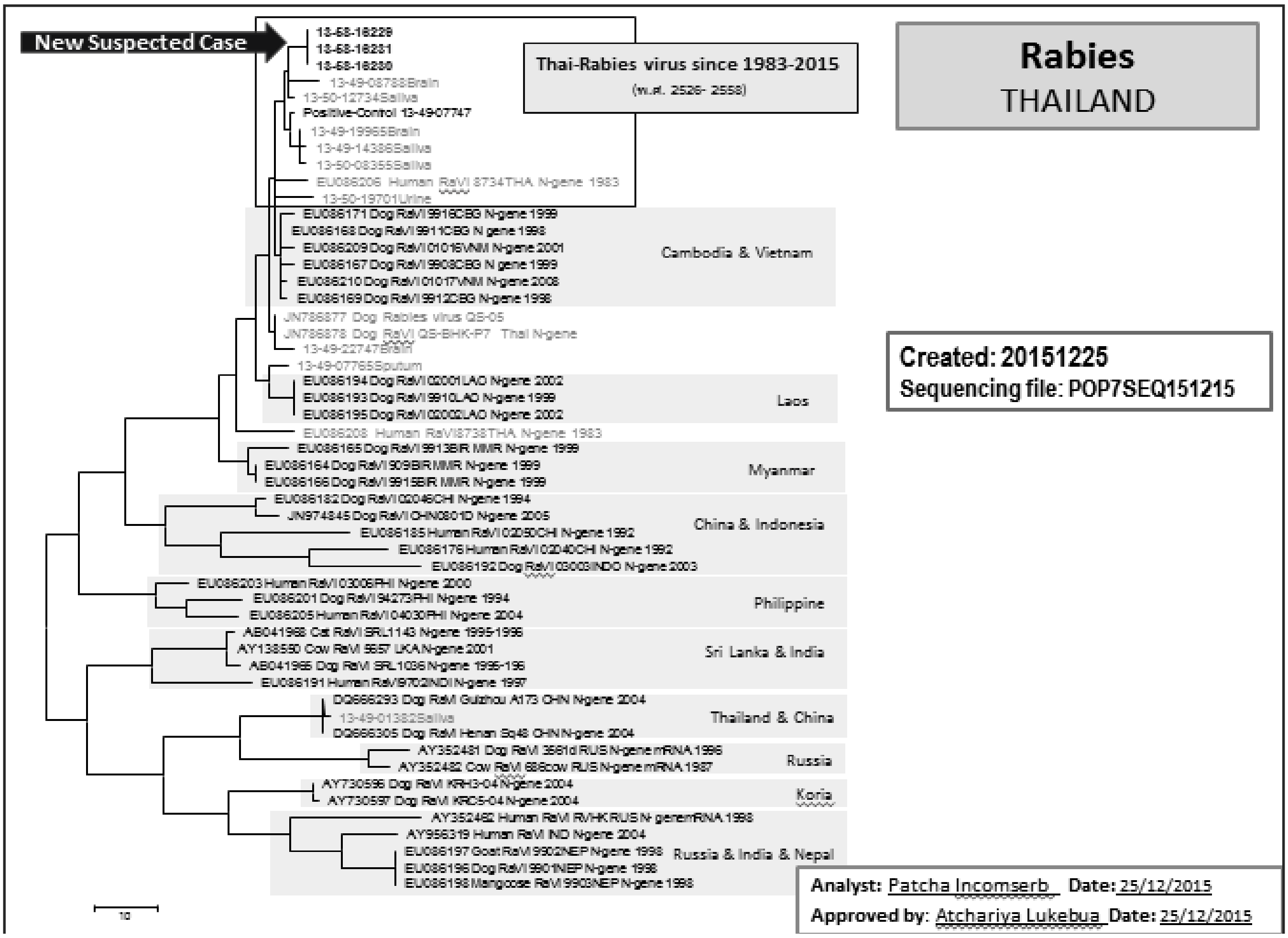

Figure 3. Phylogenetic lineages of rabies virus isolated from a human rabies case in Chanthaburi Province, Thailand, 2015

dogs in 99 (66.4%) households with dogs and/or cats. Dogs were kept as guard dogs and 82.8% of the households allowed them to roam freely.

From 63 households in Village A and 86 households in Village B, most (76.5%) of the respondents were exposed to information about rabies from local broadcasts, television, radio and posters. However, 67.8% of respondents stated that they had not seen any rabies surveillance stickers posted in the village.

Regarding to the level of knowledge about rabies transmission, disease outcome and prevention in humans and animals, the overall median percentage of items answered correctly was 62.8% (range 18.2-100%) and only 25 (16.8%) respondents answered more than 80% of the knowledge items correctly. Majority of the villagers were aware that rabies could be fatal (89.8%) and understood the route of transmission (86.4%). About 43.6% of the respondents recognized that all mammals could be infected with rabies. Nevertheless, only 47.0% realized that rabies infection in humans could be treated with curative intent. The percentage of respondents who passed the knowledge category was 27.0% for Village A and 9.3% for Village B (P-value = 0.004) (Table 1). Among the dog owners, only 14.0% passed the knowledge category. Even though only 51.0% vaccinated their pets annually, 86.1% said that they were willing to pay for the vaccination.

Overall, about 26.8% of the respondents would not receive post-exposure prophylaxis at the hospital and about 36.5% would not bring their pet(s) to the livestock office for vaccination as they assumed that it was a waste of their time and would cause a loss of income. However, 86.5% of the respondents were willing to pay for animal rabies vaccination. About 61.9% in Village A and 46.5% in Village B had passed the attitude category (P-value = 0.06) (Table 2).

In terms of rabies practices in two villages, only 24.2% would wash the affected wound with soap and water, and apply antiseptic before going to a hospital after being exposed to a suspected rabid animal. About 55.8% of dog-owners had their dogs vaccinated annually. About 22.1% of the respondents superstitiously believed that hitting the wound with a shoe would cure the infection. There were 41.3% passed the practice category in Village A as well as 83.7% in Village B (P-value <0.001) (Table 3).

Table 1. Percentage of respondents who answered the knowledge questions correctly from 2 villages related to a human rabies death in Chanthaburi Province, Thailand, 2015 (n=149)

No.	Statement	Village A	Village B	Total
1.	Rabies is fatal in humans. (n=147)	90.3	89.4	89.8
2.	All mammals can get rabies infection.	38.1	47.7	43.6
3.	Rabies can be transmitted to humans via bites or scratches of a rabid animal. (n = 147)	82.3	89.4	86.4
4.	If the bite or scratch of a rabid animal causes merely a mild wound, it is not necessary to seek medical care.	65.1	50.0	56.4
5.	Humans infected with rabies can be treated with curative intent.	49.2	45.3	47.0
6.	Pregnant women and children can receive rabies vaccine.	68.3	40.7	52.3
7.	All rabid animals behave aggressively.	52.4	48.8	50.3
8.	Puppies aged 2-3 months can receive rabies vaccine. (n = 148)	77.8	69.4	73.0
9.	Only one dose of rabies vaccine can protect animals from rabies.	74.6	80.2	77.9
	Passed >80% of all items	27.0	9.3	16.8

Table 2. Percentage of respondents who answered the attitude questions correctly from 2 villages related to a human rabies death in Chanthaburi Province, Thailand, 2015 (n=149)

No.	Statement	Village A	Village B	Total
1.	Receiving post-exposure prophylaxis at a hospital is a waste of time.	27.0	26.7	26.8
2.	I am willing to pay for post-exposure prophylaxis.	68.2	65.1	66.4
3.	Puppies cannot get rabies. (n = 147)	70.5	59.3	63.9
4.	Bringing pets to the livestock office for rabies vaccination is a waste of my time. (n = 148)	34.9	37.7	36.5
5.	I am willing to pay for animal rabies vaccine. (n = 148)	87.3	85.9	86.5
6.	Temples and schools are not appropriate places to abandon pets. (n = 148)	96.8	88.2	91.9
7.	I agree to have rabid dogs put down as long as it is done humanely.	87.3	76.7	81.2
	Passed >80% of all items	61.9	46.5	53.0

Table 3. Percentage of respondents who had good practice from 2 villages related to a human rabies death in Chanthaburi Province, Thailand, 2015 (n=149)

No.	Statement	Village A	Village B	Total
1.	Dog owners vaccinated their dogs with rabies vaccine annually (n = 104)	66.7	48.4	55.8
2.	I will manage dead dog(s) properly.	25.4	4.7	13.4
3.	I will not hit the wound with a shoe to cure rabies.	84.1	73.3	77.9
4.	I will manage the bitten wound properly.	33.3	17.4	24.2
5.	I will apply antiseptics to the wound.	58.7	53.5	55.7
6.	I do not encourage feeding of stray dogs. (n = 145)	78.7	73.8	75.9
	Passed >80% of all items	41.3	83.7	51.7

After the Department of Livestock Development announced the reported rabies outbreak in this community, all owned dogs in Village A had received full doses of the vaccine and ring vaccination was performed around the three villages. The vaccine coverage before the outbreak resulted as 14.8% for Village A and 4.2% for Village B, and increased to about 50.0% after the ring vaccination. In all three villages, all contact dogs were provided with repeated vaccination and observed for abnormal clinical signs for at least six consecutive months. Post-exposure prophylaxis was administered completely for all contact persons and monitoring for rabies continued. Public health authorities had informed the residents in the implicated areas and health education materials were distributed to increase public awareness. The people affected communities were informed to cooperate by monitoring animals in Villages A and B for signs of rabies. Moreover, a group meeting was held for staff from the provincial health office, health promotion hospitals and livestock offices to discuss future planning, prevention and control programs for rabies.

