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High Sensitivity with Suboptimal Predictive Value and Delayed Reporting: Identifying Gaps in Congenital Zika Syndrome Surveillance at Saraburi Hospital, Thailand, 2022–2023

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Abstract

Zika virus is an arboviral infection primarily transmitted by Aedes mosquitoes, with severe complications in children, notably congenital Zika syndrome (CZS). This study evaluates the surveillance system of CZS based on the R506 reporting system, the nationwide reporting platform of the Department of Disease Control, at Saraburi Hospital, Thailand, during 2022–2023. We employed both quantitative and qualitative methods. A cross-sectional quantitative study was conducted through a review of hospital records and R506 surveillance data. Attributes such as sensitivity and positive predictive value (PPV) were calculated. For the qualitative study, attributes such as acceptability, simplicity, flexibility, and stability were assessed mainly through semi-structured interviews, and a framework analysis was conducted. The surveillance system demonstrated a sensitivity of 100.0% and a PPV of 44.4%. Completeness was high for demographic variables; however, timeliness was suboptimal, with 11.1% of reports submitted within a one-week window. The system was deemed useful and stable; however, challenges in interoperability between R506 and the hospital database were noted. Notably, the in-house hospital laboratory lacked the capacity to perform Zika polymerase chain reaction (PCR) tests, necessitating external processing and likely contributing to reporting delays. While the surveillance system could detect cases effectively, improvements in timeliness, coding consistency, and data integration are needed. Revising the case definition could increase the PPV. Enhancing the hospital's laboratory capacity, particularly for PCR testing, may reduce reporting time. Strengthening reporting practices and stakeholder collaboration could further improve system efficiency.

Keywords: Zika, surveillance evaluation, sensitivity, positive predictive value

Introduction

The Zika virus is primarily transmitted by *Aedes mosquitoes*, notably *Aedes aegypti* and *Aedes albopictus*. From the 1960s to the 1980s, sporadic human infections occurred across Africa and Asia. Major outbreaks emerged globally from 2007 onwards, with significant epidemics in the Pacific Islands and the Americas.[1]

Most Zika virus infections are asymptomatic. Symptoms typically appear between 2–12 days after infection, but are usually mild and include rash, fever,

conjunctivitis, muscle and joint pain, malaise, and headache, and last for 2–7 days.[2] Due to similarities with other diseases, laboratory tests are required to confirm the diagnosis. Over the past decade, Zika virus outbreaks have been associated with increased cases of Guillain-Barré syndrome.[3] During the 2015 epidemic in Brazil, the link to microcephaly was first reported and later confirmed in French Polynesia. In 2016, the World Health Organization (WHO) declared Public Health Emergency of International Concern due to Zika-related neurological disorders, ultimately confirming its association with congenital malformations.[4]

Zika virus infection during pregnancy can cause congenital Zika syndrome (CZS), leading to microcephaly, parenchymal or cerebellar calcifications, ventriculomegaly, central nervous system hypoplasia or atrophy, arthrogryposis, abnormal visual function, and low birthweight for gestational age.[5] Additionally, the virus can be transmitted through sexual contact, blood transfusion, and organ transplantation.[6]

Diagnosis of Zika virus infection is confirmed through laboratory tests, including polymerase chain reaction (PCR) and IgG/IgM serology of blood, serum, plasma, or urine samples. There is no specific antiviral treatment. Preventive measures, such as avoiding mosquito bites and practicing safe sex, are essential to reduce the risk of infection.

