Digital immunization registry: evidence for the impact of mHealth on enhancing the immunization system and improving immunization coverage for children under one year old in Vietnam

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Background: The Vietnam National Expanded Program on Immunization (NEPI) has been successfully implementing a nationwide immunization system since 1985. From the start, the program has increased the immunization coverage rate; however, data on immunization coverage in Vietnam are gathered and aggregated from commune health centers in routine, paper-based reports, which have shortcomings. Also, calculations of coverage are inconsistent at subnational levels, which lead to uncertainty about the size of the target population used as the denominator in coverage calculations. The growth of mobile networks in Vietnam provides an opportunity to apply mHealth to improve the immunization program. In 2012, PATH and the Vietnam NEPI developed and piloted a digital immunization registry, ImmReg, to overcome the challenges of the paper system. A final evaluation was conducted in 2015 to assess the impact of ImmReg, including its use of SMS reminders, on improving the immunization program.

Methods: The study population comprised all children born in Ben Tre province in September and October of 2013, 2014, and 2015, representing pre-intervention, post-intervention, and one year post-intervention, respectively. Data exported from ImmReg were used to compare the immunization rate, dropout rate, and timeliness of vaccination before and after the intervention. Additionally, a rapid survey was conducted to understand the willingness of parents with children due for vaccination to pay for SMS reminder messages on the immunization schedule.

Results: Timely administration of oral polio vaccine, Quinvaxem, and measles 1 vaccine significantly increased over time from baseline to post-intervention to one year post-intervention. In particular, the timeliness of vaccination with the third dose of Quinvaxem increased from 53.6% to 65.8% to 77.2%. For measles 1 vaccine, the rate increased from 70.4% to 76.2% to 92.3%. In addition, the dropout rate from Quinvaxem 1 to Quinvaxem 3 declined from 4.2% in 2013 to 0% in 2015, and the dropout rate from Bacillus Calmette-Guérin (BCG) to measles 1 fell from 12.8% in 2013 to 0% in 2015. Full immunization coverage of children under one year old increased significantly from 75.4% in 2013 to 81.7% in 2014 to 99.2% in 2015. Also, survey results indicated that 93.3% of interviewees were willing to pay for SMS reminders for immunization.

Conclusions: A digital immunization registry that includes SMS reminders can improve immunization coverage and timeliness of vaccination, thereby strengthening the quality and effectiveness of immunization programs. Integrating this system into the national health information system and leveraging it for other health programs, such as maternal and child health and nutrition as well as infectious disease control, can bring more benefits to the health care system in Vietnam.

Keywords: Mobile health; vaccination; registries

Introduction

An effective vaccination approach is widely acknowledged as a critical factor in the eradication of disease. The World Health Organization thus established the Expanded Program on Immunization (EPI) in 1974 to support countries in increasing their uptake of vaccines against measles, diphtheria, pertussis, tetanus, poliomyelitis, and tuberculosis. Vaccination has also been identified as one of the most effective preventive clinical services ever developed, saving the lives of more children than any other medical intervention in the past 50 years. Yet in 2015, an average of 16,000 children under five died every day, mostly from preventable diseases (1).

The Vietnam National Expanded Program on Immunization (NEPI) was first introduced in 1981 and has been successfully implementing a nationwide immunization system since 1985 (2). In Vietnam, commune health centers are the primary point of delivery of vaccines under the supervision and guidance of the district health center, provincial preventive medicine center, and regional and national EPI offices. Immunization services are actively conducted only on fixed consecutive days each month. In some hard-to-reach villages in remote areas, a mobile team must attempt to reach the target population to administer routine vaccines.

From the start, the Vietnam NEPI has been implemented in the target population across the entire country. The program has successfully increased the crude immunization coverage rate from 90% in 2004 (at district level) to 95.2% in 2009 (3) and 97.1% in 2015 (4); however, the data on coverage are gathered and aggregated from the commune health centers in routine, paper-based reports, which have shortcomings. Also, the calculation of NEPI coverage is inconsistent at subnational levels, which leads to uncertainty about the size of the target population used as the denominator in coverage calculations. Using the estimated denominator sometimes results in immunization coverage of more than 100% at some locations. At the same time, no study has been done to evaluate the timeliness of vaccination in Vietnam, due to limited resources to review paper-based records.