Discussion and Conclusion

Rabies remains an important public health problem in humans and animals, especially in the central and eastern regions of Thailand.[10] In 2015, a human rabies death occurred in Chanthaburi Province, the eastern part of the country. Important predisposing factors included improper wound management and failure to seek post-exposure prophylaxis. This outbreak showed that the bite of an infected dog was the mode of transmission, and knowledge, attitude and practice about prevention and control of rabies in animals and humans was limited among the study population. About 25% of people exposed to rabies in Thailand during 2010 did not seek medical care as they assumed that transmission could not occur via a minor wound.[13] Moreover, in a study from the Nakhon Phanom Province, 35% of 51 respondents did not know about rabies.[6] From our review, the number of people who discontinued post-exposure prophylaxis and the percentage of animals that tested positive for rabies had been increasing during 2014-2016, which was the critical point for future rabies prevention and control in humans.

The phylogenetic lineage of rabies virus isolated from a case in Cambodia living near the Thai border revealed that the lineage was related to the rabies virus previously found in Thailand between 1983 and 2015. However, the origin of the first infected dog during this outbreak was uncertain since the majority of viruses from Cambodia, Thailand, Lao PDR and Vietnam were phylogenetically from the lineage SEA1.[14]

In this outbreak, about 80 persons had a contact with the rabies suspected dogs. All contact persons were monitored and administered a complete course of post-exposure prophylaxis at a hospital. Since after the outbreak, there had been no additional human rabies cases reported in the affected district. Vaccination of domestic animals against rabies and stray animal control programs greatly reduce the risk of rabies transmission to humans.[4,15-17] Implementation of these measures in the United States had led to drastic decline in the incidence of human rabies.[18] This indicates that a key factor for reducing human rabies is to focus on vaccination and control of animals as well as performing effective post-exposure prophylaxis monitoring system in humans.

The spread of this virus could be related to the number of freely wandering dogs around the three villages and low level of rabies vaccine coverage in animals, especially dogs. Although the Department of Livestock Development conducted two rounds of ring vaccination to dogs in these villages, the vaccine coverage in animals increased to only about 50%, which was still much lower than the recommended minimum of 80%. This low level of herd immunity was likely related to large number of free roaming dogs in the areas, which would be time-consuming and costly to catch and vaccinate them. Though oral vaccines for dogs were not available yet in Thailand, several countries in Europe had successfully used oral vaccination campaigns among red foxes and were declared as rabies free[19]. With the large number of free roaming dogs in Thailand, and the majority of the population being Buddhists following a religion which prohibits killing of animals, rabies control in Thailand would be a difficult task.

Immediately after the outbreak, the Department of Livestock Development and the district health office provided education about rabies to residents in the affected villages. Two weeks later, in early November 2015, a KAP survey of residents in Villages A and B indicated that knowledge, attitude and practice of residents of both villages were still very low, particularly for knowledge. Only 47% of all respondents recognized that people who developed the rabies symptoms could be treated with curative intent while merely 56% understood that minor wounds did not require any treatment at all. The overall average scores for rabies knowledge and attitude of both villages were below 80%.

Public Health Recommendations

More education about rabies in humans and animals was needed. Although post-exposure prophylaxis, consisting of rabies immunoglobulin and vaccine, is effective in preventing the disease when administered promptly after an exposure, villagers did not perceive the advantages of receiving it. Thus, health education and public awareness of rabies should be continued until the evidence-based effects on residents' behaviors. The implementation of oral vaccines should also be considered. Moreover, a post-exposure prophylaxis monitoring system should be developed to ensure rabies vaccination in exposed people. Finally, accessibility to health care units should be increased so that prompt treatment could be provided to those exposed.

Limitations

The KAP survey was conducted in only two villages with confirmed animal rabies. While the comparison of KAP between only two villages might not be a representative method, the study aimed to identify the factors influencing the case on malpractice. Other limitation could be the recall bias since some interviews were conducted several months following the outbreak. In addition, non-response bias might have occurred from residents during the survey period as well.

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Suggested Citation

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System, Report Sensitivity and Data Quality of the Injury Surveillance System, Ratchaburi Province, Thailand

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Abstract

Since 1993 when an injury surveillance system was established in Thailand, the central Ratchaburi Province has been consistently ranked high for traffic injuries. This study aimed to describe the operation and usefulness of the injury surveillance system at Ratchaburi Provincial Hospital, and assess the sensitivity and quality of the surveillance data. The study was carried out among the injured people who visited the emergency room and/or were admitted to Ratchaburi Hospital in 2011, including those who died upon or before arrival at the hospital. Data were collected from log books, the hospital database and interviews with key informants. The sensitivity of reports in the system revealed as 93.2% for injured patients, 71.3% for deaths upon arrival, and 67.7% for deaths before arrival. Of 33 variables assessed for data accuracy, 24 (72.2%) did not pass the standard of 90%, including age, systolic and diastolic blood pressure, pulse rate, respiratory rate, blunt/penetrating injury, diagnosis, region of injury, and severity of injury. The data were used for planning purposes and to conduct a trauma audit conference. In summary, the injury surveillance system at Ratchaburi Hospital was deemed to have a high sensitivity for detecting injured patients, yet low sensitivity for those dying before being assessed. To improve the sensitivity of reporting dead cases and quality of data, the hospital was recommended to provide annual trainings for personnel working for the surveillance system.

Keywords: injury, sensitivity, quality, accuracy, surveillance, Thailand

Introduction

An injury is the physical damage resulted when a human body is suddenly or briefly impacted with intolerable level of energy.[1] Signs and symptoms include pain, blood loss or bleeding, deformity, and organ dysfunction. Injuries can be categorized into intentional such as homicide or suicide, and unintentional like drowning, fall, burn or traffic accidents.[2]

The Bureau of Policy and Strategy in Thailand reported that during 2003-2010, the second highest fatality rate was recorded as injuries, following those of tumors and malignancies.[3] The average fatality rate for injuries in the past eight years was 56.7 per 100,000 population, with no sign of a decreasing trend. In 2014, traffic accidents were the highest cause of disability-adjusted life years (DALYs) among males and ranked sixth among females.[4]

An injury surveillance system with accurate and comprehensive data and trends is important for developing the effective strategies to reduce injuries in the population. Hence, a national injury surveillance system was established in Thailand during 1993 by the Bureau of Epidemiology, and the Regional Offices of Disease Prevention and Control under the Ministry of Public Health. The objectives of this system are to utilize the national injury data for improving services and referral system, and reducing injuries at the provincial and national levels.[5]

One of the methods for quality control of injury data is evaluation of the injury surveillance system. A general surveillance evaluation composes of assessing sensitivity, positive predictive value, data accuracy, completeness, timeliness, acceptability, simplicity, flexibility, stability and usefulness.[6]

Ratchaburi, a province in the western region of Thailand, was ranked second for the highest morbidity rate in 2007 with 14,749 injuries.[7] In 2011, the number decreased to 9,204 injuries, still making it the third highest in the western region.[8]

The injury surveillance is a complex system as more than 100 variables are collected and recorded, which need coding by the skillful officers. Although evaluation of the injury surveillance system could explain the magnitude and cause of problems, it had not been conducted in Ratchaburi Provincial Hospital for the past 10 years. Thus, the Ratchaburi Hospital was selected by comparing with standard values in the national guideline for evaluation of the injury surveillance system[9]. This evaluation was expected to highlight the critical flaws in the system which could then be targeted for further improvement.

The objectives of this study were to evaluate the injury surveillance system at Ratchaburi Hospital by describing the operation and usefulness of the system as well as assessing sensitivity, accuracy and completeness of the reports.

Methods

This surveillance evaluation was a descriptive study conducted between December 2012 and March 2013, and composed of both quantitative and qualitative assessments.

Qualitative Data Collection for Processes, Flow and Usefulness

Data collection forms and a semi-structured questionnaire were designed for interview with key informants, including nurses in emergency room and surgery intensive care unit, the chief of orthopedics department, the director of Ratchaburi Hospital, and a statistician. Contents of the questions were related to processes of the system, data collection and analysis, distribution and feedback of data to executives and officers, knowledge, workload, tools, policy, budget, usefulness of the system in terms of prevention and control[10], first aid, referral system, treatment, trauma audit, and problem solving. In addition, key informants were interviewed about co-operation among public health, local and other related organizations, obstacles, and recommendations. Data were analyzed using a content analysis method.

Quantitative Assessment for Sensitivity, Accuracy and Completeness of Data

The study population included people who had injury, visited the emergency room (ER) and/or were admitted to Ratchaburi Hospital during 1 January to 31 December 2011. People who were dead upon or before arrival during the same period were also included in the study. Among those who visited ER or hospitalized more than once, only first visit was selected for analysis.

