

HEALTHCARE WORKERS' KNOWLEDGE AND PRACTICES REGARDING EXPANDED PROGRAM ON IMMUNIZATION IN KALASIN, THAILAND

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ABSTRACT

Primary vaccine failures can occur after high immunization coverage has been achieved. Healthcare workers' knowledge and practices are influential factors in preventing vaccine failures. Adequate knowledge and practices in the cold chain system are important to keep potency of vaccines and effectiveness of immunization. This cross-sectional study was performed to assess healthcare workers' knowledge and practices regarding an expanded program on immunization and the cold chain system in Kalasin, Thailand. Data collection methods included interviews, observations and document audit. Ninety primary care units and 117 respondents were selected. Only 55.6% of respondents provided correct answers for questions regarding the immunization schedule of school children and 59.0% of respondents answered correctly for questions about Measles-Mumps-Rubella Vaccine. Healthcare workers in hospitals had better knowledge than healthcare workers in health centers ($P<0.001$). Healthcare workers who had sufficient training had better knowledge than healthcare workers who had no training ($P<0.001$). Only 61.1% of primary care units recorded the temperature in the vaccine refrigerator twice a day and 63.3% of primary care units had a flowchart regarding what to do when there is an electric power failure. About 13% of vaccine refrigerators had temperatures outside the recommended range of 2 to 8°C. Practices in hospitals were also better than those in health centers ($P=0.001$). Knowledge and practices were significantly different between healthcare workers in hospitals and in health centers. Coverage training and regular supervision on vaccine handling and the cold chain system are recommended, especially for health centers in remote areas.

Key Words: Expanded program on immunization, Cold chain system, Knowledge, Practices, Thailand

INTRODUCTION

An expanded program on immunization (EPI) was launched in 1974 by the World Health Organization (WHO) with the aim of controlling vaccine-preventable diseases, such as tuberculosis, diphtheria, pertussis, tetanus, polio and measles.^{1,2} Immunization has been proved to be one of the most cost-effective parts of health promotion since in many countries after achieving high immunization coverage, the morbidity and mortality rates of vaccine-preventable diseases tended to decline.^{3,4} On the other hand, vaccine-preventable diseases have remained a serious concern

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in some areas where immunization coverage is not high.⁵⁻⁷⁾ In 2008, WHO ascertained that the number of deaths due to vaccine-preventable diseases among children under five years from all over the world was about 1.7 million per year, and most of the deaths were in developing countries.⁸⁾

Published studies have shown inadequate knowledge and practices of healthcare workers regarding EPI and the cold chain system in many places in the world, especially in remote areas.⁹⁻¹²⁾ A previous study found that increasing knowledge regarding EPI and the cold chain system for personnel could increase vaccination coverage and increase the efficiency of EPI and cold chain practices.¹³⁾ A cold chain is a system for storing and transporting vaccines in a potent state from the manufacturer to the person being immunized. The cold chain system comprises three major elements: personnel, equipment and procedures.²⁾ Some published studies found that vaccine-preventable disease outbreaks in areas that had high immunization coverage may have occurred due to primary vaccine failure.¹⁴⁻¹⁶⁾ Vaccine failure can be divided into two categories: primary and secondary vaccine failure. Primary vaccine failure means no immunity after immunization due to lack of initial seroconversion. Secondary vaccine failure means loss of immunity after initial seroconversion.^{17,18)} Primary vaccine failure can happen by either inactive vaccine or inadequate host response. Insufficient cold chain system and practices are possible causes of primary vaccine failure due to inactive vaccines.^{19,20)}

Thailand is a country in Southeast Asia that is administratively divided into 76 provinces which are further divided into districts and sub districts, respectively. EPI has been integrated into the healthcare service system of Thailand since 1977.^{21,22)} Thailand achieved high immunization coverage rates for Bacillus Calmette-Guérin vaccine (BCG), Diphtheria–Pertussis-Tetanus vaccine (DPT), Oral Polio vaccine (OPV) and Measles of 99, 99, 99 and 98 percent, respectively, although there are still reported cases of vaccine-preventable diseases.^{23,24)}

There has been no published study about healthcare workers' knowledge and practices regarding EPI and the cold chain system in Kalasin Province. Therefore, it is necessary to conduct this study with the objective of assessing healthcare workers' knowledge and practices regarding EPI and the cold chain system at health centers and hospitals in Kalasin Province.