According to the national notifiable disease surveillance system (R506) of the Department of Disease Control (DDC), the main reporting platform of key communicable diseases from all health facilities across Thailand, there has been an increase in reported cases of Zika virus disease during 2022–2023 compared to the previous five years. Saraburi Province was among the most affected areas, reporting 39 confirmed cases in 2023, and ranked among the top four provinces (after Bangkok, Chanthaburi, and Phetchabun). Saraburi Hospital, a provincial referral hospital, had reported only sporadic cases in earlier years; however, in 2023, it reported nine newborns with microcephaly. This rise in Zika cases and the occurrence of microcephaly highlight a potential risk of CZS in the province. Because CZS can cause lifelong disability and a significant public health burden, it is critical to assess the hospital's surveillance system to ensure effective detection, reporting, and response, and to identify areas for strengthening maternal and child health protection.

Therefore, this study aims to assess the usefulness and performance of the CZS surveillance system at Saraburi Hospital from 2022 to 2023 and provide recommendations for system improvement.

Methods

Study Design

This study used a mixed-methods approach. A cross-sectional quantitative study was conducted to assess attributes such as sensitivity, completeness, and timeliness, using the surveillance data during 2022–2023. A qualitative descriptive study was also conducted to describe the system and assess acceptability and simplicity of the surveillance system.

Study Site

The study was conducted at Saraburi Hospital and the Saraburi Provincial Public Health Office (PPHO) in Saraburi Province, Thailand.

Study Period

The study focused on individuals who visited or were born at Saraburi Hospital between 1 Jan 2022 and 31 Dec 2023.

Qualitative Study

Target population and samples

Stakeholders involved in the CZS surveillance system at Saraburi Hospital and Saraburi PPHO were the target respondents. We used purposive sampling to recruit potential interviewees, covering executive-level officers, frontline physicians, and data entry operators (n=18), focusing on those with at least one year of experience in the system (Table 1).

Table 1. List of interviewees for system description and qualitative attribute assessment

Organization	Stakeholders (n=18)			
	Policy makers or executives	Information technology (IT) administrator	Data entry operator	Healthcare provider
Saraburi Provincial Public Health Office	Chief medical officer (1) and head of disease control unit (1)		Epidemiologists (2)	
Saraburi Hospital	Hospital director (1) and deputy director (1)	IT staff (1) and coders (2)	Epidemiologists (3)	Labor-ward nurses (3), internist (1), obstetrician (1), and pediatrician (1)

Data collection and analysis

In-depth and group interviews took place at the respondents' workplaces, with interviews lasting 30 minutes on average. Direct observation of the CZS reporting workflow and document review of relevant reports and guidelines related to the hospital's CZS reporting mechanism were also conducted. A semi-structured questionnaire guided the interview topics. Framework analysis was applied throughout the process.

System description

This topic included the purpose of surveillance, an overview of data flow, operational resources used, and views on public health importance and system usefulness.

Qualitative attributes

We focused on the following attributes: acceptability—the willingness of stakeholders to engage with the system, reflecting user satisfaction and cooperation; flexibility—the system's adaptability to changes, such as modifications in data collection methods or case definitions; simplicity—the ease of use and reporting processes within the system, ensuring that operations are straightforward and user-friendly; and stability—the reliability of the system's functionality over time, ensuring consistent performance without frequent disruptions.

Public health importance and usefulness

Stakeholders' perspectives on the value of the surveillance system in disease monitoring and response, indicating its effectiveness in public health management.

Quantitative Study

Data sources and data collection

We reviewed the surveillance data from the following three sources: (i) R506, (ii) the hospital information system (HIS), and (iii) the hospital serology laboratory logbook. Medical records with the International Statistical Classification of Diseases and Related Health Problems, 10th revision (ICD-10) diagnosis codes A92.5, A92.8, and P35.4. We also examined other ICD-10 codes that may mimic CZS, such as Q87.0 and Q87.1. Although our initial search focused on newborns suspected of CZS, we also expanded our search to include the mothers of these children (Table 2).