Sample Size and Sampling

The sample size was calculated using the Cochran's formula, assuming the expected sensitivity, data accuracy and completeness of 0.9, and adding 10%. The final sample size was 189 cases. We stratified records into three groups: group 1 with injured patients who were discharged from ER or hospital; group 2 with patients who visited ER or hospitalized and later died from the injury, and group 3 with patients who died before arrival at the hospital. Patients in group 1 were selected using the systematic random sampling method[11,12]. Given that there were 365 days in the study period and the average daily number of injured patients who visited ER or hospitalized was 13, the days for data collection was calculated as 15 (189/13) days with an interval of 24 (365/15) days. The first date of data collection was selected by simple random sampling from the first 25 days of 2011. Data of all cases in 15 sampled days were included in the study.

Data of patients who were dead upon or before arrival were collected for every patient from the registration log book and the injury surveillance system during the same period.

For accuracy and completeness, we excluded those died before arrival (group 3) as their diagnoses were not specifically recorded in the system. The patient's medical records were matched with those in the surveillance system using hospital number and compared to determine the accuracy of the surveillance reports.

Three data collection forms were used to collect data from the ER log book, medical records and the injury surveillance system.

Data Analyses

The sensitivity values for all three groups were calculated separately based on the correct values of three variables: hospital number, injury date and cause of injury. Overall sensitivity was calculated using a weighted average of all three groups. An acceptable level of sensitivity was based on the national guideline for evaluation of the national injury surveillance from the Bureau of Epidemiology, 2010, including 90% for reporting injury patients and 80% for reporting deaths from injuries either upon or before arrival at the hospital.[9]

Data were analyzed for accuracy using 33 variables in 18 variable groups. The variable groups included hospital number, age, date of hospital visit, systolic and diastolic blood pressure, pulse rate, respiratory rate, (total) Glasgow coma score, status during the injury (driver/passenger/pedestrian), vehicle, cause by 10th edition of international statistical classification of diseases (ICD-10) code[13], characteristics of injury, treatment result, discharge status, diagnosis[14], injury severity score (ISS), body region (BR), and severity of injury based on the abbreviated injury scale (AIS)[15]. The acceptable level of completeness was 90% of reports in the injury surveillance system having information of that variable[16].

This study was approved by the Human Research Ethical Committee of Mahidol University, Thailand (228/2555).

Results

Processes and Usefulness in Ratchaburi Hospital

Process of the injury surveillance system began when an injured patient visited ER of the hospital. An administrative clerk recorded information into the form during 08:30-16:30 on weekdays. Otherwise, injury surveillance forms were completed by ER nurses. The recorded forms were then checked and signed by nurses at ER. An officer from the Planning and Information Department of the hospital collected the completed forms every Monday, Wednesday and Friday, and entered the data into the injury surveillance program for both out-patients and in-patients. Afterwards, a medical statistician entered data of BR and AIS in the program for out-patients. For in-patients, diagnoses are based on ICD-10 code and were completed upon discharge. Data from the injury surveillance system were utilized for discussion in the monthly executive meetings in the hospital. Every three months, data from the injury surveillance system were sent to the Bureau of Epidemiology.

In Thailand, there are the "7 Dangerous Days Campaign" during the New Year and other related campaigns for specific festivals for traffic accident prevention. Data from the injury surveillance system in Ratchaburi Hospital were also sent to the Ministry of Public Health for the campaigns according to the national regulation. However, the officers who work for this surveillance system did not receive any feedback. During 2006 and 2010, data from the injury surveillance system were used in the annual trauma audit conference to search for service problems and make improvements. However, the trauma audit conference was not conducted since 2010 as the responsible doctor moved to another department.

Quantitative Assessment

Number of injury patients and sensitivity of reports during 2011 were presented in the figure 1. The sensitivity of the injury surveillance were 93.2% for patients visiting ER and/or admitted to the hospital, 71.3% for patients who died upon arrival at ER, and 67.7% for patients who died before arrival (Table 1). The overall weighted sensitivity was 89.3%.

On review of the medical records, 17 patients who died upon or before arrival at ER were incorrectly reported in the surveillance system. Of these, 13 showed the same hospital number and incorrect date of arrival at ER or cause of injury (Table 2). Four patients were not reported in the system based on the hospital number.

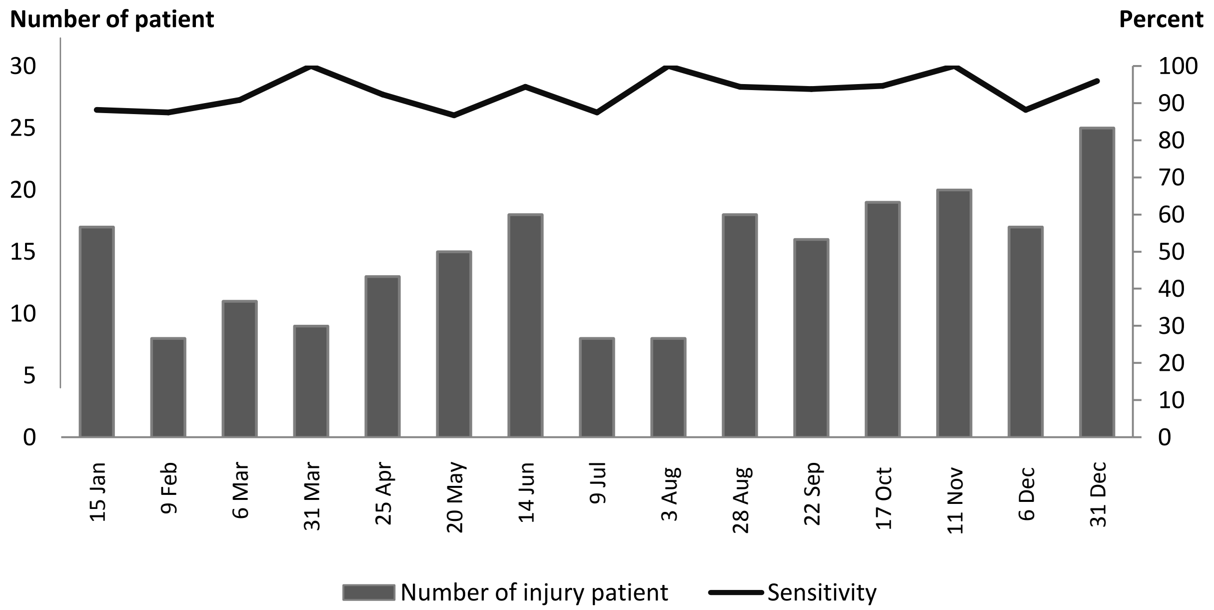

Figure 1. Injury patients visiting the emergency room and/or admitted to the provincial hospital and sensitivity of reports in the injury surveillance system during 15 sampled days, Ratchaburi Province, Thailand, 2011

Table 1. Sensitivity of injury surveillance reports by type of patient in Ratchaburi Hospital, Thailand, 2011

	Admitted	Died upon arrival	Dead before arrival
Number of injury patients recorded in the injury surveillance system	207	19	21
Number of injury patients registered in the log book of emergency room	222	26	31
Report sensitivity (%)	93.2	71.3	67.7
Evaluation criteria (%)	90.0	80.0	80.0
Interpretation	Pass	Fail	Fail

Table 2. Summary of injured patients who died upon or before arrival but were incorrectly reported in the IS system, Ratchaburi Hospital, Thailand, 2011

Description			Died upon arrival	Dead before arrival	Total
Hospital number	Visiting date	Cause of injury			
Same	Same	Different	3	3	6
Same	1 day different	Same	2	4	6
Same	>1 day different	Same	1	0	1
Not found in the system	-	-	1	3	4
Total			7	10	17

Of 33 variables assessed for accuracy, only nine passed (≥90% accurate). Apart from diagnosis, body region and abbreviated injury scale, completeness of all other variables was 100%. Of six possible diagnoses that were assigned to each patient, including severity of injury and body region, only the first diagnosis passed the completeness assessment (≥90% complete) (Table 3).

Discussion

Records of the injured patients who visited ER and/or were admitted to Ratchaburi Hospital were randomly selected and compared with the injury surveillance reports in the electronic database. The sensitivity of the injury surveillance reports (89.3%) was comparable to two hospitals in Canada which were reviewed by the Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP)[17]. In our study, the data collection process at ER was found to have affected the sensitivity of the reports. Our sensitivity of 68-93% for the injury surveillance system in Ratchaburi Province was higher than that of the chikunganya surveillance system in Chonburi Province[18] and the dengue hemorrhagic fever surveillance system in Kampangphet Province of Thailand[19], which each had a sensitivity of 31% and 15% respectively. However, the latter two evaluations used data from the national notifiable disease surveillance system, for which many characteristics were needed to report and differed from those variables in the national injury surveillance system.

The sensitivity of reports for patients who died before arrival was lower than 90% as recommended by the national guideline. That might be due to our evaluation method which required information being similar for all hospital number, ER registered number and record number in the surveillance system. Twelve out of 17 records had incorrect date of visit or cause of injury though the hospital number was the same. Using a more flexible definition (same hospital number and either same cause of injury or same date of visit) with a reviewer’s judgment, this sensitivity increased from 70% (40/57) to 91% (52/57).