On-time vaccination is important because it ensures that vaccinated children are protected from target diseases as soon as possible. Delayed vaccination can result in longer periods of susceptibility among children, and the presence of such a pool of susceptible children can result in an epidemic when a case of a specific, vaccine-preventable illness occurs (5). Receiving vaccines on time is determined by the recommended age for receipt of a given vaccine, and each country has its own immunization schedule. *Table 1* shows the national immunization schedule for Vietnam from 2010 to 2017 for children under one year old.

For better monitoring of the timeliness of EPI vaccination, a registration and reporting system is needed that can efficiently manage the due dates for vaccination of children and report the most accurate figure of full immunization coverage (3).

At this time, Vietnam is eagerly joining the expanding mobile phone and data market. Mobile networks now reach almost every location in the country, and mobile phone penetration is very high within the population (6). As the mobile phone market continues to grow, particularly in developing countries, mobile health, or mHealth, is becoming an increasingly popular tool for health care system management, especially in low-resource settings. Vietnam is no exception.

Applying information technology, especially mHealth, to increase the timeliness of vaccination and accuracy of immunization data in Vietnam is quite feasible. There are clear opportunities to leverage the existing digital infrastructure to manage immunization data in an electronic format. A custom software program, developed locally, could take advantage of the power of automatic aggregation and calculation functions to ease some of the reporting burden on health workers, while also engaging caregivers through SMS (short message service, or text) messages to possibly help increase on-time immunization in the community.

Recognizing both the need and the opportunity, PATH, a leading international nonprofit organization in the field of global health innovation, worked with the Vietnam NEPI to develop and pilot a digital immunization registry, ImmReg, to overcome the challenges of the paper-based system. Health care workers are now using this web-based application to register new clients, to quickly and easily generate lists of children and pregnant women who

Table 1 Vietnam National Immunization Schedule for children under one year old, 2010–2017

Vaccine	Vaccination time	Number of doses
Hepatitis B monovalent	Birth	1
Bacillus Calmette-Guérin	As soon as possible within 30 days of birth	1
Quinvaxem*	2, 3, 4 months	3
Oral polio vaccine	2, 3, 4 months	3
Measles 1	9–11 months	1

*Quinvaxem: diphtheria, tetanus, pertussis, hepatitis B, and *Haemophilus influenzae* type b.

are due for vaccination, and to track doses. The system automatically sends SMS reminders to clients and generates reports that higher-level officials can see in real time.

In January 2012, PATH launched ImmReg in all 17 communes in Mo Cay Nam district in Ben Tre province, located in the Mekong Delta area of Vietnam. In 2014, PATH received funding to expand ImmReg to all 164 communes in the nine districts in Ben Tre province. ImmReg was expected to reduce the time needed for health workers to plan the monthly immunization service at commune health centers, increase the rate of on-time vaccination, and improve the quality, timeliness, and availability of immunization data. A final evaluation was conducted in 2015 to assess the impact of this system on improving on-time vaccination rates and full immunization coverage; the acceptability, feasibility, and willingness to pay for SMS; and the cost of implementing the system.

This article presents key findings from the evaluation regarding the impact of ImmReg on the timeliness of vaccination and on full immunization coverage rates at different times during implementation, as well as parents' willingness to pay for SMS immunization reminders.

Methods

The assessment was carried out in Ben Tre province, 80 km south of Ho Chi Minh City and home to 1.2 million people as of 2015 (7). The entire province is crisscrossed with a network of rivers and canals, making many areas difficult to access. More than 67,000 children were born in Ben Tre from 2013 through 2015.

All children born in Ben Tre were registered into ImmReg, and all immunization data were updated soon

after vaccination. The data used in this study, exported from ImmReg, included all children born in Ben Tre province in September and October of 2013, 2014, and 2015. These cohorts represent pre-intervention, post-intervention, and one year post-intervention, respectively. A comparison of full immunization rate, dropout rate, and timeliness of vaccination before and after intervention was done.

Additionally, a rapid survey was conducted to understand the willingness to pay for an immunization reminder SMS. The survey sample included parents who had children due for vaccination in the selected communes.

