วารสารรายงานการเฝ้าระวังทางระบาดวิทยาประจำสัปดาห์

ความเป็นตัวแทนของระบบ D506 เมื่อเทียบกับฐานข้อมูลสุขภาพแห่งชาติ (43 แฟ้ม) ของประเทศไทยในช่วงเริ่มต้นของการใช้ระบบ D506

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บทคัดย่อ

บทนำ : การเฝ้าระวังโรคติดเชื้อเป็นองค์ประกอบสำคัญของระบบสาธารณสุข นับตั้งแต่การระบาดของโรคติดเชื้อไวรัสโคโรนา 2019 (โควิด 19) หน่วยงานด้านสาธารณสุขและบุคลากรทางการแพทย์มีภาระงานท่วมท้น ซึ่งส่งผลกระทบต่อการเฝ้าระวังทางสาธารณสุข กองระบาดวิทยาได้พัฒนาระบบเฝ้าระวังโรคติดต่อ (R506) ให้เป็นระบบดิจิทัลโดยการพัฒนาระบบเฝ้าระวังโรคติดเชื้อ (D506) ซึ่งนำร่องจากโรคโควิด 19 การศึกษานี้มีจุดประสงค์เพื่อพรรณนาระบบ D506 ประเมินความเป็นตัวแทนของระบบ D506 และให้ข้อเสนอแนะในการปรับปรุงระบบ

วิธีการศึกษา : เป็นการศึกษาเชิงพรรณนาแบบภาคตัดขวางโดยการทบทวนเอกสารที่เกี่ยวข้องกับระบบ D506 เพื่อพรรณนาระบบ D506 จากนั้นทำการดึงข้อมูลผู้ป่วยโรคโควิด 19 และโรคปอดบวม (pneumonia) จากฐานข้อมูลระบบ D506 และฐานข้อมูลสุขภาพแห่งชาติ (43 แฟ้ม) โดยใช้ข้อมูลในการศึกษาระหว่างวันที่ 1 มกราคม–30 มิถุนายน 2566 ทำการเลือกโรงพยาบาลแบบเจาะจงจาก 4 ภาคของประเทศไทย ได้แก่ ภาคเหนือ ภาคใต้ ภาคตะวันออกเฉียงเหนือ และภาคกลาง โดยเลือกโรงพยาบาลที่มีการรายงานจำนวนผู้ป่วยโควิด 19 สูงที่สุดในแต่ละภาค คณะผู้ศึกษาทำการเปรียบเทียบความเป็นตัวแทนระหว่างระบบ D506 และฐานข้อมูล 43 แฟ้ม ซึ่งระบบ D506 จะได้รับข้อมูลโดยตรงจากผู้ให้บริการด้านสุขภาพโดยใช้ Application Programing Interface (API)

ผลการศึกษา : พบว่าจำนวนผู้ป่วยโรคโควิด 19 และโรคปอดบวมทั้งหมดแตกต่างกันอย่างมากระหว่างระบบ D506 และฐานข้อมูล 43 แฟ้ม โดยเฉพาะอย่างยิ่งในผู้ป่วยโรคโควิด 19 เมื่อพิจารณาการกระจายตามเพศพบว่าในผู้ป่วยโรคโควิด 19 มีอัตราส่วนเพศชายน้อยกว่าเพศหญิง ทั้งในระบบ D506 และฐานข้อมูล 43 แฟ้ม แต่พบว่าอัตราส่วนเพศชายมากกว่าเพศหญิงในผู้ป่วยโรคปอดบวม ทั้งในระบบ D506 และฐานข้อมูล 43 แฟ้ม เมื่อเปรียบเทียบการกระจายตามกลุ่มอายุ ที่อยู่ในระดับจังหวัด และวันที่รักษาของผู้ป่วยโรคโควิด 19 พบว่าระบบ D506 มีการกระจายของกลุ่มสูงอายุในสัดส่วนที่น้อยกว่าฐานข้อมูล 43 แฟ้ม อย่างไรก็ตามระบบ D506 มีการกระจายตามที่อยู่ในระดับจังหวัดที่ครอบคลุมทั่วประเทศกว่า และสามารถสะท้อนช่วงเวลาการรักษาที่มีความเคลื่อนไหวมากกว่าฐานข้อมูล 43 แฟ้ม

