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Monthly trends of basic immunization coverage before and during the COVID-19 pandemic in Solo Raya, Indonesia (2019-2021)

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Abstract

Purpose: This study aimed to describe the temporal changes in monthly basic immunization coverage before and during the COVID-19 pandemic in Solo Raya, Central Java, Indonesia, and identify implications for maintaining immunization services during health emergencies. **Methods:** This descriptive study used the Exploratory Data Analysis (EDA) approach. We obtained secondary data on monthly immunization coverage from January 2019 to August 2021 from the District Health Offices in Surakarta, Sukoharjo, Karanganyar, Klaten, and Sragen. Immunization indicators included BCG, Measles, HB0, DPT-HB-Hib, Polio, and IPV. We obtained additional COVID-19 case data from the Kawal COVID-19 dataset. We analyzed the data using time-series visualization and descriptive statistics. Document review and informal operational consultations supported the interpretation of quantitative findings. **Results:** Before the pandemic, monthly immunization coverage showed relatively stable patterns across the study areas. During the pandemic, month-to-month fluctuations were more pronounced, with IPV coverage showing the greatest variability. The later period of the pandemic in 2021 also showed marked fluctuations in several indicators. Operational challenges during the pandemic include temporary suspension of *Posyandu* services, vaccine supply shortages, parental concerns about COVID-19 transmission, and reassignment of health workers to COVID-19 services. Catch-up immunization activities were also reported. Despite monthly fluctuations, annual immunization coverage remained above the national target of 95% across the study areas. **Conclusion:** Routine childhood immunization coverage in Solo Raya showed greater monthly instability during the COVID-19 pandemic, despite relatively high annual coverage. Strengthening adaptive immunization services, maintaining vaccine availability, and implementing innovative service delivery strategies may help sustain routine immunization services during future public health emergencies.

Keywords: child health service; COVID-19; immunization; Indonesia; vaccination coverage

INTRODUCTION

Routine childhood immunization is a key public health intervention that prevents vaccine-preventable diseases (VPDs) and reduces morbidity, disability, and mortality among children [1]. The Indonesian government provides a comprehensive basic immunization program in the first year of life to protect children against diseases such as tuberculosis (TB), hepatitis B, diphtheria, pertussis, tetanus, polio, and measles [2]. High, equitable immunization coverage is essential to maintain population protection and prevent the resurgence of vaccine-preventable diseases. In Indonesia, Community Health Centers (*Puskesmas*) and Integrated Health Posts (*Posyandu*) primarily deliver routine immunization services as part of maternal and child health services. However, these services may be disrupted when health systems face public health emergencies. Disruptions to immunization services are a major concern because delayed or missed vaccinations may leave children unprotected according to the recommended schedule and increase their vulnerability to VPDs.

The COVID-19 pandemic that emerged in 2020 placed substantial pressure on the delivery of essential health services, including routine immunization programs. Several countries reported declines in immunization service utilization during the early phase of the pandemic due to mobility restrictions, changes in health facility operations, and the reallocation of health resources to the COVID-19 response [3–5]. Global analyses show that immunization coverage disruptions varied over time and across regions, with substantial declines during the early phase of the pandemic followed by recovery in some settings [1,5]. Similar findings were observed in Indonesia. According to a Rapid Assessment conducted by the Ministry of Health of the Republic of Indonesia and UNICEF, the pandemic's impact on routine immunization services was reflected in the national complete basic immunization coverage, which reached only 83.3% in 2020, below the 92.9% target set in the National Strategic Plan (Renstra) [2,6,7]. Immunization coverage also declined at the provincial level, including in Central Java. Research in Indonesia indicates that the pandemic's impact on immunization programs varied by location, with differences between urban and rural areas [8–10]. Another study also reported changes in basic or advanced immunization coverage among children under two years of age when comparing the pre-pandemic and pandemic periods [11,12].

Although several studies have documented disruptions to immunization programs during the COVID-19 pandemic, research in Indonesia has largely relied on annual coverage indicators or aggregate pre-pandemic and pandemic comparisons [8,11,13]. While these approaches help assess overall program performance, they may obscure short-term fluctuations in specific months. International evidence indicates that immunization service disruptions varied over time, by vaccine type, and by pandemic period [1,5]. In addition, a systematic review showed that the pandemic may have exacerbated inequalities in immunization coverage across certain populations and geographical areas [14], while studies from other settings have indicated that changes in access to and utilization of health services may also influence patterns of immunization service delivery during the pandemic period [15,16]. Thus, limited evidence remains on monthly temporal patterns and changes in vaccine-specific immunization coverage at the local level in Indonesia. This information matters because relatively high annual coverage does not necessarily reflect continuity of immunization services each month. Monitoring monthly patterns can help identify periods of decline, subsequent recovery, and vaccines that changed more during service disruptions.