Table 2. List of the International Statistical Classification of Diseases and Related Health Problems, 10th revision (ICD-10) codes retrieved for quantitative attribute assessment

Group	ICD-10	Diagnosis
Exact	A92.5	Zika virus disease
	A92.8	Other specified mosquito-borne viral fevers
	P35.4	Congenital Zika virus disease
	P35.8	Other congenital viral diseases
Mimic	Q00.0	Anencephaly
	Q02	Microcephaly
	Q87.0, Q87.1, Q872, Q87.4, Q87.8	Congenital anomalies (congenital malformation syndromes predominantly affecting facial appearance, congenital malformation syndromes predominantly associated with short stature, congenital malformation syndromes predominantly involving limbs, Marfan syndrome, other specified congenital malformation syndromes, not elsewhere classified)
	P05.0, P05.1, P05.9, P07.0, P07.1	Light for gestational age, small for gestational age, slow fetal growth, unspecified, extremely low birth weight, other low birth weight

Quantitative attributes

The following attributes were assessed: sensitivity—the proportion of true cases reported out of the total actual cases according to the case definition; positive predictive value (PPV)—the proportion of reported cases that meet the case definition; completeness—the proportion of records containing complete data for key variables, including age, sex, current address, and date of diagnosis; accuracy—the percentage of matched variables between cases reported in the R506 system and those recorded in the HIS; timeliness—the duration between diagnosis and reporting to the PPHO, with a seven-day window set as the threshold, indicating the promptness of the system's reporting mechanism; and representativeness—the comparison of the number of cases meeting the case definition with monthly trends and overall male-to-female ratio between the HIS and R506.

Sample size calculation to assess sensitivity and PPV

We applied the prevalence estimation formula for sample size calculation.[7] The expected sensitivity was 19%, adapted from a previous study in Thailand, with an acceptable error of 5%.[8] We assumed that the percentage of cases meeting the case definition out of the total reviewed cases was 100% for Zika-related ICD-10 codes and 35% for Zika-mimicking ICD-10 codes. We hypothesized that 80% of the information would be incomplete.

Due to the small number of medical charts with an exact diagnosis (based on ICD-10), we reviewed them all. However, we used stratified random sampling on the pool of Zika-mimicking ICD-10 codes with the overall sampling fraction of 44.5% (250/562) (Table 3). A total of 305 medical charts were reviewed. During sampling, a non-proportional to size approach was used to ensure that ICD-10 codes with very few charts (not more than five) were not omitted; all charts for those codes were examined.

Concerning PPV, we applied the same formula, using an expected PPV of 10%, adapted from the previous study with an acceptable error of 5%.[8] This resulted in a minimum sample size of 35. However, there were only nine Zika records in the R506, thus we reviewed all nine cases for PPV estimation.

Table 3. Sampling frame of the medical charts for sensitivity assessment

ICD-10 category	Total number in the pool	Number to be reviewed	Note
Exact	7	7	Review all
Mimic	562	250	Stratified sampling
Mothers of infants with microcephaly or Zika	48	48	Review all

ICD-10: International Statistical Classification of Diseases and Related Health Problems, 10th revision.

Case definition and data analysis

The case definitions for CZS (as well as mothers of CZS newborns) were adapted from the Centers for Disease Control and Prevention and the Division of Epidemiology guidelines, with minor adjustments to align with the evaluation process (Table 4).[9] An investigation into R506 commenced following the identification of a probable case. Descriptive statistics, including frequency and proportion, were used to analyze quantitative attributes. Weighted analysis was applied to account for the sampling design. For the qualitative study, key quotes from interviewees were extracted verbatim.

Table 4. Case definition for quantitative attribute assessment

Type	Criteria
Suspected	Newborn infant aged less than a month who received treatment at Saraburi Hospital during 2022–2023 with a head circumference less than the 3rd percentile according to sex and gestational age.
	Mother of newborns who were reported as Zika disease or diagnosed with microcephaly according to Zika-related ICD-10 at Saraburi Hospital during 2022–2023.
Probable	A suspected case with any of the following: • Maternal history of Zika disease with plasma or urine showing Zika PCR positive, or • History of staying in the subdistrict with a confirmed case found within the same month, or • Dengue Ns1Ag showing negative within 3 days of illness, or • Other laboratory tests for measles, rubella, dengue, and chikungunya negative within that month.
Confirmed	Suspected case with specific laboratory result for Zika positive: • Plasma and/or urine is/are Zika PCR positive, or • Zika IgM showing positive, or • Zika seroconversion IgG showing positive (more than 3 weeks).