In ER, senior nurses trained the junior ones about the injury surveillance reports. Apart from the nurses, there was another officer responsible for collecting data for the injury surveillance during daytime. Injury cases were very often easier to record than infectious or communicable disease surveillance reports since most injury cases were associated with easily identifiable causes. Therefore, the sensitivity of an injury surveillance system should be higher than those of other surveillance systems. Nonetheless, the sensitivity of reports of those dying upon or before arrival at ER resulted less than 80%. It might be due to the fact that those with the same hospital number, date of hospital visit, and cause of injury in both ER logbook and reports in the injury surveillance system was classified as the same case. In fact, reports with date of hospital visit differing for one day could be the same case as well.

Accuracy of patient's age was less than 90%, probably because nurses collected the age from the screening page of medical records, which was provided directly by the patients. Age should be calculated from patient's date of birth, which was documented on the first page of medical records. Data accuracy of blood pressure level, pulse rate and respiratory rate were also less than 90%, which might be due to incorrect recording, rounding error, or high workload (service first and record later). When nurses were busy, another officer recorded information in the surveillance record forms only after the medical records were returned to the storage room. Thus, the data might not be as accurate as they could be.

The accuracy of all six diagnoses was less than 90% and ranged from 15% (diagnosis 4) to 77% (diagnosis 1). Incorrect diagnoses might be due to missing or incomplete diagnosis by the attending ER doctor or

Table 3. Accuracy and completeness of data in the injury surveillance reports by variables recorded, Ratchaburi Hospital, Thailand, 2011

Variable	Number of case	Evaluation			
		Accuracy (%)	Interpretation	Completeness (%)	Interpretation
Hospital number	186	100	Pass	100	Pass
Age	186	88.2	Fail	100	Pass
Date of hospital visit	186	96.2	Pass	100	Pass
Systolic blood pressure	186	81.2	Fail	100	Pass
Diastolic blood pressure	186	82.8	Fail	100	Pass
Pulse rate	186	86.6	Fail	100	Pass
Respiratory rate	185	82.2	Fail	100	Pass
Glasgow coma score	182	92.9	Pass	100	Pass
Status of patient	186	98.9	Pass	100	Pass
Vehicle	186	97.3	Pass	100	Pass
Cause	186	92.5	Pass	100	Pass
ICD-10 cause	186	87.6	Fail	100	Pass
Characteristics of injury	186	84.9	Fail	100	Pass
Treatment result at the emergency room	186	98.4	Pass	100	Pass
Diagnosis 1	186	76.9	Fail	97.8	Pass
BR 1	186	93.5	Pass	97.8	Pass
AIS 1	186	78.0	Fail	97.8	Pass
Diagnosis 2	105	41.9	Fail	56.2	Fail
BR 2	105	55.2	Fail	56.2	Fail
AIS 2	107	45.7	Fail	56.2	Fail
Diagnosis 3	47	21.3	Fail	27.7	Fail
BR 3	47	25.5	Fail	27.7	Fail
AIS 3	47	23.4	Fail	27.7	Fail
Diagnosis 4	20	15.0	Fail	15.0	Fail
BR 4	20	10.0	Fail	15.0	Fail
AIS 4	20	15.0	Fail	15.0	Fail
Diagnosis 5	9	22.2	Fail	22.2	Fail
BR 5	9	11.1	Fail	22.2	Fail
AIS 5	9	22.2	Fail	22.2	Fail
Diagnosis 6	4	25.0	Fail	25.0	Fail
BR 6	4	25.0	Fail	25.0	Fail
AIS 6	4	25.0	Fail	25.0	Fail
Status at hospital discharge	185	96.8	Pass	98.4	Pass

ICD-10 = International Classification of Disease version 10, BR = Body region, AIS = Abbreviated injury scale code error. The coder might record it into a wrong code in the injury surveillance data using ICD-10 codes, without reviewing medical records. Nurses might record wrong diagnosis in the surveillance record form as well. Low accuracy of diagnosis also affected the accuracy of the severity of injury which was used to calculate the probability of survival[5] in the trauma audit conference. For completeness, most variables showed values more than 90% and many were 100% complete. One possible reason for this result was that nurses in ER set a high priority for recording data in the paper record forms for the injury surveillance.

The trauma audit conference could be resumed and continued if officers perceived the usefulness of the injury surveillance system. In addition, data accuracy should be improved in order to estimate the survival probabilities more accurately.

In 2012, a specialist ER doctor was assigned to conduct the regular trauma audit conferences in Ratchaburi Hospital.

Recommendations

Annual training should be conducted in the hospital for all recorders in the injury surveillance on recording data correctly and in a standardized way. The trauma audit conferences should be set as a key performance indicator of hospitals in 2014. There should be an internal discussion between doctors and officers about calculation of survival probabilities, followed by organizing a meeting about the survived patients with a low probability of survival.

Acknowledgement

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Suggested Citation

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Epidemiological Situation of Malaria in Rakhine State, Myanmar during 2000-2014

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Abstract

Rakhine State is the state with highest number of malaria cases in Myanmar. The objective of the study was to investigate the malaria situation in Rakhine State during 2000-2014. Data on malaria monthly reports from all townships during 2000-2014 were reviewed and analyzed. The malaria morbidity rate in Rakhine State was observed to decrease from 40.0 per 1,000 population in 2000 to 13.5 per 1,000 in 2014. Marked reduction in mortality and case-fatality rates were also observed. Although the morbidity and mortality rates were reduced in all townships, some townships had maintained high malaria positivity rate and low annual blood examination rate. Ten percent of cases in under 5-year children indicated the endemicity and local transmission of malaria. Malaria cases treated by community volunteers were increased from 1.7% in 2011 to 27.9% in 2014. The majority of malaria cases were caused by *Plasmodium falciparum*. Reduction in malaria morbidity and mortality might be due to early detection and treatment of cases. Efforts to detect and treat cases earlier should be a high priority in townships with high malaria positive rate and low annual blood examination rate in order to reduce the burden of malaria infection in Myanmar.

Keywords: malaria, morbidity, mortality, case-fatality, Rakhine State, Myanmar

Introduction

Malaria is one of the priority diseases in Myanmar and has been endemic in 284 out of 330 townships. The objective of the National Malaria Control Programme was to reduce malaria morbidity and mortality by 60% in 2016, compared to the baseline in 2007. The prevention and control activities were based on eight strategies, including early diagnosis and appropriate treatment. Community-based malaria control, case detection using the rapid diagnostic testing (RDT) and treatment by volunteers had been started since 2006.[1] Malaria cases were diagnosed clinically or microscopically and treated before the use of RDT. All examined and treated cases from health facilities and volunteers were recorded in registration, compiled and reported monthly.[2]

Long-term trend showed decreasing malaria morbidity and mortality in Myanmar. Morbidity rate per 1,000 population and mortality rate per 100,000 population were 24.4 and 12.6 in 1990, and 6.4 and 0.5 in 2013. Four malaria parasite species are detected in Myanmar. In 2013, the proportion of *Plasmodium falciparum* was 73% and *Plasmodium vivax* was 24%. The proportion of mixed infection was low (3%). *Plasmodium malariae* and *Plasmodium ovale* accounted for very low as 0.001%.[3]

Rakhine State is one of the malaria highest-risk areas in Myanmar. Each year, Rakhine State contributes about 20-25% of total malaria cases in Myanmar.[4] However, not all townships in Rakhine State reveal equal risk for malaria. The objective of the study was to investigate the malaria situation in Rakhine State during 2000-2014.

Methods

Rakhine State is situated between Rakhine Mountain Range and the Bay of Bengal in western part of Myanmar. In 2014, the state consisted of 17 townships, 3 sub-townships, 123 wards, 1,044 village tracts and 3,805 villages. The total population in 2014 was about three million, with 83% lived in rural areas.[5]

A descriptive cross-sectional study was carried out. Data on malaria monthly reports from all 17 townships and the state during 2000-2014 were reviewed and analyzed. Data were analyzed using morbidity and mortality rates by year and township during 2000-2014. Monthly cases for seasonal pattern, proportion of cases by gender, age group and malaria species from 2011-2014 were analyzed. Annual blood examination rate (ABER), including both active and passive cases identified by all service providers, and malaria positive rate (MPR) by townships in 2014 were also investigated.

Malaria slide microscopy had been used for malaria diagnosis in centers where microscopes were available and the RDT was used in all centers. Malaria case definition differed from year to year. Before the introduction of RDT, the reported malaria cases included those confirmed with slide-positive examination by microscope and clinically suspected ones based on only patient's clinical symptoms and those receiving treatment. The RDT was introduced in 2008, detecting only *P. falciparum*. However, it was not enough for all centers. In 2010, the RDT was distributed to all health centers, and malaria was diagnosed as confirmed cases by microscopy or RDT. For those clinically suspected cases with negative RDT were diagnosed as probable malaria. Both confirmed and probable malaria cases were reported. From 2011 onwards, the RDT that could diagnose both *P. falciparum* and *P. vivax* was distributed, and all reported malaria cases were confirmed ones.[2]

Descriptive statistics included frequency, rate and proportion. Malaria morbidity rate was calculated based on the number of malaria cases per 1,000 population and mortality rate was calculated based on number of malaria death per 100,000 population. ABER was calculated by percentage of the examined cases in the population and MPR was calculated by number of positive cases per examined cases.