ข้อสรุปและข้อเสนอแนะ : ในการประเมินระบบ D506 ว่าสามารถใช้แทนระบบ R506 ได้ จะต้องประเมินปัจจัยสำคัญ เช่น ความสามารถในการใช้งาน ประสิทธิภาพ การรวมข้อมูลแบบเรียลไทม์ และความคุ้มทุน หาก D506 แสดงให้เห็นถึงความแม่นยำ ประสิทธิภาพ และผลกระทบต่อสุขภาพของประชาชนที่เหนือกว่า ระบบ D506 จะสามารถตอบสนองและบูรณาการเป็นระบบเฝ้าระวังทางสาธารณสุขได้ดี

คำสำคัญ : ระบบเฝ้าระวังโรคติดเชื้อ, ประเมิน, ความเป็นตัวแทน, D506

Representativeness of D506 compared to the National Health Database (43-file) in Thailand during the early phase of D506 implementation

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Abstract

Introduction: Notifiable disease surveillance is a vital component of public health systems. Since the COVID-19 pandemic, public health agencies and healthcare professionals have been overwhelmed, and public health surveillance has been affected. The Division of Epidemiology digitalized the existing notifiable disease surveillance system (R506) by developing a D506 system piloting COVID-19 which has been fully implemented since January 1, 2023. We aim to describe the D506 system, evaluate its representativeness, and give recommendations for system improvements.

Methods: We did a descriptive cross-sectional study by reviewing relevant documents of D506 to describe the system. Then we retrieved data of COVID-19 and pneumonia cases from D506 and the national health database (43-file). The study period was January 1–June 30, 2023. The study site was purposively selected to the hospitals from four regions of Thailand: North, South, Northeastern, and Central. We did a comparison between D506 and 43-file database for the representativeness. The D506 system received data directly from healthcare providers using an Application Programming Interface (API).

Results: Overall, we discovered that the number of total COVID-19 and pneumonia cases differed markedly between the D506 and 43-file databases, especially for COVID-19 cases. When examining the sex distribution, COVID-19 cases showed a lower proportion of males compared to females in both the D506 and 43-file databases. In contrast, the male proportion was higher among pneumonia patients across both databases. When comparing age group distribution, address (province), and treatment date of COVID-19 cases, the D506 database underrepresented older age groups relative to the 43-file database. However, D506 provided a broader provincial distribution and captured a more dynamic treatment timeline.

Conclusion & Recommendations: To assess the D506 system as a replacement for R506, key factors such as usability, performance, real-time data integration, and cost-efficiency must be evaluated. If D506 demonstrates superior accuracy, efficiency, and public health impact, it could offer a more responsive and integrated surveillance system.

Keywords: notifiable disease surveillance, evaluation, representativeness, D506

Introduction

Thailand's national public health surveillance consists of two key components: notifiable disease surveillance and the national health database. Notifiable disease surveillance, known as R506, specifically monitors communicable diseases, whereas the national health database, called the 43-file, encompasses data on both communicable and non-communicable diseases. Both surveillance systems are integral to Thailand's public health strategy, providing essential data for the monitoring, prevention, and control of diseases across the country.

The R506 system, established by the Division of Epidemiology (DoE), is a critical tool for monitoring infectious diseases in accordance with the Communicable Disease Act of 2015 [1], which classifies diseases into three types: dangerous communicable diseases, communicable diseases under surveillance, and disease outbreaks. Data is collected offline from all medical facilities across Thailand, reported through the Provincial Health Offices, and submitted weekly to the DoE.[2]

The 43-file database, managed by the Health Data Center (HDC) under the Ministry of Public Health (MoPH), is a comprehensive data collection system that includes information on patient demographics, hospital admissions, immunizations, disease-specific data, maternal and child health, and other key health indicators. Non-communicable disease data must be reported within three months and updated monthly by public healthcare facilities. Data is entered at the district level, aggregated at the provincial level, and ultimately transmitted to the MoPH for national-level analysis and integration into the national health information system. [3]

Since the COVID-19 pandemic, public health agencies and healthcare professionals have required to prioritize COVID-19 management as a pandemic response.[4] When public health officers responded to investigate and control COVID-19, there was less time to report R506 as a result, which resulted in a more than 50% decline in reporting of other diseases.[5] DoE modified the reporting system to receive data directly from health facilities using an application programming interface (API) piloting COVID-19. This system improves the timeliness of reporting data while also lessening the burden on public health officers. Eventually, DoE was tasked with expanding the API system to include all communicable diseases under surveillance, leading to the development of the "D506" digital notifiable disease, which was implemented in several provinces but has not yet been evaluated.