ICD-10: International Statistical Classification of Diseases and Related Health Problems, 10th revision. PCR: polymerase chain reaction.

Results

System Description

Overall, the surveillance system for CZS at Saraburi Hospital is a hospital-based passive surveillance system. Its primary purpose is to detect, confirm, and report suspected CZS cases to the R506 system to allow early investigation. The system involves multiple stakeholders. Obstetricians and ultrasonographers provide routine pre-natal care and detect suspected fetal abnormalities. Pediatricians perform neonatal examinations and manage suspected cases; laboratory

staff conduct Zika virus testing and hospital epidemiologists are responsible for case verification and notification to the R506.

Patient Flow

Pregnant women receive routine care by ultrasonography. If fetal microcephaly is suspected, blood and urine tests for Zika virus are performed. Positive cases are reported to obstetricians and epidemiologists. For newborns, head circumference is routinely measured against the 3rd percentile for gestational age and sex. Those with a head circumference less than the 3rd percentile receive additional tests to confirm CZS. Positive cases are then notified to the in-charge pediatrician and hospital epidemiologists (Figure 1).

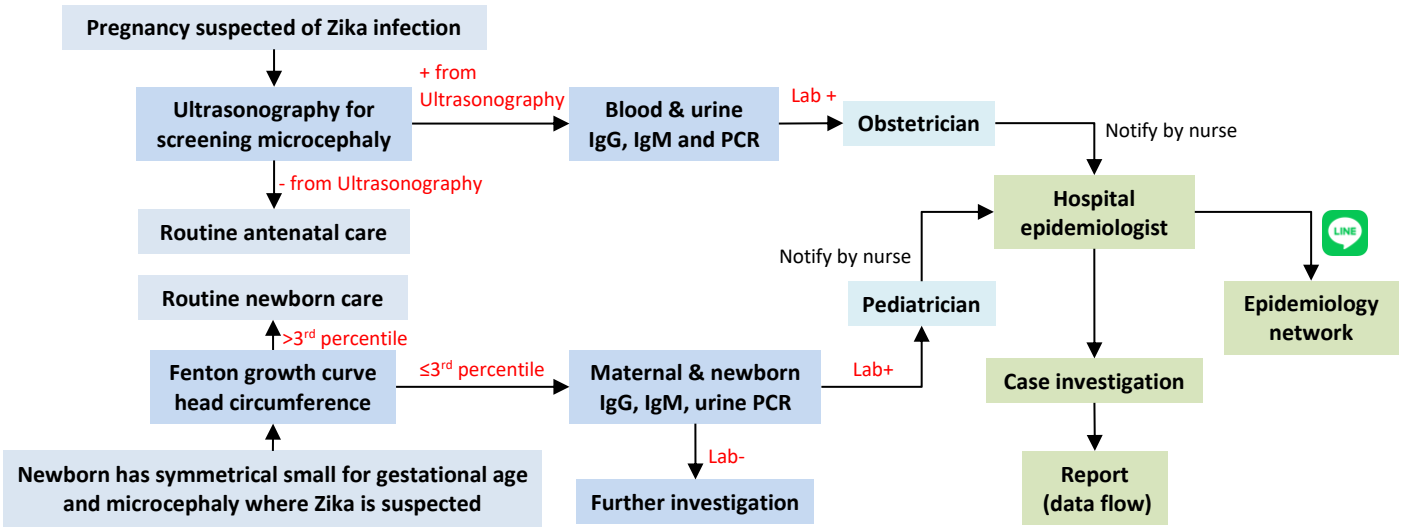

Figure 1. Patient flow of congenital Zika syndrome in Saraburi Hospital, 2023

Data Flow

Data on suspected Zika cases are collected from various sources, including antenatal care clinics, health screening units, obstetric and pediatric units, and outpatient departments. All records from these sources are transferred to the HIS. Laboratory results—primarily PCR in routine settings and IgG/IgM during Emergency Operating Center activation—are sent to the laboratory information system. Zika PCR testing is conducted by external laboratory units, either by the Department of Medical Sciences network or by the Bamrasnaradura Infectious Diseases Institute, DDC. HIS data should be submitted to the epidemiological