MATERIALS AND METHODS

This cross-sectional study was conducted in Kalasin Province during July to September 2010. There was one general hospital in the central area of the province, and 13 community hospitals in the central area of the districts. In outlying areas in sub districts there were 157 health centers. All of those facilities together provided healthcare services covering 950,000 people in 18 districts of Kalasin Province.²⁵⁾

In Thailand the primary care unit (PCU) provides primary healthcare services, such as immunization, health promotion and antenatal care. In hospitals, the PCU is a department of the hospital, but at health centers the PCU means the whole health center. There are 171 PCUs in Kalasin Province.

A total of 90 PCUs were selected. We selected 76 units from the health centers by simple random sampling and all 14 units from the hospitals were selected. In the 76 health centers, one healthcare worker who was responsible for EPI was selected by random sampling from each health center. In hospitals, 41 healthcare workers were selected from among all personnel responsible for EPI and were present in the office on the visit day. Since there were only 14 hospitals in Kalasin Province, we then collected data from all hospitals this way to increase the sample size inside central areas.

Our questionnaire and checklist were adapted from the questionnaire and checklist of the Disease Control Department, Thailand Ministry of Public Health (MoPH). The MoPH questionnaire and checklist were usually used for EPI's supervision activities in Thailand. MoPH also used that questionnaire to evaluate healthcare workers' knowledge after training regarding EPI and cold chain management. MoPH experts conducted the questionnaire and handled the checklist based on the cold chain training manual for health workers produced by WHO. The questionnaire consisted of two sections as follows. 1. General information and demographic characteristics of respondents. 2. Knowledge regarding EPI and the cold chain system of respondents. The checklist had three sections as follows. 1. Practice in cold chain system and equipment. 2. Immunization registers and report system. 3. Manual and Guidelines for EPI and cold chain management that were produced and distributed to PCUs by MoPH. The staff from the Health Promotion Division of the Kalasin Public Health Offices went to PCUs and used the questionnaire to collect data about knowledge regarding EPI and the cold chain system and used the checklist for direct observation and document audit about practices and equipment regarding EPI and the cold chain system.

Collected data were analyzed using the Statistical Package for Social Science (SPSS) program version 16.0 (SPSS Inc., Chicago, IL, USA). Frequencies, percentages, mean and median were used to describe demographic characteristics, knowledge and practices. Knowledge and practices were assigned a score of 1 and 0 for correct and false responses, respectively. Total score of knowledge and total score of practices were calculated. Independent *t*-test was used to compare means of total scores. In cases where the distribution of total scores by healthcare worker characteristics was not normal, the Mann-Whitney U test was used to compare the median instead of the Independent *t*-test. Normality of distribution of data was assessed by the Kolmogorov-Smirnov test. Chi-square analyses were used to compare categorical variables, and a P value of < 0.05 was considered statistically significant. Permission to collect data for this study was approved by the Kalasin provincial chief medical officer who was the chief executive officer of the MoPH, Thailand at the provincial level.

RESULTS

General information of respondents

Table 1 shows the characteristics of the 117 respondents, 90.6% of whom had a bachelor degree level of education and the rest had master degree level. 78.6% of respondents were nurses and 61.5% of respondents had work experience in EPI services of less than 2 years. Approximately 20% had no training regarding EPI and the cold chain system. In total, among 23 respondents with no training, 22 worked in health centers.

Knowledge

From 15 questions about knowledge regarding EPI and the cold chain system, our study revealed that questions with few correct answers concerned dose and route of DPT (63.2%), dose and route of measles vaccine (64.1%), and dose and route of measles-mumps-rubella vaccine (MMR) (59%). A vaccination interval longer than scheduled will not decrease the effect of immunity (60.7%). A person who comes late on the schedule can receive his or her next vaccination; it is not necessary to restart (63.2%). An immunization schedule is in place for schoolchildren (55.6%), and if vaccinations cannot be started on time per schedule, they should begin as soon as possible (61.5%). Details are summarized in Table 2.