Evaluating the performance of notifiable disease surveillance systems is crucial for ensuring quality improvement. The evaluation enables the measurement of their performance in terms of timeliness, sensitivity, and specificity in detecting and reporting diseases.[6] Additionally, these assessments also identify potential data quality issues, including completeness, accuracy, and reliability, and offer recommendations for improvement.[7] We aim to describe the D506 system, evaluate its representativeness against the 43-file database, and give recommendations for system improvements so that the new system can be used to monitor and control diseases effectively.

Methods

We did a cross-sectional study by reviewing relevant documents establishing D506 launched by DoE to describe the D506 system. Then we use a secondary data analysis approach to evaluate the notifiable disease surveillance system. We retrieved data from existing surveillance data which the health facilities reported the data to public health office at the national level. There were two data sources involved in this study which were D506 and 43-file databases. The study population consists of all disease data reported in the D506 from its implementation, January 1 to June 30, 2023, as well as the corresponding disease data from the 43-file database for the same disease and time period. These databases typically contain information on reported cases of notifiable diseases, including demographic data, clinical and treatment history, and other relevant variables that were extracted for analysis.

The study period was defined based on the availability of the D506 surveillance data which was January 1– June 30, 2023. The study site was purposive to the hospitals from four regions of Thailand: North, South, Northeastern, and Central, all of which were ranked first in D506 reporting in their respective region. We selected COVID-19 and pneumonia to be evaluated since D506 was piloted from COVID-19 and pneumonia was also reported in R506.

After retrieving the data, we checked the originality of each record. If there are duplicate records, we maintain the one with the earliest treatment date, as the D506 guideline indicates. We performed a descriptive analysis that began with describing the D506 system by reviewing the manual of reporting guideline for D506.[5] We then compared the proportion and distribution of characteristics for COVID-19 and pneumonia cases reported in the D506 and 43-files database. The comparison focused on sex, age group, address (province), and treatment date across both databases. This represented a representativeness of D506 during its early phase of implementation compared to the existing surveillance system.

Ethics

All data used in the study were anonymized to protect patient confidentiality. Given that the data were collected as part of routine surveillance and administrative procedures, informed consent from individual patients was not performed but obtained permission from the data controller.

Results

D506 system establishing, data flow, and disease under surveillance

The DoE, in collaboration with the Division of Digital Disease Control, is creating information technology to receive data in real-time directly from healthcare providers throughout Thailand via an API. In addition, they linked the D506 system for public health surveillance. Information technology can improve surveillance systems in terms of disease vigilance, data integration, and disease reporting effectiveness. We may also use surveillance data to conduct rapid response outbreak investigations, predict diseases and health problems, and improve prevention and control systems. The D506 is a notifiable disease reporting platform to enhance reporting timeliness and reduce the workload of local public health officers. The system utilized

an API, which linked hospital systems with the D506 platform of the Department of Disease Control (DDC) at the national level. As a result, the data from healthcare facilities will be directly delivered to the DDC. The system also provides local health authorities

who are responsible at each level to access the database for re-checking and editing, ensuring data quality and accuracy throughout the reporting chain. (Figure 1)
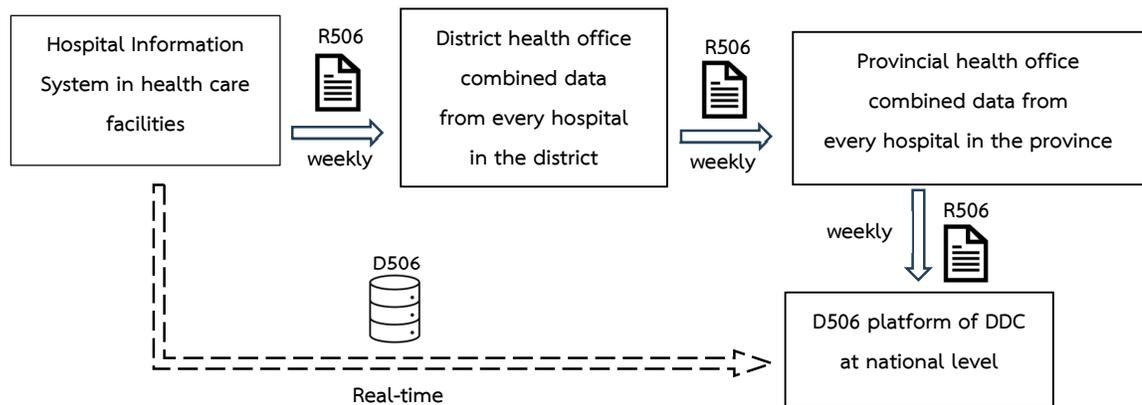