Results

The malaria morbidity rate in Rakhine State reduced from 40.0 per 1,000 population in 2000 to 13.5 per 1,000 in 2014 (Figure 1). The mortality rate also reduced from nine per 100,000 population in 2000 to 0.3 per 100,000 in 2014. The highest morbidity rate was observed in 2003 and the highest mortality rate occurred in 2001.

The malaria case fatality rate reduced from 0.23% in 2000 to 0.02% in 2014 (Figure 2). The highest case fatality rate was found in 1-4 year age group during 2011 to 2014.

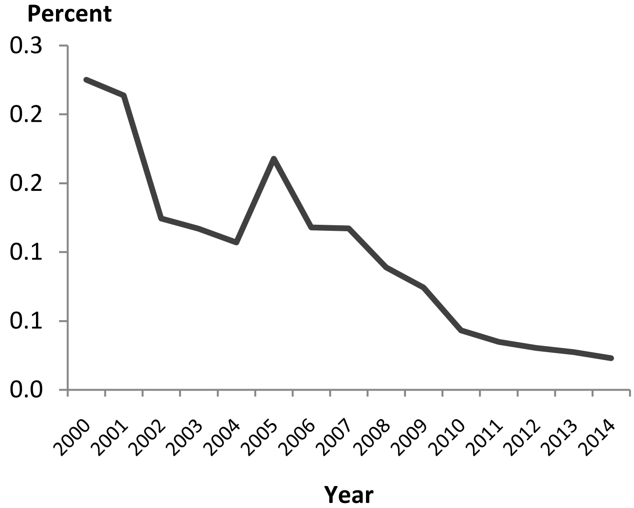

Figure 2. Case fatality rates of malaria by years in Rakhine State, Myanmar, 2000-2014

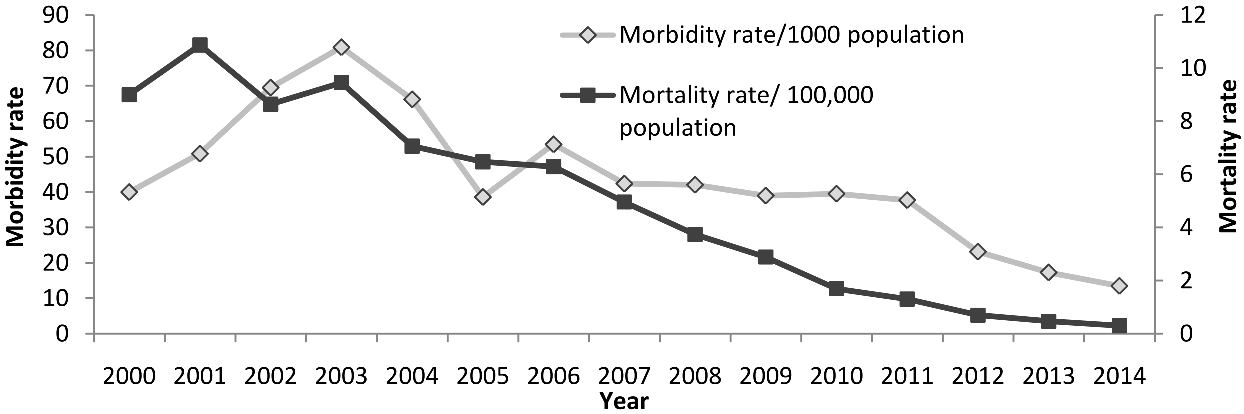

Figure 1. Malaria morbidity and mortality rates by years in Rakhine State, Myanmar, 2000-2014

In Rakhine State, malaria cases were high throughout the year, except in March and April, early summer months (Figure 3).

Malaria endemicity differed from township to township. However, all townships showed a decreasing trend. The township with the highest mortality rate (18.0/100,000 population) in 2000 had no malaria death for two consecutive years (2013-2014) (Figures 4 and 5).

In Rathedaung Township, though the highest MPR resulted as 42.6% in 2014 (Figure 6), the ABER was only 1.7%. The lowest positivity rate was found in Manauang Township (1.3%). Ann Township revealed the highest ABER of 40.6% and the MPR as only 15.6%.

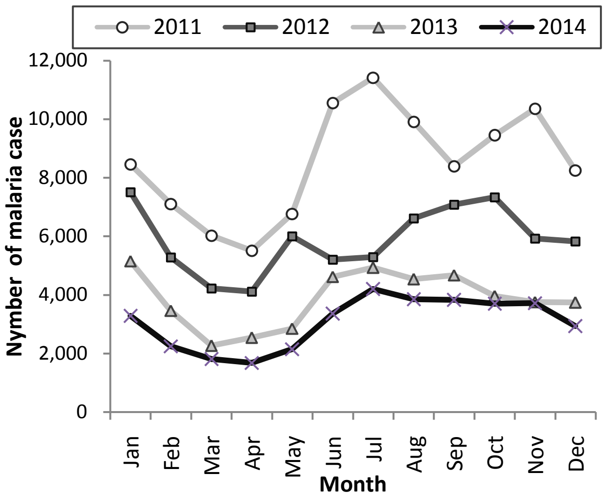

Figure 3. Malaria cases by months in Rakhine State, Myanmar, 2011-2014

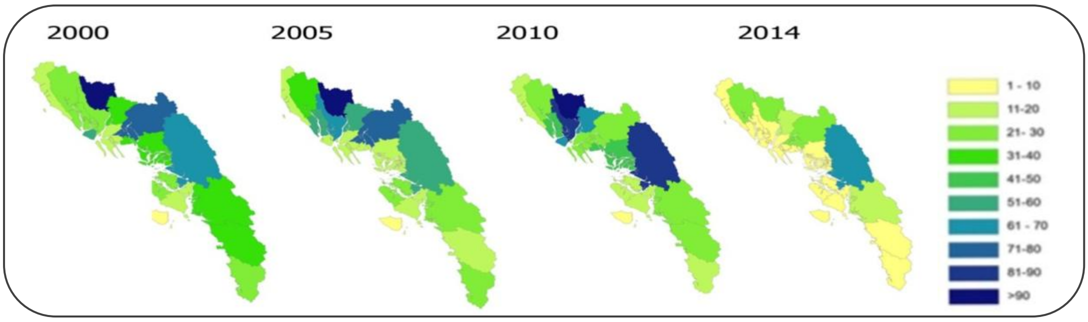

Figure 4. Malaria morbidity rates per 1,000 population by townships in Rakhine State, Myanmar, 2000-2014

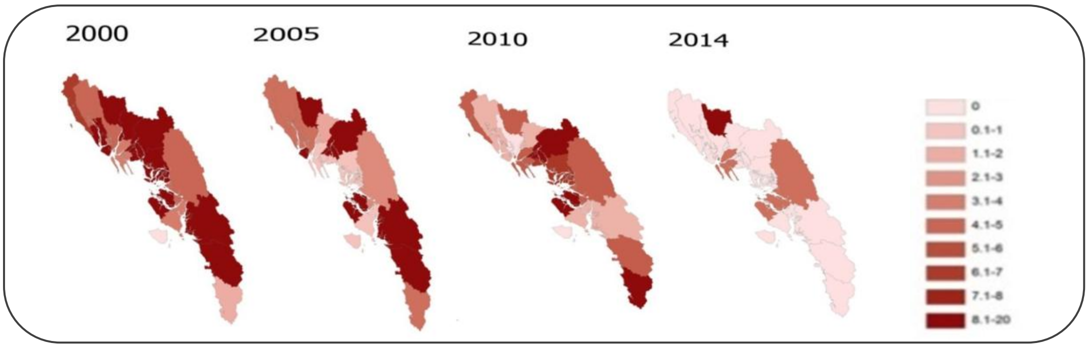

Figure 5. Malaria mortality rates per 100,000 population by townships in Rakhine State, Myanmar, 2000-2014

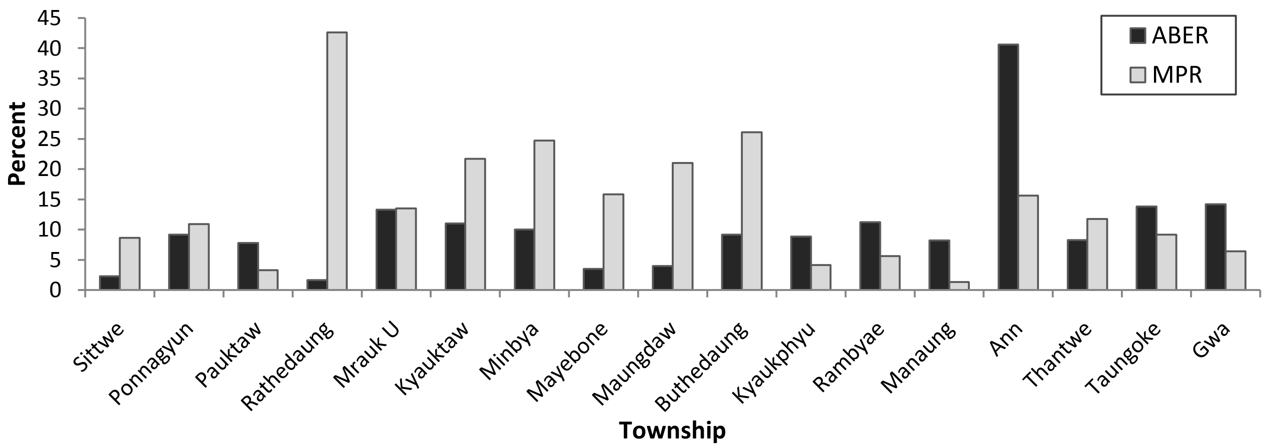

Figure 6. Malaria positivity rate (MPR) and annual blood examination rate (ABER) by townships in Rakhine State, Myanmar, 2014