Solo Raya is a region in Central Java comprising Surakarta City and the regencies of Sukoharjo, Karanganyar, Klaten, and Sragen, providing a relevant local context for examining the dynamics of immunization service delivery during the pandemic [9,10]. However, limited evidence describes monthly changes in basic immunization coverage by vaccine type in Solo Raya before and during the COVID-19 pandemic. Therefore, this study aimed to describe temporal changes in monthly basic immunization coverage during the pre-pandemic period (January 2019–February 2020) and the pandemic period (March 2020–August 2021) across the five districts/city in Solo Raya, Central Java. This study used a time-series-based Exploratory Data Analysis (EDA) approach to describe coverage patterns by geographic area and vaccine type, including BCG, HB0, DPT-HB-Hib, Polio, IPV, and measles vaccines. We used information from interviews with local health officials and document reviews as contextual information to describe service conditions during the study period, rather than as evidence of causal relationships with changes in immunization coverage. This approach is expected to provide a more detailed description of immunization coverage dynamics during the pandemic and to inform the monitoring and strengthening of immunization program resilience in future public health emergencies.

METHODS

Study design and subjects

This study used a descriptive retrospective design to observe temporal patterns and fluctuations in routine childhood immunization coverage before and during the COVID-19 pandemic. We conducted Exploratory Data Analysis (EDA) on monthly immunization coverage data from January 2019 to August 2021 and presented it within a time-series analytical framework. The study was conducted in the Solo Raya region, Central Java Province, Indonesia. During the preliminary assessment of data availability, not all districts/cities in the region could provide complete immunization data for the predefined study period. Therefore, the analysis was restricted to five district/city health offices that provided complete and usable data: Surakarta City, Sukoharjo Regency, Karanganyar Regency, Klaten Regency, and Sragen Regency.

The quantitative component used aggregated district/city-level secondary data, with the primary unit of analysis being district/city-monthly coverage rather than individual children. The dataset comprised monthly coverage data for six basic immunization indicators: Bacillus Calmette–Guérin (BCG), hepatitis B birth dose (HB0), diphtheria-tetanus-pertussis–hepatitis B–Haemophilus influenzae type b (DPT-HB-Hib), polio, inactivated poliovirus vaccine (IPV), and measles. Monthly COVID-19 case counts for Central Java Province were additionally used as contextual epidemiological data.

The study conducted brief key informant consultations, open-ended interviews with public health officers involved in immunization services, and document reviews to provide contextual information for interpreting the quantitative findings; these were not designed as a standalone qualitative component of the study. The study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for observational studies.

Data collection

The immunization data were derived from Local Area Monitoring (PWS) Immunization records maintained by the respective district/city health offices and from the Kawal COVID-19 dataset. Formal written requests were submitted to the relevant district/city health offices to obtain access to the secondary immunization data collected between December 2021 and February 2022.

The six immunization indicators had different recommended doses and schedules. BCG was administered once at approximately one month of age. HB0 was administered once, within a maximum of one week after birth. DPT-HB-Hib was administered in three doses at approximately 2, 3, and 4 months of age. Polio was administered in four oral doses, beginning at one month of age and repeated monthly. Measles immunization was administered once at approximately nine months of age. IPV was administered once by injection to continue the polio immunization schedule.

The respective health offices validated all immunization data obtained from the district/city health offices before analysis. Monthly immunization coverage was calculated as the number of infants receiving a specific immunization during a given month divided by the annual target population for the corresponding district/city and year, multiplied by 100%. The annual target population represented the estimated number of live births and was determined annually by the Regional Development Planning Agency (Bappeda) for each district/city. The national target for annual immunization coverage was 95%. Because the annual target population served as the denominator for each monthly calculation, monthly values represented each month's contribution toward achieving the annual target and generally ranged from approximately 5% to 10%.