Figure 1. Data flow of the original notifiable disease reporting system (R506) compared to the new system (D506)

With the exception of COVID-19, which was recently added to D506 but was not reported to R506, the notifiable diseases reported to D506 included 57 diseases that followed the R506 regulations. The diseases were categorized into groups of disease as follows:

- Foodborne diseases i.e., Cholera, Food poisoning, Shigellosis, Acute hepatitis A/E virus, Mushroom poisoning, etc.

- Respiratory diseases i.e., Influenza, Pneumonia, COVID-19

- Vaccine preventable disease i.e., Rubella, Varicella, Poliomyelitis, Measles, Diphtheria, Pertussis, Mumps, etc.

- Central nervous system infection i.e., Meningococcal meningitis, Encephalitis

- Vector-borne diseases i.e., Dengue infection, Malaria, Scrub typhus, Chikungunya fever, Zika fever

- Sexual Transmitted Diseases i.e., Acute hepatitis B/C/D virus, Syphilis, Genital Herpes Simplex, etc.

- Contact diseases i.e., Hand foot and mouth disease, Monkeypox, etc.

- Zoonosis diseases i.e., Rabies, Leptospirosis, *Streptococcus suis* infection, etc.

Data of surveillance system

From four hospitals, there was a total of 17,744 reports containing COVID-19 or pneumonia in the D506 database. In terms of ICD–10, 64.93% (11,522/17,744) were coded as U072 (COVID-19, virus not identified); 29.97% (5,318/17,744) as U071 (COVID-19, virus detected); and 5.09% (904/17,744) as J189 (pneumonia, undefined organism). Females were diagnosed with COVID-19 (59.39%) more than males (40.61%), while females (43.69%) were diagnosed with

pneumonia less than males (56.31%). The distribution of COVID-19 cases was found to be highest in the 26–35 age groups, accounting for 19.97%, whereas the over-65 age group had the highest number of pneumonia cases, accounting for 42.81%. (Table 1) The addresses of the COVID-19 cases treated at these four hospitals were scattered primarily throughout Thailand, while pneumonia cases were allocated in the province where the facility was located. (Figure 2 & 3)

There were 1,448 reports including COVID-19 or pneumonia extracted from both inpatient and outpatient registries, as well as all diagnosis types (principal diagnosis and other diagnosis) from the 43-file database. We discovered that pneumonia (J189) was coded as the diagnosis in 89.64% (1,298/1,448) of cases, COVID-19 with virus detected (U071) in 8.56% (124/1,448), and COVID-19 with virus not identified (U072) in 1.80% (26/1,448). Females were also diagnosed with COVID-19 (50.42%) more than males (49.58%), while females (41.34%) were diagnosed with pneumonia less than males (58.66%). The distribution of COVID-19 and pneumonia cases was found to be highest in the over-65 age group, accounting for 43.70% and 37.53%, respectively. (Table1) The majority of COVID-19 and pneumonia patients have been diagnosed in the same province as the health care providers. (Figure 2 & 3)

Comparison of COVID-19 and pneumonia cases reported to D506 and 43-file databases

COVID-19 and pneumonia cases retrieved from the D506 database were compared with data from 43-file database, January 1–June 30, 2023. The D506 system originated by receiving COVID-19 instances before

expanding to other notifiable diseases such as pneumonia. The 43-file database, on the other hand, was a national health database that collected all healthcare services utilization of both communicable and non-communicable diseases.