During 2011-2014, the proportion of malaria cases in males was much higher than that in females. In 2014, the proportions of malaria in males and females were 70% and 30% respectively. The proportions of confirmed malaria cases in under 1-year and 1-4-year old groups in Rakhine State were 8.7% of the total cases. The proportion of malaria in under one year old group was 1.9% in 2011 and 0.7% in 2014. Among 1-4 years old children, it was 11.6% in 2011 and 8.0% in 2014. Of the 5-9 year old group, it was 13.7% in 2011 and 10.2% in 2014 (Figure 7).

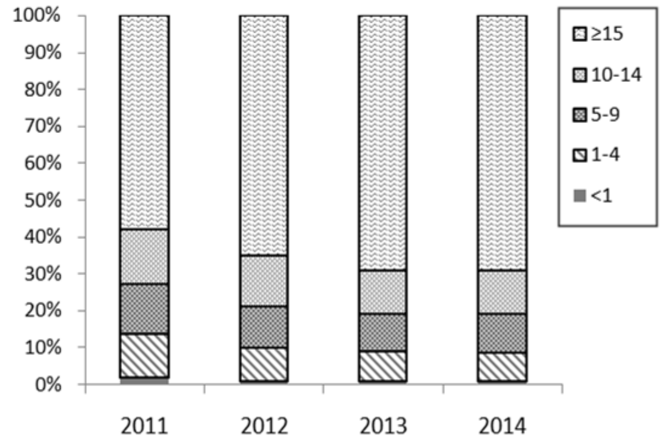

Figure 7. Yearly proportion of malaria cases by age groups in Rakhine State, Myanmar, 2011-2014

There was no malaria death in less than 1-year age group. The highest case-fatality rate was in the 1-4 age group. In 2014, CFR of 1-4 year old group was 0.1%. Malaria case management was performed not only in health facilities but also in the community level by volunteers trained by the National Malaria Control Programme. International NGOs and local NGOs also conducted case management through mobile and fixed clinics. In 2011, 19,488 cases (15.7%) were treated by NGOs and only 1.7% were treated by volunteers. The proportion of cases treated by volunteers increased year by year. In 2014, 56.2% of cases were treated at health facilities, 27.9% were treated by volunteers and 15.9% were treated by NGOs (Figure 8).

Number of malaria cases diagnosed by microscope and RDT were nearly the same in 2011. However, number of cases examined by microscope reduced year by year and only 14,015 (7.0%) of cases were examined by microscopy in 2014. Proportion of *P. falciparum* malaria parasite was higher than *P. vivax* diagnosed by both microscopy and RDT. In 2014, 72.4% of malaria cases identified by microscopy and 82.4% of those tested by RDT were *P. falciparum* (Figure 9 and table 1).

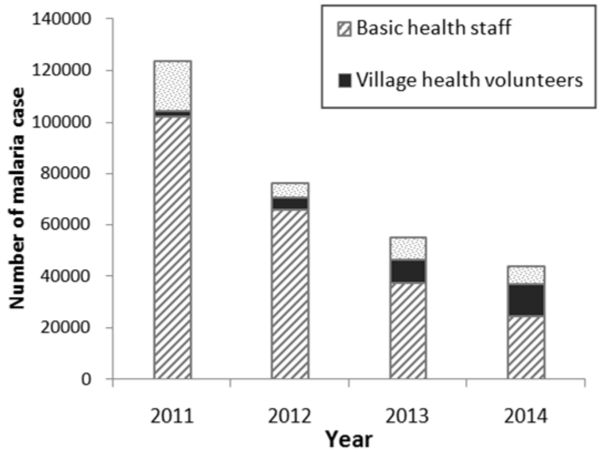

Figure 8. Malaria cases treated by different services in Rakhine State, Myanmar, 2011-2014

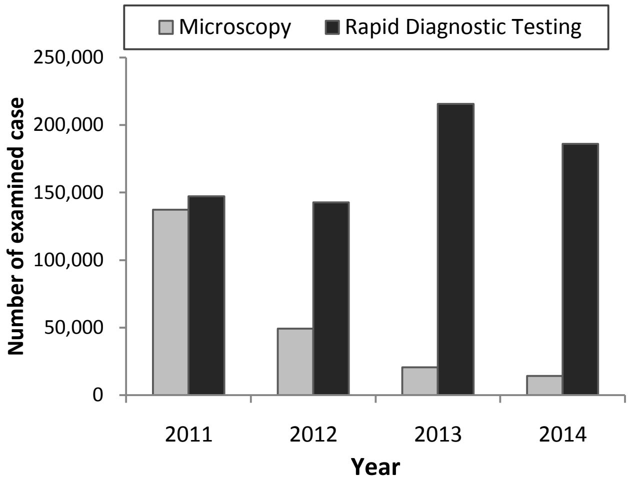

Figure 9. Number of examined cases by type of diagnosis in Rakhine State, Myanmar, 2011-2014

Table 1. Diagnostic method and malaria species distribution in Rakhine State, Myanmar, 2014

Year	Diagnostic method	Total number examined (%)	Number of positive case (%)			
			Plasmodium falciparum	*Plasmodium vivax*	Mixed	*Plasmodium malariae/ Plasmodium ovale*
2011	Microscopy	137,320 (48.3)	19,799 (56.0)	14,386 (40.7)	1,037 (2.9)	137 (0.4)
	Rapid test	147,203 (51.7)	49,053 (73.3)	14,034(21.0)	3,789 (5.7)	
2012	Microscopy	49,163 (25.6)	7,953 (63.9)	4,237 (34.1)	195 (1.6)	52 (0.4)
	Rapid test	142,797 (74.4)	45,146 (78.2)	9,446 (16.4)	3,176 (5.5)	
2013	Microscopy	20,533 (8.7)	2,685 (71.0)	948 (25.1)	130 (3.4)	21 (0.5)
	Rapid test	215,668 (91.3)	34,539 (81.8)	6,650 (15.6)	1,553 (3.6)	
2014	Microscopy	14,105 (7.0)	985 (72.4)	301 (22.1)	75 (5.5)	0 (0.0)
	Rapid test	186,076 (93.0)	29,240 (82.4)	4,932 (13.9)	1,293 (3.6)	

Discussion

The malaria morbidity and mortality rates in Rakhine State reduced during 2000-2014. After the introduction of RDT (*P. falciparum* only), more cases could be examined at peripheral levels and probable cases were included as malaria cases. Therefore, the morbidity did not significantly reduce between 2008 and 2011. After that the RDT which could examine both *P. falciparum* and *P. vivax* was used. All malaria cases were then confirmed cases and no more probable and suspected cases, giving the markedly reduction of morbidity.

Community case management activities by volunteer in Rakhine State started in 2009.[5] Therefore, early diagnosis and treatment could be done not only in health facilities, but also in the village level by volunteers, which significantly contributed to the reduction in the morbidity and mortality after 2011. Reduction in case fatality rate of malaria was likely a result of early diagnosis and treatment.[4] The seasonal pattern of transmission was not observed with the reduction of malaria transmission. Instead, a more constant level of perennial transmission was observed.

Malaria morbidity and mortality differed from township to township and might be due to different ecological conditions of the townships.[4] Even though the morbidity and mortality reduced by year, some townships still had high morbidity. Malaria mortality rate was high in many townships in 2000. However, in 2014, only a few townships had malaria death cases. Malaria positivity rate is one of the indicators in malaria control.[6]

In Rathedaung Township, the positivity rate was high even though the morbidity rate was not high in 2014. It might be due to the blood examination performed only in the suspected cases. When the disease burden becomes low, all cases should be find out to remove the residual parasite for transmission interruption.[6] In Ann Township, annual blood examination rate was high and the positivity rate was also high, indicating the high burden of malaria in the township.

The main economy of the state is forest-related works.[4] It was found that predominance of males among malaria cases might be due to their occupational exposure. Studies in Vietnam also showed that regular forest activities was the main factor for malaria infection.[7,8] The information on case's occupation could not be found from monthly report and it was a limitation of this study. In Myanmar, malaria cases occurred mainly in the age group of 15 years and above, and only about 4% were in age under-5-year old group.[9] In Rakhine State, about 10% of total cases occurred in children under five years old, which was a high burden of disease in the state. The proportion of malaria cases among under five children indicates the local transmission since children usually stay home.