Full immunization, as defined by NEPI, is when a child has received his or her eight childhood vaccines: Bacillus Calmette-Guérin (BCG), Quinvaxem (pentavalent diphtheria-pertussis-tetanus, hepatitis B, and *Haemophilus influenzae* type b) doses 1 through 3, oral polio vaccine (OPV) doses 1 through 3, and the first dose of measles vaccine. The full immunization rate is then defined as the number of children who are fully immunized with all of these basic vaccines before their first birthday, divided by the total number of surviving children who were born in the same period.

The timeliness of receipt of a specific vaccine is determined by the recommended age for receipt of the vaccine. In Vietnam, NEPI vaccination service is conducted on fixed days each month. If a child is born one day after the last day of the monthly vaccination service, this child will have to wait one more month to receive vaccine. Therefore, the Vietnam NEPI and this study define on-time vaccination as indicated in *Table 2*.

The dropout rate was calculated as the difference in coverage between consecutive vaccines (OPV 1 versus OPV 3, Quinvaxem 1 versus Quinvaxem 3, and BCG versus measles 1). The dropout rate was calculated with the following formula:

$$\frac{\#\ of\ children\ administered\ dose\ 1 - \#\ of\ children\ administered\ dose\ 3}{\#\ of\ children\ administered\ dose\ 1} \times 100\%$$

The data were analyzed using Stata 12.0 software. A chi-square test was calculated to compare the difference between pre- and post-intervention data (full immunization rate and on-time vaccination rate) at a 95% confidence interval. Additionally, a survival analysis method was used to compare the duration of time until children were fully immunized in pre- and post-intervention groups.

The study request was reviewed and determined to be not human subjects research by the PATH Research Determination Committee. Prior to the interviews, all participants were thoroughly informed of the study's

Table 2 Vietnam on-time vaccination definition for children under one year old

Vaccine	Vaccination time	On-time vaccination
Bacillus Calmette-Guérin	As soon as possible within first 30 days of birth	30 days after birth
Oral polio vaccine 1, Quinvaxem 1	2 months	56–89 days after birth
Oral polio vaccine 2, Quinvaxem 2	3 months	28–31 days after receiving the first shot
Oral polio vaccine 3, Quinvaxem 3	4 months	28–31 days after receiving the second shot
Measles 1	9–11 months	270–330 days after birth

Table 3 Study population characteristics by gender and geographic classification, Ben Tre province, 2013–2015

Characteristics	2013 (n=3,997)	2014 (n=4,078)	2015 (n=3,374)
Gender			
Male	53.4	52.5	50.9
Female	46.6	47.5	49.1
Geographic			
Rural	90.3	90.2	90.0
Urban	9.7	9.8	10.0

Table 4 On-time vaccination by dose in Ben Tre province, 2013–2015

Vaccine dose	2013		2014		2015	
	n	%	n	%	n	%
Bacillus Calmette-Guérin	2,005	50.2	2,020	49.5	1,677	49.7
Oral polio virus 1	2,376	59.4	2,735	67.1	2,439	72.3
Oral polio virus 2	2,438	61.0	2,898	71.1	2,708	80.3
Oral polio virus 3	2,319	58.0	2,675	65.6	2,411	71.5
Quinvaxem 1	2,282	57.1	2,740	67.2	2,429	72.0
Quinvaxem 2	2,326	58.2	2,906	71.3	2,726	80.8
Quinvaxem 3	2,144	53.6	2,683	65.8	2,604	77.2
Measles 1	2,812	70.4	3,108	76.2	3,113	92.3

objectives, the rights of participants, and the confidentiality of their personal information. Interviews were conducted after all required information was explained and questions by the participants were answered.

Results

Study population characteristics

As shown in *Table 3*, there was a slightly higher birth rate for boys compared to girls in the three birth cohorts. Also, more than 90% of the children lived in rural areas.