Overall, we discovered that the number of total COVID-19 and pneumonia cases differed markedly between the D506 and the 43-file database, especially for COVID-19 cases. (Table 1) There were 16,840 COVID-19 cases recorded to the D506 database, but only 150 COVID-19 cases were reported to the 43-file database. On the contrary, the D506 database received 904 pneumonia reports, but the 43-file database received 1,298 pneumonia reports. COVID-19 cases were male in 40.61% and 49.58% of D506 and 43-file, respectively. While 56.31% of pneumonia cases in D506 and 58.66% in 43-file were male. The age distribution of COVID-19 cases in D506 ranged from 10.91% to 19.97%, although 43.70% of over-65 age group cases were recorded in the 43-file database. The distribution of pneumonia cases by age group followed the same pattern in both the D506 and the 43-file databases. Over-65 age group made up the largest age group, accounting for 42.81% in the D506 and 37.53% in the 43-file database. The distribution of COVID-19 cases by their address (province) recorded in D506 was distributed throughout Thailand, however, the distribution of the address of the cases reported in the 43-file database followed the health care providers. (Figure2) For pneumonia cases, the distribution of their address (province) documented in the D506 and 43-file databases was quite similar since they were diagnosed in the same province as the health care providers (Figure 3).

The number of COVID-19 cases in the D506 database increased in late April, peaking around mid–May, while only a few cases were recorded in the 43-file during the first trimester (January–March) of 2023, and no further cases were reported later. Similarly, pneumonia cases were only recorded in the 43-file database until March 2023. While the number of pneumonia cases in D506 was continually recorded till June 2023. Despite the difference in patient numbers, the pattern of pneumonia treatment dates remained consistent between D506 and the 43-file database from January to March 2023. (Figure 4)

Table 1. Characteristics of COVID-19 and pneumonia cases reported in D506 and 43-file database from four hospitals in North, South, Northeastern, and Central region, Thailand, January 1–June 30, 2023

| Characteristics	D506		43-file	
	n	%	n	%
COVID-19 (U071–072)				
<u>Sex</u>				
Male	6839	40.61	59	49.58
Female	10001	59.39	60	50.42
<u>Age group (yrs.)</u>				
<16	2215	13.15	27	22.69
16–25	2520	14.96	3	2.52
26–35	3363	19.97	5	4.20
36–45	2846	16.90	7	5.88
46–55	2202	13.08	7	5.88
56–65	1856	11.02	18	15.13
66+	1838	10.91	52	43.70
Pneumonia (J189)				
<u>sex</u>				
Male	509	56.31	691	58.66
Female	395	43.69	487	41.34
<u>Age group (yrs.)</u>				
<16	190	21.02	443	36.70
16–25	27	2.99	10	0.83
26–35	37	4.09	27	2.24
36–45	50	5.53	47	3.89
46–55	76	8.41	81	6.71
56–65	137	15.15	146	12.10
66+	387	42.81	453	37.53
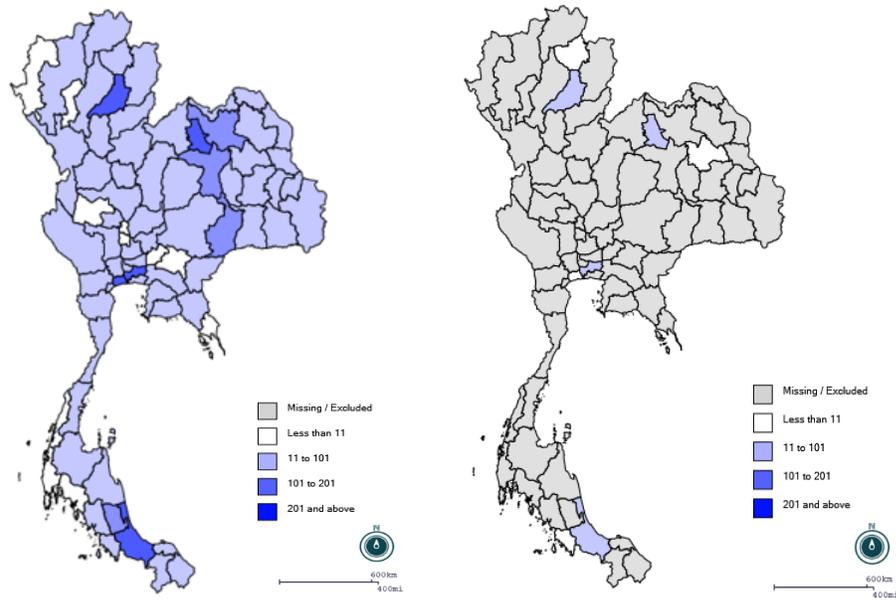
Figure 2. Distribution of COVID-19 cases reported in D506 (left) and 43-file (right) database, by province, January 1–June 30, 2023
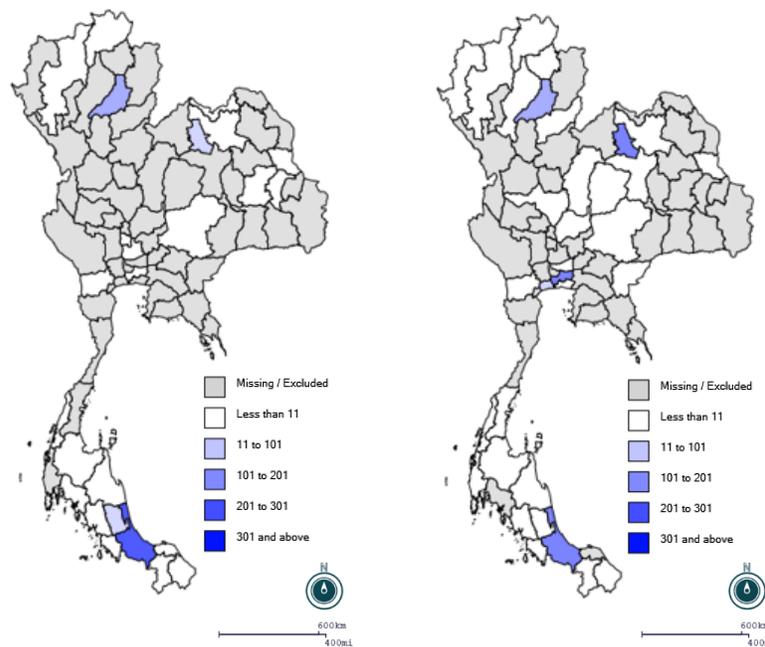