Monthly coverage values of 0% represented periods when no immunization services were provided, or no vaccine doses were administered, not missing data. We retained these values because the respective health offices validated them. Contextual information from health officers indicated that such periods were associated with temporary suspension of immunization services and/or vaccine shortages. Health offices also retained annual coverage exceeding 100% as reported and validated. This may occur because the reporting system uses a geographically defined annual target population as the denominator. In contrast, the numerator is based on children receiving services at health facilities in the reporting area. Children from outside a facility's administrative catchment area may therefore be vaccinated at that facility because of geographic accessibility. This cross-boundary service utilization may result in potential double counting across reporting areas and contribute to coverage estimates exceeding 100%. Because the routine reporting system aggregates data by reporting area and lacks individual-level identifiers, it cannot systematically identify or exclude potential duplicate service utilization.

Document review and informal operational consultations

The team reviewed documents to provide context and identify relevant policies or regulations on health-service delivery during the pandemic. The team searched Google Scholar using the keywords “circular letter immunization service policy Surakarta City during the pandemic.” The team used relevant documents as supporting documentary evidence. The team conducted brief mobile phone consultations with one health officer from each participating health office responsible for immunization data and reporting to clarify the administrative and operational circumstances surrounding immunization service delivery during the COVID-19 pandemic. Each consultation lasted approximately 15 minutes and focused on changes in service operations, the availability of health personnel and vaccines, barriers to service delivery, and recovery efforts, including catch-up immunization activities.

The consultations served as a supplementary source of contextual information to support the interpretation of quantitative findings and were not designed as a formal qualitative investigation. The health officers' information was summarized descriptively and used solely to clarify observed patterns in immunization coverage. No formal qualitative coding or thematic analysis was performed, and no patient-level information or personally identifiable health data were collected during the consultations.

Data analysis

We first compiled monthly immunization coverage data by study area, month, and vaccine type, and checked for consistency in the observation period, indicator types, and reported coverage values. The data were divided into two observation periods: T0 (pre-pandemic, January 2019–February 2020) and T1 (pandemic, March 2020–August 2021).

Data analysis followed an Exploratory Data Analysis (EDA) approach, using univariate analysis to describe each variable's distribution and temporal patterns. Descriptive statistics, including mean and standard deviation, were calculated using statistical software. Frequency distributions and temporal patterns of immunization coverage for each vaccine type were graphically visualized monthly for each district/city using Tableau. We visualized monthly COVID-19 case data for Central Java alongside mean monthly immunization coverage to provide temporal context for the observed changes. Because this study was strictly descriptive and time-series-based, no inferential statistical tests, regression models, pre-existing trends, seasonality, or autocorrelation were formally modeled to estimate the causal effect of the COVID-19 pandemic. Differences or pattern shifts between T0 and T1 were interpreted purely descriptively.

This study used anonymized and aggregated secondary administrative data with no direct interaction with human participants or access to individually identifiable patient information. Accordingly, the study did not involve direct human-subject research, and the requirement for formal ethical approval and informed consent was determined in accordance with applicable institutional policies and regulations.

RESULTS

Monthly coverage of the basic immunization program in Solo Raya before and during the COVID-19 pandemic

BCG immunization

Figure 1 shows that during the pre-pandemic period (T0), BCG coverage was relatively stable in most areas, generally ranging from 7% to 10%. The lowest value was recorded in Sukoharjo Regency in December 2019, at 5.6%. During the pandemic period (T1), BCG coverage showed greater month-to-month variation than during the preceding period, with different patterns of increases and decreases across districts/cities.

Measles immunization

In Figure 2, during T0, measles coverage was relatively consistent, with monthly values ranging from 6.2% to 10.7%. During T1, however, the coverage pattern became more variable, with monthly changes differing across districts/cities. Thus, the temporal variation during the pandemic period did not follow a uniform pattern across all study areas.

HB0 immunization

Figure 3 shows that HB0 coverage appeared relatively stable across all study areas during T0. At T1, most areas maintained coverage between 5.8% and 9.6%. Sragen Regency showed greater month-to-month variation than the other areas.

DPT-HB-Hib immunization

Coverage was relatively stable during T0, as shown in Figure 4. At the beginning of T1, coverage decreased to 0% in Sukoharjo and Karanganyar Regencies in April 2020. Subsequently, coverage increased in several areas between June and December 2020. In 2021, coverage decreased again in four areas, while Sukoharjo Regency showed a different pattern.