The total score of knowledge from the 15 questions were calculated. The mean total score

Table 1 Demographics of respondents

Factors	No. of respondents (N = 117)	Percentage
Level of education		
Bachelor degree	106	90.6
Master degree	11	9.4
Position		
Public health officer	25	21.4
Nurse	92	78.6
Years of service		
< 2 year	72	61.5
≥ 2 years	45	38.5
EPI ^a training		
Yes	94	80.3
No	23	19.7

^a EPI = Expanded program on immunization

Table 2 Correct answers about EPI knowledge of respondents

Questions	Number (percentage)			Number (percentage)			Total N=117
	Health center	Hospital	P	No training	Have training	P	
	n=76	n=41		n=23	n=94		
Dose and route of vaccine tetanus in pregnancy	60 (78.9)	38 (92.7)	.055	18 (78.3)	80 (85.1)	0.527	98 (83.8)
Dose and route of vaccine Japanese encephalitis	42 (55.3)	37 (90.2)	<.001	12 (52.2)	67 (71.3)	.080	79 (67.5)
Dose and route of vaccine BCG	53 (69.7)	39 (95.1)	.001	13 (56.5)	79 (84.0)	.009	92 (78.6)
Dose and route of vaccine Hepatitis B	44 (57.9)	36 (87.8)	.001	8 (34.8)	72 (76.6)	<.001	80 (68.4)
Dose and route of vaccine DPT	39 (51.3)	35 (85.4)	<.001	4 (17.4)	70 (74.5)	<.001	74 (63.2)
Dose and route of vaccine Measles	42 (55.3)	33 (80.5)	.007	7 (30.4)	68 (72.3)	<.001	75 (64.1)
Dose and route of vaccine MMR	32 (42.1)	37 (90.2)	<.001	5 (21.1)	64 (68.1)	<.001	69 (59.0)
Vaccinated interval longer than scheduled, no decreased effect of immunity	38 (50.0)	33 (80.5)	.001	8 (34.8)	63 (67.0)	.005	71 (60.7)
Low-grade fever person can receive vaccination	54 (71.1)	31 (75.6)	0.598	10 (43.5)	75 (79.8)	<.001	85 (72.6)
No need to restart if vaccination is late	42 (55.3)	32 (78.0)	.015	5 (21.1)	69 (73.4)	<.001	74 (63.2)
DPT loses potency by freezing	43 (56.6)	34 (82.9)	.004	9 (39.1)	68 (72.3)	.003	77 (65.8)
Immunization schedule of schoolchildren	36 (47.4)	29 (70.7)	.015	8 (34.8)	57 (60.6)	.025	65 (55.6)
Asymptomatic HIV child can receive vaccine	52 (68.4)	29 (70.7)	0.796	9 (39.1)	72 (76.6)	<.001	81 (69.2)
Must use open vaccine within 24 hr	46 (60.5)	31 (75.6)	0.101	6 (26.1)	71 (75.5)	<.001	77 (65.8)
If cannot start on time, begin vaccination as soon as possible	40 (52.6)	32 (78.0)	.007	11 (47.8)	61 (64.9)	0.132	72 (61.5)

BCG = Bacillus Calmette-Guérin; DPT = Diphtheria-Pertussis-Tetanus; MMR = Measles-Mumps-Rubella; EPI = Expanded program on immunization

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Table 3 Compare mean and median of total score of knowledge regarding EPI

Variables	n	(Total score = 15)		P
		Mean (SD)	Median (IQR)	
Workplace ^a				
Health center	76	8.72 (2.97)	9 (4.75)	
Hospital	41	11.07 (2.35)	11 (3.50)	< .001
Work experience ^a				
< 2 years	72	8.65 (2.96)	9 (5.00)	
≥ 2 years	45	10.97 (2.44)	11 (4.00)	< .001
Training ^b				
No training	23	5.60 (1.72)	5 (2.00)	
Have training	94	10.51 (2.37)	10 (3.00)	< .001
Position ^b				
Public health officer	25	8.84 (2.89)	9 (5.00)	
Nurse	92	9.73 (2.99)	10 (4.75)	0.215

^a Use Student's *t*-test (compare mean)

^b Use Mann-Whitney U test (compare median)

EPI = Expanded program on immunization

was 9.54. Maximum score and minimum score were 15 and 3, respectively. In Table 3, the mean and median total score of knowledge regarding EPI and the cold chain system were compared by Student's *t*-test and Mann-Whitney U test, respectively. Comparisons showed that the mean total score in the group of respondents who worked in hospitals was significantly higher than in those who worked in health centers, the mean in the group with work experience of more than or equal to two years was significantly higher than in the group of respondents who had experience of less than two years. The group of respondents who had training regarding EPI and the cold chain system also had a significantly higher median total score than in the group with no training.

Practices

The findings from direct observation about equipment and practices regarding the cold chain system in PCUs are summarized in Table 4. We found that 100% of PCUs had no expired vaccines in refrigerators and in 86.7% of PCUs the temperature inside refrigerators was in the range of 2–8°C. A total of 95.6% of PCUs that kept OPV on the freezer shelf, and 100% of PCUs kept DPT, diphtheria-tetanus vaccine (DT) and hepatitis B vaccine on the normal shelf.