unit within one day and to the PPHO within one week. HIS data were expected to be submitted to the epidemiological unit within a day. If a suspected case was identified but laboratory results were still pending, the epidemiological staff received phone notifications from ward nurses. Laboratory results are communicated via the LINE application. Once notified, hospital epidemiologists will investigate the event. The findings are then shared with public health officers in the hospital's epidemiological unit, who subsequently enter the data into the R506 system, while the Saraburi PPHO serves as the primary recipient. The PPHO's R506 data are then shared with the Office of Disease Prevention and Control Region 4 Saraburi (ODPC 4) and the DDC (Figure 2).

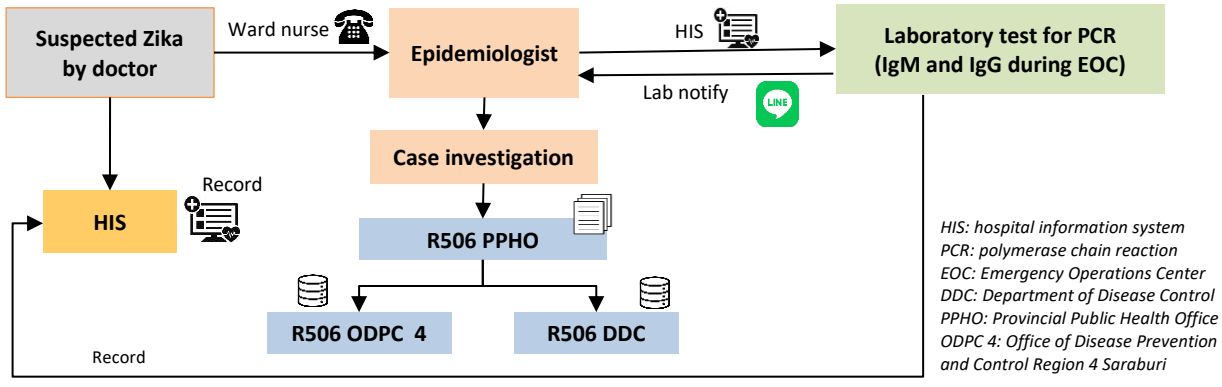

Figure 2. Data flow of congenital Zika syndrome based on R506, 2023

Saraburi Hospital had three full-time epidemiologists managing CZS cases through the R506 surveillance system. Funding primarily came from the hospital's routine budget, while local government units supported field disease control. Coordination between the health sector and these local units was essential. Laboratory costs were mainly covered by the hospital, with partial reimbursement from the National Health Security Office (NHSO).

Qualitative Attribute Assessment

Public health importance and usefulness

All interviewees, including executives from Saraburi Hospital and the PPHO, viewed R506 as an important tool for Zika disease control. However, operational-level staff were less aware of its significance. Compared with other informal reporting channels, such as the LINE application, R506 was perceived as less favorable by operational staff.

"Anyway, more or less, it (the R506) is always useful for disease monitoring." (Executive staff, PPHO)

Simplicity

Most interviewees stated that R506 was easy to operate and could be integrated with the HIS. However, some respondents reported difficulties in automatically linking R506 data with the HIS due to outdated HIS software.