Contribution of case detection by volunteers increased by year and might be due to the fact that malaria cases were more detected in hard-to-reach areas where health services were not available. From 2011 onwards, the RDT which could detect both *P. falciparum* and *P. vivax* were distributed. Health staff might prefer to use RDT, which increased the number of examined cases by RDT and decreased cases examined by microscopy in recent year.

Although the number of cases reduced in both *P. falciparum* and *P. vivax* cases, proportion of *P. falciparum* malaria was high in both microscopy and RDT. It might be due to higher incidence of *P. falciparum* compared to *P. vivax* in Rakhine.[2]

The highest malaria burden is found in Rakhine State compared with other states and regions[3]. Malaria morbidity and mortality rates reduced markedly and need to be sustained.

Public Health Recommendations

Since early case finding and treatment are major contributed factors[10], this program should be strengthened such as increased active case finding or training of more volunteers in rural remote areas. Community case management activity through volunteers should also be expanded and covered in high risk areas[11].

As the townships of Ann, Kyauktaw, Mrauk U, Minbya and Butheaung remained high malaria burden, control activities should be prioritized in these area. More prevention and control measures and locally appropriate vector control measures should also be considered in these townships. For malaria elimination, MPR is needed to achieve less than 5% in order to shift from the control to the pre-elimination phase,[9] for which, the ABER should also be considered. The township with very low ABER and high MPR should examine more patients, especially those with fever to get actual malaria positive rate. To increase ABER, malaria diagnosis should be scaled up and all fever cases should be screened in all health facilities.

Factors related to male predominance in malaria should be investigated. If it was due to occupational exposure, specific measures to prevent the exposure should also be considered. To reduce the case fatality rate in children, rectal artesunate could be provided for pre-referral treatment.

Conclusions

Reductions in malaria morbidity and mortality were strongly related to early detection and treatment of cases. Therefore, efforts to detect and treat cases early should be a high priority in townships with high MPR and low ABER. The efforts would reduce the burden of malaria illness in Myanmar.

Suggested Citation

Khine SK, Swaddiwudhipong W, Lwin NN, Timasarn K, Hlaing T. Epidemiological situation of malaria in Rakhine State, Myanmar during 2000-2014. OSIR. 2017 Sep;10(3):16-21.

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The Grammar of Science: Let's 'Log' (Part 2)

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Part 1 of this paper is available at:

Kaewkungwal J. The grammar of science: let's 'log' (Part 1). OSIR. 2017 Jun;10(4):23-27.

Last time, we have shown how 'Log" play roles in mathematics and statistics. Now we will take a close look at how it applies in data management and analysis.

Statisticians also love "log transformed" data

Many statistical procedures have the assumption that the variables in the model should be normally distributed. A significant violation of the assumption can increase errors in study conclusion, depending on the nature of the methods used and the level of non-normality[1]. Even though we can avoid such limitation by using non-parametric statistics that has no explicit assumption about normality, we may sometimes still face with inconclusive results due to the effect of severe non-normally distributed data[2-3].

When our data are not normal, we should explore the reasons behind it. The non-normality may be due to mistakes in data entry (not real extreme-value data), presence of outliers, or the nature of the variable itself. Let's look only at the issue of the latter case where skewedness is due to the nature of variable itself. There are variables in biomedical and clinical study that are almost always not normal, e.g., viral load, titre, length of stay in hospital admission, survival time, etc. But we want to use statistical procedures that require normality assumption for those variables. One way to do it and most commonly used is to do "data transformation" or changing the scale of the data. Data transformation is not cheating, but rather look at data in another way, for example, we can say that 4 is equivalent to square-root of 16 ($\sqrt{16}$). When we change the scale of the data, the distribution will change; generally the extreme values will be pulled closer, e.g., $\sqrt{9}\rightarrow 3$, $\sqrt{16}\rightarrow 4$, $\sqrt{25}\rightarrow 5$. There are many valid reasons for utilizing data transformations, not only for changing the non-normality characteristics but also for improving variance stabilization, conversion of scales to interval measurement, etc.[1-4]

Three data transformations most commonly used in handling non-normality included: square root, logarithm, and inverse. If the distribution of a variable has a positive skew, "log transformation" will usually be used to make that positively skewed distribution to be more approximately normal[4]. As an example, if we plot the histogram of viral load collected from HIV-infected patients, we will see a significant right skew in this data (most patients had low amount of viral loads but a few had extreme amount of viral loads). After we "take log" of the raw data of viral loads, then we plot the histogram of the logarithm of viral loads, we now see a distribution that looks much more like a normal distribution as shown in figure 1.

Data Transformation : Raw data vs. Log-scale data

id	Viral load (cpm)	Log10(Viral load)
1.	404	2.61
2.	472	2.67
3.	573	2.76
4.	948	2.98
5.	1135	3.05
::	::	::
76.	19417	4.29
77.	19665	4.29
78.	20008	4.30
79.	20180	4.30
80.	20465	4.31
::	::	::
190.	292056	5.47
191.	294796	5.47
192.	426080	5.63
193.	601630	5.78
194.	1534830	6.19

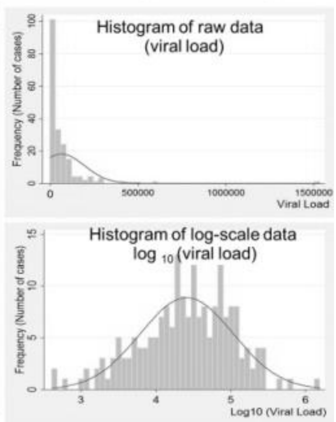

Figure 1. Data transformation in Log base 10 scale (Viral load of HIV patients)

In this example, we took log base 10, but we could take "natural log" or log of other bases and getting somewhat similar normality pattern from different scaling of data transformation. However, when we interpret the results of the statistical procedures, we have to explain that transformed variable in log-scale, or we have to "anti-logarithm" the results of that variable back to original scale ($\log_{10}X \rightarrow 10^X$, $\ln(X) = \log_e X \rightarrow e^X$, etc)

What is "Logit" in logistic regression?

Before we talk about "logit" in "Logistic regression", let's start with the basic "Linear Regression". Linear regression is a statistical technique for relating the outcome or dependent variable (Y) to one or more predictors or exploratory/independent variables (X). The model is based on a linear relationship between the expected value of Y (y-hat) and each independent variable (when the other independent variables are held fixed)[5].

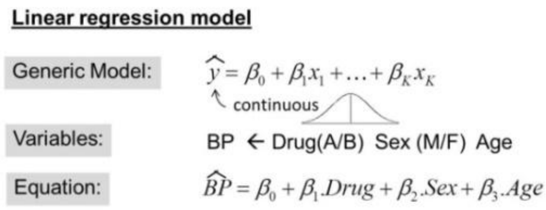

Figure 2. Linear regression model

As shown in figure 2, the "structural model" (generic model) would tell us that when exploratory variable (X) change for 1 unit, the outcome Y would change about β (after controlled for or adjusted for other exploratory variables in the equation). In other words, the structural model describes how the mean response of Y changes with X[5-7]. Based on the example of variables in linear regression equation in figure 2, we can say that the mean differences of blood pressure (BP) between patients taking Drug A vs. Drug B is about β_1; between male vs. female patients, about β_2; and between those ages difference of 1 year, about β_3.

There are several assumptions in fitting the linear regression model. Historically, the normal distribution had a pivotal role in the development of regression analysis and it continues to play an important role[6]. Assumptions about outcome variables are that Y should be normally distributed and variance of Y should be constant[5-8]. When the variance of the Y is not constant, it will lead to violation of another assumption that the error variance in the model becomes not constant (or a fancy term - assumption about homoscedasticity in Y). The assumption about error variance, so-called the "error model", indicates that for each particular X, if we have or could collect many subjects with that x value, their distribution around the population mean should also be normally distributed. The error model suggests that the linear regression not only assumes "normality" and "equal variance", but also the assumption of "fixed-X" (i.e., the explanatory variable is measured without error)[7-8].

When the assumptions are significantly violated, the results of the analysis may be incorrect or misleading. For example, if the assumption of independence of variables in the model is violated, then model may not be appropriate. If the assumption of normality is violated, or outliers are present, then the linear regression goodness of fit test may not be the most powerful or informative test available[5,7].

When we encounter a problem with the equal variance or normality assumptions, we may solve it by using data transformation either using log(y) or y^2 or $\sqrt{y}$ or 1/y instead of y for the outcome. But if we get into non-linearity relationship between exploratory and outcome variables, we may try transformation of X, Y, or both. In fact, this generic model written as "linear" in "linear regression" does not imply that it can apply for only linear relationships. If we transformed X or Y then we could assess non-linear relationships to be represented on a new scale that makes the relationship linear. However, technically the β's must not be in a transformed form[7-8].

Now let's discuss about "logistic regression".

The logistic regression model is a statistical technique for presenting the relation between a binary response or a multinomial response/outcome (Y) and several predictors or exploratory variables (X)[9]. This type of outcome is very common in the field of health science and others, say die - not die, cured - not cured, mild – moderate – severe, etc. Historically, the "logistic function" was originally invented for the purpose of describing the population growth and it was evolving by many statisticians in several academic fields in the US and European. The "logistic regression" name was given by a Belgian mathematician, Pierre François Verhulst (1804-1849)[10].