Only 47.8% of PCUs maintained stock cards for vaccines and 61.1% of PCUs had a temperature chart and recorded the temperature inside the refrigerator 2 times daily. Only 63.3% of PCUs had a flowchart about what to do in case of a power outage, and 65.6% of PCUs had a special plug for refrigerators.

Table 5 shows practices of PCUs regarding immunization records and registers. The number of PCUs that had an immunization register for every target groups was as follows: 83.3% in the group of children below five years, 70% in the group of pregnant women and 66.7% in the group of school-age children. Otherwise, the details of records such as lot numbers of used DT vaccines were recorded by only 55.6% of PCUs, the vial numbers of used MMR vaccines were

Table 4 Correct practices regarding cold chain system and equipment in PCU

Variables	Number (percentage)			P
	Health center n=76	Hospital n=14	Both N=90	
No expired vaccine found in refrigerator	76 (100.0)	14 (100.0)	90 (100.0)	–
Have temperature chart and record temperature in refrigerator 2 times daily	44 (57.9)	11 (78.6)	55 (61.1)	.040
Have special refrigerator plug	46 (60.5)	13 (92.9)	59 (65.6)	.029
Maintain stock card for vaccines	31 (40.8)	12 (85.7)	43 (47.8)	.002
Have flowchart of electricity breakdown	47 (61.8)	10 (71.4)	57 (63.3)	.013
Have ≥ 4 ice packs on freezer shelf	68 (89.5)	14 (100.0)	82 (91.1)	0.349
No used needles retained in vaccine vial	70 (92.1)	14 (100.0)	84 (93.3)	0.585
Keep refrigerator temperature at 2–8°C	65 (85.5)	13 (92.9)	78 (86.7)	0.683
Keep OPV on freezer shelf	72 (94.7)	14 (100.0)	86 (95.6)	1.0
Keep DPT, DT, Hepatitis B vaccine on normal shelf	76 (100.0)	14 (100.0)	90 (100.0)	–

OPV = Oral polio vaccine; DPT = Diphtheria–Pertussis–Tetanus vaccine; DT = Diphtheria–Tetanus vaccine; EPI= Expanded program on immunization; PCU = Primary care unit

Table 5 Correct practice regarding immunization registers and record in PCU

Records	Number (percentage)			P
	Health center n=76	Hospital n=14	Both N=90	
Maintain register in group of children < 5 year	62 (81.6)	13 (92.9)	75 (83.3)	0.450
Record DTP lot no.	48 (63.2)	13 (92.9)	61 (67.8)	.031
Maintain register in pregnant woman group	49 (64.5)	14 (100.0)	63 (70.0)	.008
Record DT lot no.	38 (50.0)	12 (85.7)	50 (55.6)	.013
Maintain register in school children group	46 (60.5)	14 (100.0)	60 (66.7)	.004
Record MMR vial no.	27 (35.5)	8 (57.1)	35 (38.9)	.007
Maintain register of immunization coverage	60 (78.9)	14 (100.0)	74 (82.2)	.066

DPT = Diphtheria–Pertussis–Tetanus vaccine; DT= Diphtheria–Tetanus vaccine; MMR = Measles–Mumps–Rubella vaccine; PCU = Primary care unit

Table 6 Compare median total score of practices regarding EPI in PCU

Variables	n	Practices regarding Cold chain system (total score=10)	P	Practices regarding Registers and records (total score=7)	P
		Median (IQR)		Median (IQR)	
Work place ^a					
Health center	76	8.50 (2.0)		4.00 (2.00)	
Hospital	14	9.50 (1.0)	.001	6.00 (1.00)	< .001

^a Use Mann-Whitney U test

EPI = Expanded program on immunization; PCU = Primary care unit

recorded by only 38.9% of PCUs, and 82% of PCUs maintained a register of immunization coverage.

In Table 6, the median total score of practices regarding EPI and the cold chain system were compared by the Mann-Whitney U test. Comparisons showed that median total scores of practices of PCUs in hospitals were significantly higher than those of PCUs in health centers.

The present study found that the total of respondent PCUs (100%) had at least one item from three of the standard manual and practices guidelines regarding the cold chain system and EPI that were provided by MoPH, and 76.7% of respondent PCUs had all three items.