Flexibility

While R506 was flexible to operate, its adaptability depended on the HIS, which served as the primary gateway for data entry. Maintaining flexibility required frequent HIS updates (e.g., ICD-10 list updates). Additionally, any modifications to the HIS required explicit directives from executives rather than being solely managed by information technology staff.

Stability

Overall, the Zika surveillance system based on R506 was stable in terms of human resources and materials. Additionally, R506 had a strong firewall to prevent system failures.

Acceptability

Interviewees generally accepted the system, as it provided a clear understanding of outbreak situations. However, its acceptability was limited to disease monitoring rather than prompting immediate action.

"Using a case investigation form is better (than R506) to initiate investigation" (Executive staff, Saraburi Hospital)

Other concerned points

A mismatch existed between the Zika ICD-10 code specified by the DDC guideline (A92.5) and the code in the WHO-2016 coding manual (A92.8). This discrepancy also affected the NHSO reimbursement process for inpatient records, as NHSO auditing typically followed the WHO-2016 coding manual. Additionally, stakeholders (ODPC, PPHO, and Saraburi Hospital) had varying interpretations of the reimbursement criteria for Zika laboratory testing. In some cases, doctors ordered Zika PCR tests to rule out other diseases on a case-by-case basis. However, the ODPC generally covered laboratory costs only for disease investigation purposes.

"We must follow ICD-10 of the coding manual. We are fine to change our coding practice if there are clear directives from the NHSO, like in the COVID era." (Coder, Saraburi Hospital)

"To tackle this problem, we negotiated with the hospital from time to time. And if the ODPC can relax the criteria, this will be helpful." (Executive staff, Saraburi PPHO)

Quantitative Attribute Assessment

Sensitivity and PPV

Of the 305 records reviewed, four met the case definition for reporting, all of which were reported, resulting in a 100% sensitivity. For PPV, nine records were reported in R506, of which four met the case definition, yielding a PPV of 44.4%. All nine cases involved newborns diagnosed with conditions related to microcephaly. No cases were classified under ICD-10 codes mimicking Zika. To this end, although weighted analysis was planned from the outset, the results (100% sensitivity and 44.4% PPV) were similar to those of the non-weighted analysis, as all cases included in the calculation had the same sampling fraction. Further exploration with the in-charge physicians suggested that the low PPV was likely attributable to discrepancies between the case definition and the providers' clinical perceptions in certain instances. For example, some newborns exhibited positive laboratory results, but their head circumference did not fall below the 3rd percentile, rendering them incompatible with the case definition, even though the physicians classified them as CZS. Table 3 provides a summary of the reviewed medical records at Saraburi Hospital.

Completeness

The completeness of key variables—age, sex, current address, and date of diagnosis—was 100%.

Timeliness

Timeliness was assessed based on the time between the date of diagnosis and the date of reporting to R506. The median lag time was 14 days (Q1–Q3: 9–54 days). Only one out of nine cases (11.1%) was reported to R506 within one week.

Accuracy

The accuracy of the sex variable was 100%, while the accuracy for the diagnosis date, age, and residential address was 55.6% (5/9), 22.2% (2/9), and 22.2% (2/9), respectively.

Representativeness

The male-to-female ratio of Zika cases in the HIS was 3:1, which was higher than the ratio recorded in the R506 of the PPHO and DDC (1.25:1). The fluctuation of cases in the HIS generally aligned with the trends observed in R506, except in August 2023, when cases were reported in R506 despite no corresponding cases meeting the case definition in the HIS (Figure 3).