Polio immunization

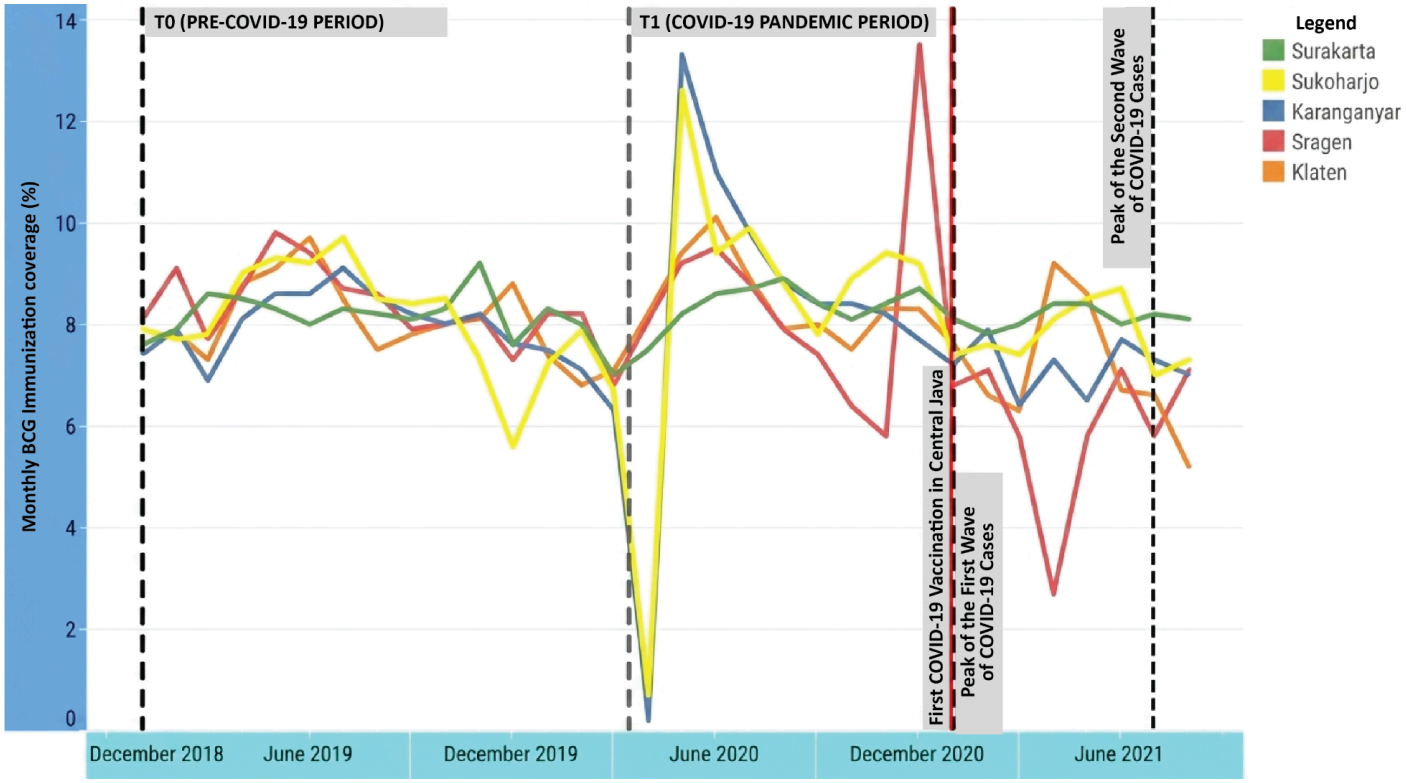
Figure 5 shows that polio coverage was relatively stable during T0 but showed greater variation during T1. In 2020, coverage increased in Karanganyar, Sukoharjo, and Sragen Regencies. In 2021, coverage decreased again, particularly in Sragen and Karanganyar Regencies. In Sragen Regency, coverage was below 2% in several months, whereas in Karanganyar Regency, coverage approached 0% at several points.

IPV immunization

Based on Figure 6, IPV coverage was relatively stable across districts/cities from January to October 2019. Subsequently, variations in coverage became apparent during the observation period. IPV coverage remained low in several months and approached 0% in some areas. Coverage increased between October and December 2020, particularly in Klaten, Sukoharjo, and Karanganyar Regencies. Coverage then remained relatively stable from January to March 2021 before declining again from April 2021 through the end of the observation period in August 2021.