Figure 3. Distribution of pneumonia cases reported in D506 (left) and 43-file (right) database, by province, January 1–June 30, 2023
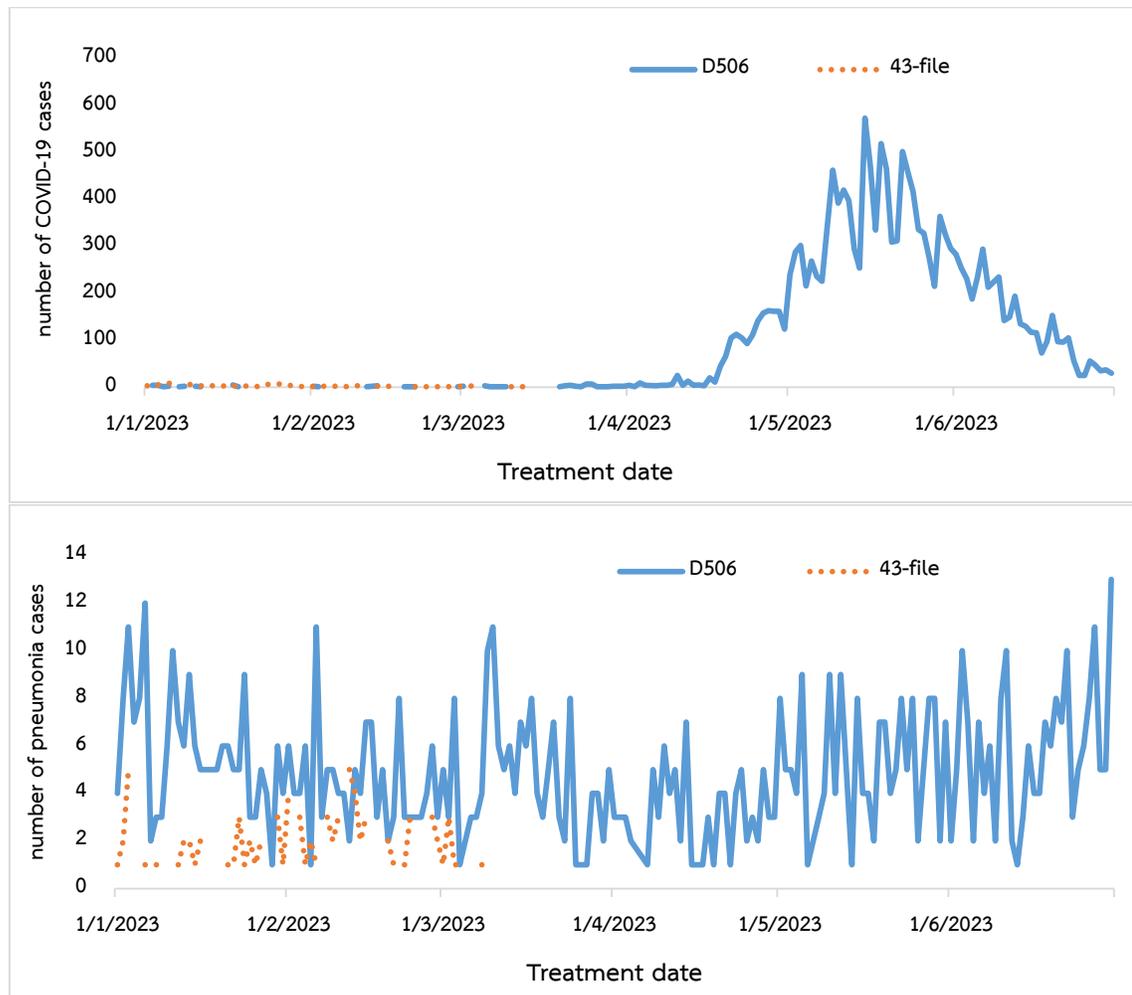
Figure 4. The number of COVID-19 (above) and pneumonia (below) cases in the D506 and 43-file databases, by treatment date, January 1–June 30, 2023