Timeliness of vaccine administration

Table 4 shows that timely administration of OPV, Quinvaxem, and measles 1 vaccines increased significantly from baseline, post-intervention, one year post-intervention. Particularly, the timeliness of the third dose of Quinvaxem increased from 53.6% to 65.8% to 77.2%,
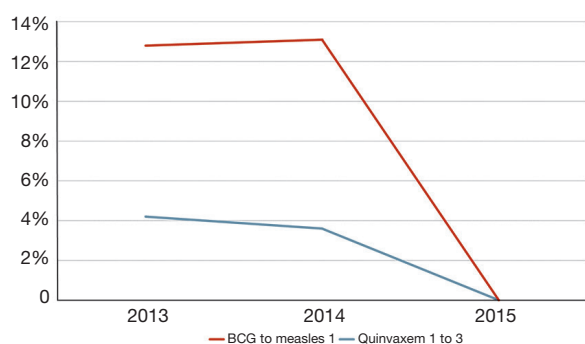
Figure 1 Dropout rate from BCG to measles 1 and from Quinvaxem 1 to Quinvaxem 3 in 2013, 2014, and 2015. BCG, Bacillus Calmette-Guérin.
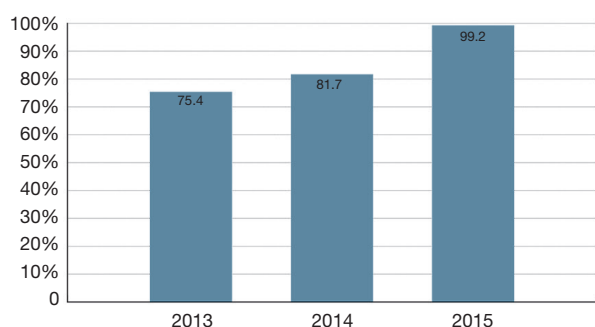

Figure 2 Full immunization coverage of children under one year old before and after ImmReg intervention.

and the timeliness of measles 1 vaccination increased from 70.4% to 76.2% to 92.3%. These differences are statistically significant (P<0.01).

Dropout rate

Figure 1 shows that the dropout rate from BCG to measles 1 vaccination and from Quinvaxem 1 to Quinvaxem 3 vaccination declined over time. The dropout rate from Quinvaxem 1 to Quinvaxem 3 declined significantly from 2013 to 2014 and then fell to 0% in 2015. Although the dropout rate from BCG to measles 1 increased 0.3 percentage points between 2013 and 2014, it declined to 0% in 2015.

Full immunization coverage

Figure 2 shows that full immunization coverage of children under one year old increased significantly, from 75.4% (pre-intervention) to 81.7% (post-intervention) to 99.2%
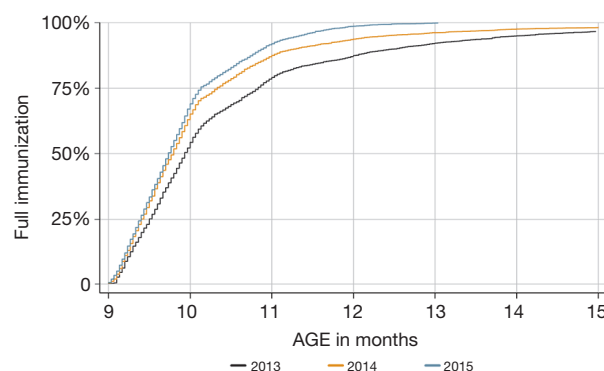

Figure 3 Full immunization coverage by age and birth cohort before and after ImmReg intervention.

(one year post-intervention) (P<0.01).

Figure 3 uses Kaplan-Meier curves to show how quickly each birth cohort reached full immunization (95% coverage). Although children born in 2013 took 14 months to reach full immunization, those born in 2014 took approximately 12 months to reach the same target. Also, 99.2% of children born in 2015 were fully immunized in the first year of life.

Parents' willingness to pay for immunization schedule reminder SMS texts

One-hundred twenty people participated in interviews to evaluate the benefits of immunization schedule reminder SMS texts. This included 81 parents who brought their children for vaccination (67.5%), 36 pregnant women (30.0%), and 3 grandparents (0.3%). Almost all of the interviewees who received the SMS texts (98.3%) said that the reminders were useful, noting they could receive them anywhere, even when they were not at home.