We could say that the emergence of the logistic function started from the growth curve and mathematically it was evolved making it a close resemblance to the normal distribution function[10,11].To make it easier in explaining the basic concept of logistic regression, let's follow the same idea of linear regression. The model is based on the same generic model of linear relationship between the expected value of outcome Y (y-hat) and each exploratory variable (when the other exploratory variables are held fixed). The difference is that Y in linear regression is continuous but Y is logistic regression is categorical.

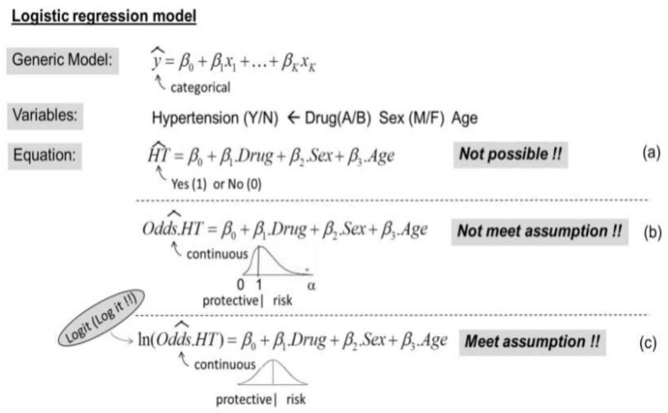

Figure 3. Logistic regression model

Figure 3 presents an example of logistic regression model of binary outcome. We now don't want to know the expected value of BP like in linear regression but we want to assess the expected value of hypertension (HT), whether the person has or do not have HT, coding as 1 and 0, respectively. As shown in equation (a), it is not possible mathematically to get expected value of Y (as 0 or 1) from the calculation of known values of Xs and the estimated β's in the equation.

The problems are also about the assumptions of the generic model. As previously mentioned the main assumptions of linear regression are about the "error model" that the errors or residuals (distances of each X around the expected mean of Y) are normally distributed and Y does have to be continuous and measured on an interval or ratio scale[5-8]. Unfortunately, our Y (HT) now is a categorical variable and it could not fit these assumptions. No matter what data transformations, we could not get normal residuals from a model with a categorical response variable[12-14].

Since we cannot use the equation to get the expected value Y of 0/1, we then say that we want to use the equation to explain the "odds" of getting the outcome Y[14-16]. "Odds" is defined as the probability (p) that the event Y occurs (Y=1) over the probability (1-p) that the event Y does not occur (Y=0). "Odds" is (p/1-p). As shown in figure 4, "odds" is now a continuous number, ranging from 0 to infinity. But we still have a problem about the model assumption! Let's look at the concept of "odds". When we have 100 people walk by and 50 of them have the disease (Y occur) and 50 do not have the disease (Y not occur), the odds will be (50/100)/(50/100) = 1. When we have 10 people walk by and 9 of them have the disease and 1 do not have the disease, the odds will be (9/10)/(1/10) = 9. On the opposite scenario, When we have 10 people walk by and 1 of them have the disease and 9 do not have the disease, the odds will be (1/10) / (9/10) = 0.1111.

P/(1-P)		Odds		Log_{10}(Odds)		Log_e(Odds)
00001/99999	0	0.00001	-∞	-5.0000	-∞	-11.5129
0001/9999	↑	0.00010	↑	-4.0000	↑	-9.2102
001/999		0.00100		-2.9996		-6.9068
01/99		0.01010		-1.9956		-4.5951
1/9		0.11111		-0.9542		-2.1972
50/50	1	1	0	0.0000	0	0.0000
9/1		9		0.9542		2.1972
99/01		99		1.9956		4.5951
999/001		999		2.9996		6.9068
9999/0001	↓	9999	↓	4.0000	↓	9.2102
99999/00001	+∞	99999	+∞	5.0000	+∞	11.5129

Figure 4. Odd and Log (odds)

Back to the regression model, as shown in equation (b) of figure 3, we now can substitute the values of Xs and the estimated β's to calculate for outcome that is now continuous. But the assumption still does not hold regarding normally distributed of errors and non-linearity of the model. This is because our outcome (odds of Y) is still not normal due the fact that "odds' is positive skewed, ranging from 0-1 for protective side (fewer subjects have the outcome Y) and 1-infinity for risk side (more subjects have the outcome). So equation (b) is not quite appropriate and does meet the basic assumptions.

What can we do? Back to what we discussed before, when linearity fails to hold, even approximately, it may be possible to transform the variables in the regression model to improve the linearity. And if regression on the transformed scale appears to meet the assumptions of linear regression, then we may decide go with the transformations[4-12]. Again, when the data is positively skewed, logarithm is the common way that statisticians use to make the data normally distributed. Regression attempts to model the relationship between exploratory and outcome variables by fitting an equation to observed data. The "logarithm" concept is also about relationship between time and growth. The analogy is that in logarithm we ask "as time change, how much is the growth" and in regression "as an exploratory variable (X) changes, how much is the outcome (Y)". As shown in figure 4, the "odds" after transformed into log scale, either common or natural log would become approximately normally distributed.

The final equation (c) in figure 3 then appears to meet the assumptions. The expected outcome Y is now ln(odds), so-called "logit" term. Thus the logistic regression model is simply a non-linear transformation of the linear regression[13-14].

So we can now tell that when exploratory variable (X) change for 1 unit, the ln(odds) of having the outcome Y would change about β (after controlled for or adjusted for other exploratory variables in the equation). Based on the example of variables in the logistic regression equation in figure 3, we can say that the ln(odds) or ln(p/1-p) of having HT between patients taking Drug A vs. Drug B is about β_1; between male vs. female patients, about β_2; and between those ages difference of 1 year, about β_3.

But how do we tell the patients - if they take Drug A, their ln(odds) to have HT is β_1? No patients will understand that! To make it meaningful – let's simply focus on effect of Drug on odds of getting HT as shown in figure 5. If you take Drug A (code 1), the equation will tell you that ln(odds of HT) = $\beta_0+\beta_1$; but If you take Drug B (code 0), the equation will tell you that ln(odds of HT) = β_0. That means, ln(odds) of the two groups are different by β_1. Solving the equation of subtraction of ln(odds) of the two groups, we get division in log scale (conversion rules between division and subtraction!). The odds of group 1 (Drug A) vs. odds of group 0 (Drug B) is called "odds ratio" (OR). This OR will tell us how much the two groups are different in terms of chance to get HT over chance of not getting HT.

But still based on solving the equation (a)-(b) as shown in figure 5, we do not yet have OR, but have ln(OR) =β_1. No patients will understand that ln(OR)! In most cases, when we report the result, we have to "back transform" the expected value (point estimates and its confidence intervals) from the model for better interpretability. The "back transform" is the inverse of the transformation to return to the original scale; that is, the antilogarithm. In case of this logistic regression model, the inversion of the equation, ln(OR) =β_1, becomes OR = $e^{\beta 1}$. Thus, after we estimate β_1 by fitting the logistic regression model, we can then simply exponential it. And we now can explain to our patients how much the two groups are different in terms of their odds of having the outcome!

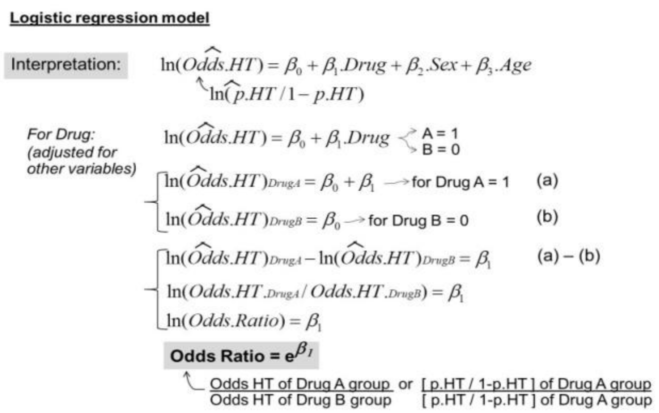

Figure 5. Interpretation of logistic regression model

Beyond "Log"

Logarithm is used a lot more in different statistical techniques. Some make argument on the limitation of "logarithm" that it cannot handle negative numbers. But Euler had once said "To those who ask what the infinitely small quantity in mathematics is, we answer that it is actually zero. Hence there are not so many mysteries hidden in this concept as they are usually believed to be."

Since natural logarithm is used quite often to explain relationship of changes, I would like to end this "Let's Log" with Euler's equation that is considered as the "beautiful equation"[17] of all and proved to be true, $e^{i\pi}$ - 1 = 0. Interestingly, 1 and 0 are real numbers, e and π are irrational numbers (values that can't be given precisely in decimal notation) and i is the "imaginary" number which is √ -1 (mathematically invented imaginary number as doubling -1 can never get -1). An imaginary number seems strange but getting real number from the power (inverse of logarithm) of an imaginary number and irrational numbers is even awesome (rockin!).

Suggested Citation

Kaewkungwal J. The grammar of science: let's 'log' (Part 2). OSIR. 2017 Sep;10(3):22-26.

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