DISCUSSION

This study showed that healthcare workers in hospitals have better knowledge than healthcare workers in health centers. The knowledge of healthcare workers who have longer work experience in EPI was better than that of healthcare workers who have less work experience. Moreover, trained healthcare workers had better knowledge than untrained healthcare workers. Practices in the cold chain system in hospitals were also significantly better than practices in health centers. These findings were consistent with previous studies in other areas.⁹⁻¹²⁾

Personnel who had no training regarding EPI and the cold chain system invariably worked in health centers. The reason may be the intense workload at health centers. Most health centers in Kalasin Province have only three or four personnel who are responsible for broad service in primary health care.²⁵⁾

The questions with few correct answers pertained to knowledge about the immunization schedule of schoolchildren (55.6%) and MMR vaccine (59.0%). If sufficient vaccine manual guidelines are available, healthcare workers can deal correctly with the dose and route of vaccine by following the guidelines, but our study also found that 23.3% of service units had incomplete manual guidelines. Actually, those documents were provided in the beginning by Thailand MoPH in hardback form and distributed to all PCUs and currently on the website of the MoPH; some softback copies are available. In cases where there are incomplete manual guidelines in PCUs, complete softback copies can be provided on the website and the staff can be encouraged to access the information.

Regarding consistency with previous studies, one disturbing finding pertained to inadequate refrigerator management that included failing to record the temperature inside the refrigerator twice daily. The PCU might have a flowchart detailing what to do when an electrical power outage occurs and how to maintain refrigerator temperature within the recommended range.^{26,27)} WHO recommended that the temperature during storage should be kept at 0–4°C for OPV and 2–8°C for other vaccines.^{2,14)} Temperatures in vaccine refrigerators should be read and recorded twice a day.^{12,14)} The WHO recommendations were effective for self monitoring to prevent breaking the cold chain that can reduce the potency of vaccines and contribute to primary vaccine failure.

Most registers and records regarding immunization activity were kept but in some important details were neglected; for example, only 38.9% of PCUs verify who received MMR from the same vial, and only 55.6% check who received DT from the same lot number. Thus, if problems occur in a particular lot of vaccines or vials of vaccines, with such as manufacturing defects, PCUs cannot know who will be affected by those defective vaccines.

We cannot actually identify inactivated vaccines except by potency tests, which are expensive and not widely available in Thailand. Our study had limitations in time and budget. Further studies that can explore relationships among knowledge, practices and vaccine potency are warranted. Also, a larger-scale study should be considered.

Although this study is not representative of all of Thailand or other areas where high immunization coverage was achieved, it does show inadequate management can occur in Kalasin Province where immunization coverage is high. Although raising immunization coverage is important, the quality of vaccine storage and handling is equally important.

In conclusion, there were gaps in knowledge and practices regarding the cold chain system among healthcare workers in hospitals and health centers in Kalasin Province. To ensure optimal immunization effectiveness, continuous training and regular supervision on EPI and the cold chain system are necessary. It is also strongly recommended especially for health centers in outlying areas.

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REFERENCES

- 1) World Health Organization. Health reform and priority health interventions: the case of immunization services. pp.1–2, 2001, World Health Organization, Geneva.
- 2) World Health Organization. Safe vaccine handling, cold chain and immunizations. pp.8–10, 1998, World Health Organization, Geneva.
- 3) World Health Organization. GIVS Global Immunization Vision and Strategy 2006–2015. pp.17–20, 2005, World Health Organization, Geneva.
- 4) Brenzel L, Wolfson LJ, Fox-Rushby J, Miller M, Halsey NA. Vaccine-preventable diseases. *In: Disease control priorities in developing countries*. Edited by Jamison DT, Breman JG, Measham AR, et al. pp. 394–399, 2006, World Bank, Washington (DC).
- 5) Arevshatian L, Clements CJ, Lwanga SK, Misore AO, Ndumbe PN, Seward JF, Taylor P. An evaluation of infant immunization in Africa: is a transformation in progress? *Bull World Health Organ*, 2007; 85 (6): 449–457.
- 6) Som S, Pal M, Chakrabarty S, Bharati P. Socioeconomic impact on child immunization in the districts of West Bengal, India. *Singapore Med J*, 2010; 51(5): 406–412.
- 7) Teklay K, Asnakew Y, Yodit S, Tesfaye B, Hiwot M, Tesfanesh B, Filmona B, Daniel B, Nehemie M, Babaniyi O. National EPI coverage survey report in Ethiopia, 2006. *Ethiop J Health Dev*, 2008; 22(2): 148–157.
- 8) World Health Organization. The global burden of disease 2004 Update. pp.14–16, 2008, World Health Organization, Geneva.
- 9) Joao Carlos de T M, Gunnar B. Cold chain management: Knowledge and practices in primary health care facilities in Niassa, Mozambique. *Ethiop J Health Dev*, 2007; 21: 1–6.
- 10) Yuan L, Daniels S, Naus M, Brcic B. Vaccine storage and handling knowledge and practice in primary care physicians' offices. *Can Fam Physician*, 1995; 41: 1169–1176.
- 11) Berhane Y, Demissie M. Cold chain status at immunization centers in Ethiopia. *East Afr Med J*, 2000; 77: 476–479.
- 12) Pai HH, Ko YC. Vaccine storage practices in primary care physicians' offices in Taiwan. *Kaohsiung J Med Sci*, 1999; 15: 274–279.
- 13) Uskun E, Uskun SB, Uysalgenc M, Yagiz M. Effectiveness of a training intervention on immunization to increase knowledge of primary healthcare workers and vaccination coverage rates. *Public Health*, 2008;