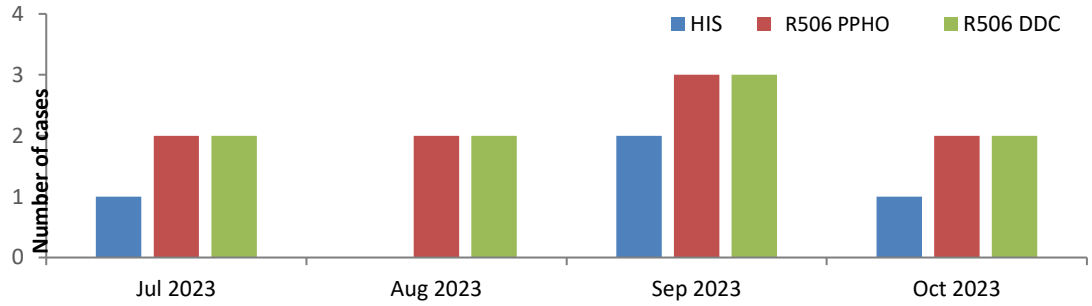

Figure 3. Number of congenital Zika syndrome cases by months in the hospital information system (HIS) and the R506 at Provincial Public Health Office (PPHO) and Department of Disease Control (DDC), 2023

Discussion

The CZS surveillance system at Saraburi Hospital plays a critical role in disease detection and response. Interviews with stakeholders confirmed its usefulness and public health importance. While stakeholders generally viewed the system positively, operational staff preferred alternative reporting channels over the R506 surveillance system for prompting disease investigation. Effective integration with the HIS system remains essential for accurate and timely reporting.

The sensitivity of R506 for Zika surveillance was high, though the PPV was relatively low. Unlike prior studies on other vector-borne diseases, where PPV was high and sensitivity was low, the opposite was observed here.[8] This is likely because all Zika cases reported in R506 at Saraburi Hospital were confirmed through laboratory testing, leading to high sensitivity. However, nearly half of the reported cases did not meet the case definition, primarily due to discrepancies in head circumference measurements. Some cases had head circumferences above the 3rd percentile despite laboratory confirmation. This situation occurred since the providers relied mainly on laboratory findings while focusing less on the circumference measures, as indicated in the clinical definition. Additionally, the reporting was broadened as a precautionary measure to avoid missing potential cases.

The findings of this study contrast with those of a study in Rayong Province, although that study focused on Zika disease more broadly rather than focusing specifically on CZS.[8] The study found low sensitivity but high PPV, which is not surprising since the case definition for Zika disease in adults does not always require laboratory confirmation. Clinical symptoms (e.g., rash) and a history of residence in endemic areas are often sufficient, increasing the denominator for calculation of sensitivity. Additionally, methodological differences—such as variations in including ICD-10 codes—may have contributed to differences in findings between studies.

Timeliness remains a major challenge, as only about one-tenth of cases were reported within a week. A key contributing factor is the lag time for laboratory results, which relied on external laboratory facilities. Similar challenges have been reported in Latin America, where limited laboratory capacity delayed Zika disease reporting, particularly in cases involving Guillain-Barré syndrome.[10]

Limitations

This study has several limitations. First, recall bias may have influenced responses, as data collection occurred more than a month after the Zika outbreak. Second, selection bias cannot be ruled out, as we examined only specific ICD-10 codes relevant to CZS rather than a comprehensive list of ICD-10 codes involved with Zika disease. Third, since this study focused on a single hospital, the generalizability of the findings is inherently limited. Additionally, at the time

of the study, the introduction of the new national surveillance system, Digital Disease Surveillance (DDS), aimed at replacing R506, was imminent. As a result, our findings based on R506 may soon become less applicable. The DDS aims at synchronizing the HIS and the R506 data. The upcoming reporting platform is likely to improve data accuracy, especially for some key variables such as age and residential address through an application programming interface. Therefore, a re-evaluation of the surveillance system will be necessary to assess whether the new system functions as intended.

Despite these limitations, this study offers valuable lessons for other settings where CZS is of public health concern. Several practical lessons have emerged, including the importance of clear case definitions, effective integration of hospital information systems with central reporting mechanisms, and achieving an optimal balance between sensitivity and positive predictive power.