Discussion

According to the COVID-19 pandemic, D506 has been developed to be a notifiable disease surveillance for diseases under surveillance, with COVID-19 being the first to be piloted. The system received data directly from health care providers using API. Digitalization of surveillance systems using information technology can enhance surveillance systems, particularly in terms of timeliness. [8,9]

Overall, we discovered that the number of total COVID-19 and pneumonia cases differed markedly between D506 and the 43-file database, especially for COVID-19 cases. D506 recorded a higher number of COVID-19 cases compared to the 43-file database during its early deployment. This is not surprising given that D506 uses API to receive data directly from health care providers, whereas 43-file requires input from humans to deliver data into the system. Since the COVID-19 pandemic, the pressure on healthcare workers has escalated and overburdened. As a result, the public health surveillance system was impacted [10–12], including the 43-file database, which was an offline surveillance report that required public health

professionals to manually extract data from the hospital and upload it to the system. [13]

When examining the sex distribution, COVID-19 cases showed a lower proportion of males compared to females in both the D506 and 43-file databases. In contrast, the male proportion was higher among pneumonia patients across both databases. This supports D506's sex representation. The majority of surveillance evaluations discovered that sex was highly representative because it was well-defined and straightforward to collect. [14]

When compared to the 43-file database, the D506 database lacked representation in the age group distribution, address (province), and treatment date for COVID-19 cases. Conversely, the data on age groups, address (province), and treatment date of pneumonia patients in D506 appeared to be more representative. The age distribution of COVID-19 cases in the D506 database showed a relatively uniform representation across different age groups, with percentages ranging from 10.91% to 19.97%. In contrast, the 43-file database recorded a predominant proportion of cases among individuals over 65 years old, accounting for 43.70% of cases. This discrepancy may be attributed to the D506 system's initial focus on COVID-19 before expanding to include other notifiable diseases, which could have influenced reporting practices. [15] The consistent age distribution in D506 raises questions about its representativeness. It is possible that younger populations were more likely to be tested or report mild cases, while older individuals may have been underrepresented due to barriers in accessing healthcare or differences in testing protocols. [16–18]

Further studies are needed to explore these dynamics and assess whether similar trends are observed in other regions or databases.

The distribution of COVID-19 cases by province in the D506 database was widespread throughout Thailand, whereas the 43-file database reflected patterns aligned with healthcare providers' locations. This inconsistency may stem from differences in data collection methods; the D506 database's broader geographic coverage stems from its initial design as a COVID-19 reporting system. The DDC emphasizes the importance of comprehensive data collection in monitoring disease outbreaks effectively, allowing for better resource allocation and response strategies across different regions. [19] In contrast, the 43-file database's focus on healthcare utilization may lead to a concentration of cases in areas with more accessible healthcare services. This phenomenon is consistent with findings that indicate healthcare utilization patterns significantly influence reported case distributions. Regions with better healthcare access tend to have higher reporting rates due to increased testing and diagnosis capabilities. [20,21] Both databases exhibited similar provincial distributions for pneumonia cases, indicating that both systems captured data from comparable healthcare settings. This alignment suggests that pneumonia diagnoses were consistent across different reporting systems, which could be useful for understanding regional healthcare delivery and disease prevalence.