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- 122: 949–958.
- 14) Haworth EA, Booy R, Stirzaker L, Wilkes S, Battersby A. Is the cold chain for vaccines maintained in general practice? *BMJ*, 1993; 307: 242–244.
 - 15) Briss PA, Fehrs LJ, Parker RA, Wright PF, Sannella EC, Hutcheson RH, Schaffner W. Sustained transmission of mumps in a highly vaccinated population: assessment of primary vaccine failure and waning vaccine-induced immunity. *J Infect Dis*, 1994; 169: 77–82.
 - 16) Michalik DE, Steinberg SP, Larussa PS, Edwards KM, Wright PF, Arvin AM, Gans HA, Gershon AA. Primary vaccine failure after 1 dose of Varicella vaccine in healthy children. *J Infect Dis*, 2008; 197: 944–949.
 - 17) Sanz-Moreno JC, Limia-Sánchez A, García-Comas L, Mosquera-Gutiérrez MM, Echevarria-Mayo JE, Castellanos-Nadal A, de Ory-Manchón F. Detection of secondary mumps vaccine failure by means of avidity testing for specific immunoglobulin G. *Vaccine*, 2005; 23: 4921–4925.
 - 18) Hayden GF. Measles vaccine failure. A survey of causes and means of prevention. *Clin Pediatr*, 1979; 18: 155–156.
 - 19) Nkowane BM, Bart SW, Orenstein WA, Baltier M. Measles outbreak in a vaccinated school population: epidemiology, chains of transmission and the role of vaccine failures. *Am J Public Health*, 1987; 77: 434–438.
 - 20) Pannuti CS, Morello RJ, Moraes JC, Curti SP, Afonso AM, Camargo MC, Souza VA. Identification of primary and secondary measles vaccine failures by measurement of immunoglobulin G avidity in measles cases during the 1997 Sao Paulo epidemic. *Clin Diagn Lab Immunol*, 2004; 11: 119–122.
 - 21) Bhunbhu T. Expanded program on immunization in Thailand. *Rev Infect Dis*, 1989; 11: S514–S517.
 - 22) Chunsuttiwat S, Biggs BA, Maynard J, Thamapalo S, Laoboripat S, Bovornsinsri S, Charanasri U, Pinyowiwat W, Kunasol P. Integration of hepatitis B vaccination into the expanded programme on immunization in Chonburi and Chiangmai Provinces, Thailand. *Vaccine*, 1997; 15: 769–774.
 - 23) Bureau of Epidemiology. Annual Epidemiological Surveillance Report 2008. pp.13, 2008, Thailand Ministry of Public Health, Bangkok.
 - 24) Bureau of Epidemiology. Annual Epidemiological Surveillance Report 2009. pp.14, 2009, Thailand Ministry of Public Health, Bangkok.
 - 25) Kalasin Public Health Office. Kalasin health information [Internet]. Kalasin: Kalasin Public Health Office [cited 2011 Apr 25]. Available from: <http://giskls.moph.go.th/>.
 - 26) Hanjeet K, Lye MS, Shinniah M, Schnur A. Evaluation of cold chain monitoring in Kelantan, Malaysia. *Bull World Health Organ*, 1996; 74: 391–397.
 - 27) Grasso M, Ripabelli G, Sammarco ML, Manfredi Selvaggi TM, Quaranta A. Vaccine storage in the community: a study in central Italy. *Bull World Health Organ*, 1999; 77: 352–355.