Conclusion

The sensitivity of the R506 surveillance system for congenital Zika syndrome at Saraburi Hospital during 2022–2023 was 100%, while the PPV was 44.4%. Only 11.1% of reported cases were submitted timely. The cases reported in R506 generally reflected the case trends in the hospital information system. Most stakeholders found the reporting system useful, acceptable, simple, and stable. However, inconsistencies in ICD-10 coding for Zika and challenges in reimbursement for laboratory testing remained key concerns.

Recommendations

Update the hospital information system: Saraburi Hospital should update its HIS to ensure compatibility with the national reporting system. Hospital executives should clearly communicate reporting roles to all relevant staff and address any misunderstandings, particularly regarding diagnosis coding. This will not only enhance R506 data reporting but also prepare the hospital for the transition to the new surveillance system.

Strengthen monitoring and coordination: The Saraburi PPHO should actively monitor and encourage hospitals to report cases in R506. Additionally, a series of consultative meetings should be organized with key stakeholders, including ODPC and Saraburi Hospital, to establish a common understanding of key issues such as optimal CZS reporting criteria and their implications for monetary reimbursement.

Enhance laboratory capacity: Saraburi Hospital should strengthen its laboratory capacity for Zika virus PCR testing. This improvement will enhance overall laboratory performance, reduce waiting time for test results, and ultimately improve the timeliness of case detection.

Re-evaluate Zika case definition: The DDC should consider revising the Zika case definition in the current guidelines. Newborns with a head circumference above the 3rd percentile but with positive laboratory results should be classified as meeting the case definition.

Certain lessons from this setting may be relevant for broader public health contexts. Streamlining the disease definitions established by central agencies with the practices of local providers is important for improving the sensitivity and predictive power of surveillance systems. Additionally, internal laboratory capacity is a fundamental component in enhancing surveillance system performance, particularly regarding timely diagnosis and more precise reporting. Other health facilities may consider using the surveillance evaluation process described in this study to assess their own surveillance system performance for CZS and other infectious diseases of concern.

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Author Contributions

Nouannipha Simmalavong: Conceptualization, data collection, methodology, writing—original draft, writing—review & editing. **Soutthongkham Sitthideth:** Data collection. **Wanchat Saowong:** Data collection, formal analysis. **Supanut Chotichavalrattanakul:** Data collection, formal analysis. **Chanakan Duanyai:** Data collection, formal analysis. **Ingkarat Somarungson:** Data collection, formal analysis. **Panupong Tantirat:** Data collection, formal analysis. **Sutham Jirapanakorn:** Data collection, formal analysis. **Thanaphon Yisankhun:** Data collection, formal analysis. **Thanit Rattanathamsakul:** Conceptualization, methodology, project administration, supervision, validation. **Rapeepong Suphanchaimat:** Conceptualization, supervision. All authors have read and agreed to the published version of the manuscript.

Ethical Approval

As the study is part of the routine monitoring of the Division of Epidemiology, Department of Disease Control, Ministry of Public Health, ethics approval was

not required. However, all results are presented anonymously. No individual information has been disclosed.

Informed Consent

For the quantitative data, access was granted by Saraburi Hospital, utilizing routine service records; therefore, individual informed consent was not required. For the qualitative data, all interviewees were fully informed about the study and provided verbal consent to participate in the interviews.

Data Availability

The data that support the findings of this study are available from Saraburi Hospital. Access to these data is generally restricted, as they were used under license for this study. However, data may be available based on reasonable request from the corresponding author with permission from Saraburi Hospital.

Conflicts of Interest

None declared.

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Declaration of Generative AI and AI-assisted Technologies in the Writing Process

During the preparation of this work, the authors used ChatGPT to enhance clarity in some parts of the text. The content produced by this tool was reviewed and re-edited by the authors, who accept full responsibility for the final text.

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