Interviewees were asked about their desire to receive reminder SMS texts as well as their willingness to pay for this service. The vast majority (93.3%) said they wanted to receive the texts and were willing to pay 10,000 VND (approximately US$0.50) to receive monthly reminder SMS texts for two years, whereas 3.3% did not wish to receive and pay for SMS messages and 3.4% did not respond.

Discussion

The full immunization coverage rates for the three birth cohorts in this study are higher than the 75% rate found in a 2009 study in Ben Tre (3). Results of our evaluation

provide evidence of the significant impact of ImmReg on improving immunization coverage. They show that ImmReg has helped to boost full immunization coverage and on-time vaccination rates for children under one year old, even after the project ended. Additionally, ImmReg increased the effectiveness of the NEPI program through a decline in the dropout rate from BCG to measles 1 and from Quinvaxem 1 to Quinvaxem 3.

By helping to increase the ability of the vaccine delivery service to reach children multiple times in the first year of life, ImmReg helped to protect these children from several vaccine-preventable diseases at a time when children are at high risk. The results also indicate that the integration of a mHealth component into a digital health system can enhance the impact of the system. Health workers with access to ImmReg at all levels clearly understand the benefits of the system. For this reason, the system has been sustained and used after the project ended. With mobile application of ImmReg, health workers can easily access the system to track or enter immunization data anytime and anywhere using their mobile phones or tablets. ImmReg is helpful not only for health workers but also for parents, who recognize the benefit of SMS reminders in helping them bring their children to immunization events on time.

Applying mobile and information technology in health care is not new. This technology has been introduced in many low- and middle-income countries, where it has gained interest from governments as a complementary strategy for strengthening health systems. Many innovative approaches use the power of mHealth in immunization programs. Some programs in neighboring countries of Vietnam and in the region have developed software to target different gaps within the system that could be integrated into future versions of ImmReg. For example, the StatelessVac project on the border of Thailand, Myanmar, and Laos significantly increased coverage of various vaccines for children in vulnerable populations by incorporating phone-to-phone information sharing for both case identification and prevention; "case identification" refers to valid case registration on the EPI scheme for ethnic-minority and stateless children, while "prevention" refers to proper case management so as to receive fundamental immunizations (8). Interactive Research & Development's application Zindagi Mehfooz (Safe Life) in Pakistan reminds parents of vaccination appointments, enables health workers to track individual children enrolled, what vaccine children administered and includes conditional cash transfer incentives for health workers (9). South Sudan applies the SMS application to export collected data to an existing health information system for onward submission to the State Ministry of Health to improve timeliness and efficiency of reporting (10). India conducts the Mother & Child Tracking System to track delivery of immunization services for every child based on real-time reporting, which at the same time helps implement and monitor services more efficiently and effectively by generating work plans and decision-support dashboards (11).

Despite these successes, the dominant form of mHealth programs in developing countries is characterized by small-scale pilots or informal projects with limited implementation. Furthermore, more than 80% of downloaded health applications or software are abandoned within two weeks (12). Also, competing health system priorities are consistently rated as the greatest barrier to mHealth adoption (13). Therefore, careful evaluation of the challenges and lessons learned from Ben Tre's pilot will be very valuable for scale-up decisions and strategies. An important point to keep in mind is that mHealth is merely a means to an end; thus, as much as we appreciate the enormous opportunities offered by new technologies, health programs should focus on the actual impact these tools have on individual health workers, patients, and the health of the general public. The human factor is especially pivotal in the implementation strategy.

Conclusions

Our study shows that use of a digital immunization registry and SMS immunization reminders can improve immunization coverage and the timeliness of vaccination and strengthen the quality and effectiveness of an immunization program. Because the ImmReg system is highly accepted and appreciated by health workers, health leaders, and clients, it has continued to be used even after the project ended, without any support from the project. Integrating this system into the national health information system and leveraging it for other health programs, such as maternal and child health and nutrition as well as infectious disease control, may bring more benefits to the health care system in Vietnam.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: The study request was reviewed and determined to be not human subjects research by the PATH Research Determination Committee. Therefore, it was not required to be reviewed by PATH IRB. Prior to the interviews, all participants were thoroughly informed of the study's objectives, the rights of participants, and the confidentiality of their personal information.

Disclaimer: The content represents the views of the authors and does not necessarily represent the views of the United Nations Foundation or PATH.

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