The treatment date distribution for COVID-19 cases revealed a notable increase in the D506 database during late April, peaking around mid-May, while the

43-file database recorded only a few cases during the first trimester of 2023 and none thereafter. This disparity indicates that the D506 database was more responsive to emerging trends in COVID-19 cases during this period. Conversely, pneumonia cases were consistently recorded in D506 until June 2023, while the 43-file database only captured pneumonia cases until March 2023. The differences in treatment date reporting may reflect variations in data collection and reporting practices or healthcare access between the two systems. This could imply that it delayed reporting to the 43-file database since non-communicable diseases could be reported within three months. [3] The D506 database appears to provide a more dynamic view of ongoing disease trends, suggesting that it may be better equipped to track real-time changes in case numbers.

The representativeness of health databases can significantly impact the conclusions. Factors such as the scope of diseases covered, data collection methods, and patient demographics play critical roles in determining how well a database reflects the broader population. The discrepancies in case reporting often arise from differences in data collection protocols, definitions of cases, and population coverage. [22–24] This emphasized the importance of understanding the context in which data is collected to assess representativeness accurately.

Limitations

This study had several limitations. First, the purposive selection of hospitals from four regions of Thailand, specifically those ranked first in D506 reporting, introduces potential selection bias. This non-random approach may not accurately represent all hospitals across Thailand, especially those with differing reporting practices or lower engagement with the D506 system, limiting the generalizability of the findings. The focus on COVID-19 and pneumonia was due to D506's initial pilot on COVID-19 and the high reporting frequency of these diseases. This focus may not fully reflect the performance of the D506 database for other notifiable diseases, as other diseases had fewer reports.

Furthermore, the R506 system was not used for COVID-19 surveillance as the DoE chose to utilize the D506 system instead, following the reclassification of COVID-19 as a disease under surveillance. As a result, researchers could not quickly obtain nationwide data to evaluate the D506 system, leading to the use of the 43-file database as a representative dataset for COVID-19 and pneumonia cases occurring in the community. However, the 43-file database, primarily designed for non-communicable diseases and functioning as a passive surveillance system, may have incomplete data for communicable diseases, including COVID-19 and pneumonia.

Also, the reliance on secondary data from the D506 and 43-file databases introduces potential information bias, as the accuracy and completeness depend on the reporting practices of healthcare facilities. These factors underscore the need for careful interpretation of the results.

Recommendations

To evaluate the D506 system as a replacement for the R506, key aspects should be systematically evaluated. Field studies should be conducted to examine

usability and system performance focusing on user feedback, interface efficiency, and the system's ability to handle large volumes of data. Integration with existing hospital systems and real-time data flow is essential for maintaining seamless surveillance. A cost-benefit analysis is also necessary to determine whether D506 is more efficient and less resource-intensive than R506, especially regarding the workload of local health officers. If the D506 system demonstrates superior accuracy, efficiency, real-time reporting, and overall public health impact, it may be an effective replacement for R506, contributing to a more responsive and integrated public health surveillance system.

Conclusion

The D506 system, an API-based disease reporting platform, directly transmits data from healthcare facilities to the national public health office. A marked discrepancy was observed in the total COVID-19 and pneumonia cases reported between the D506 and the 43-file databases, especially for COVID-19. In both databases, COVID-19 cases showed a lower proportion of males, while pneumonia cases had a higher proportion of males, supporting D506's representation of sex distribution. When comparing age group distribution, address (province), and treatment date of COVID-19 cases, the D506 database underrepresented older age groups relative to the 43-file database. However, D506 provided a broader provincial distribution and captured a more dynamic treatment timeline. Thus, to assess the D506 system as a replacement for R506, key factors such as usability, performance, real-time data integration, and cost-efficiency must be evaluated. If D506 demonstrates

superior accuracy, efficiency, and public health impact, it could offer a more responsive and integrated surveillance system.

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