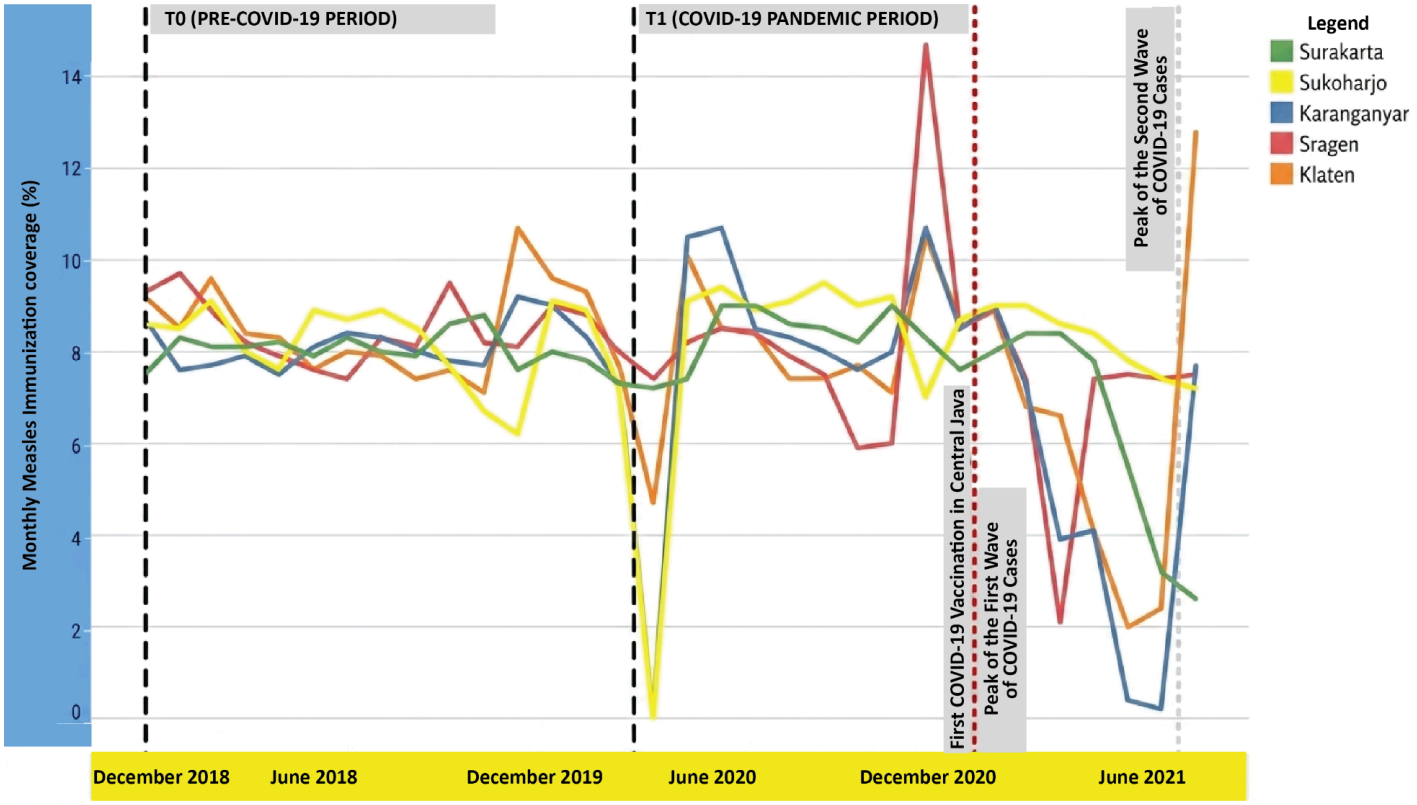
Average monthly coverage of the basic immunization program in Solo Raya during the COVID-19 pandemic with monthly COVID-19 cases

In Figure 7, during the pandemic, all immunization indicators showed similar monthly patterns until about April 2021, whereas IPV showed a more distinct pattern. In 2021, COVID-19 case data showed two notable periods of increased cases, peaking in January and July 2021. During periods of increased cases, several immunization indicators showed decreases in coverage in certain months. After these periods, several indicators increased in coverage toward the end of the observation period. Figure 7 illustrates this temporal pattern.



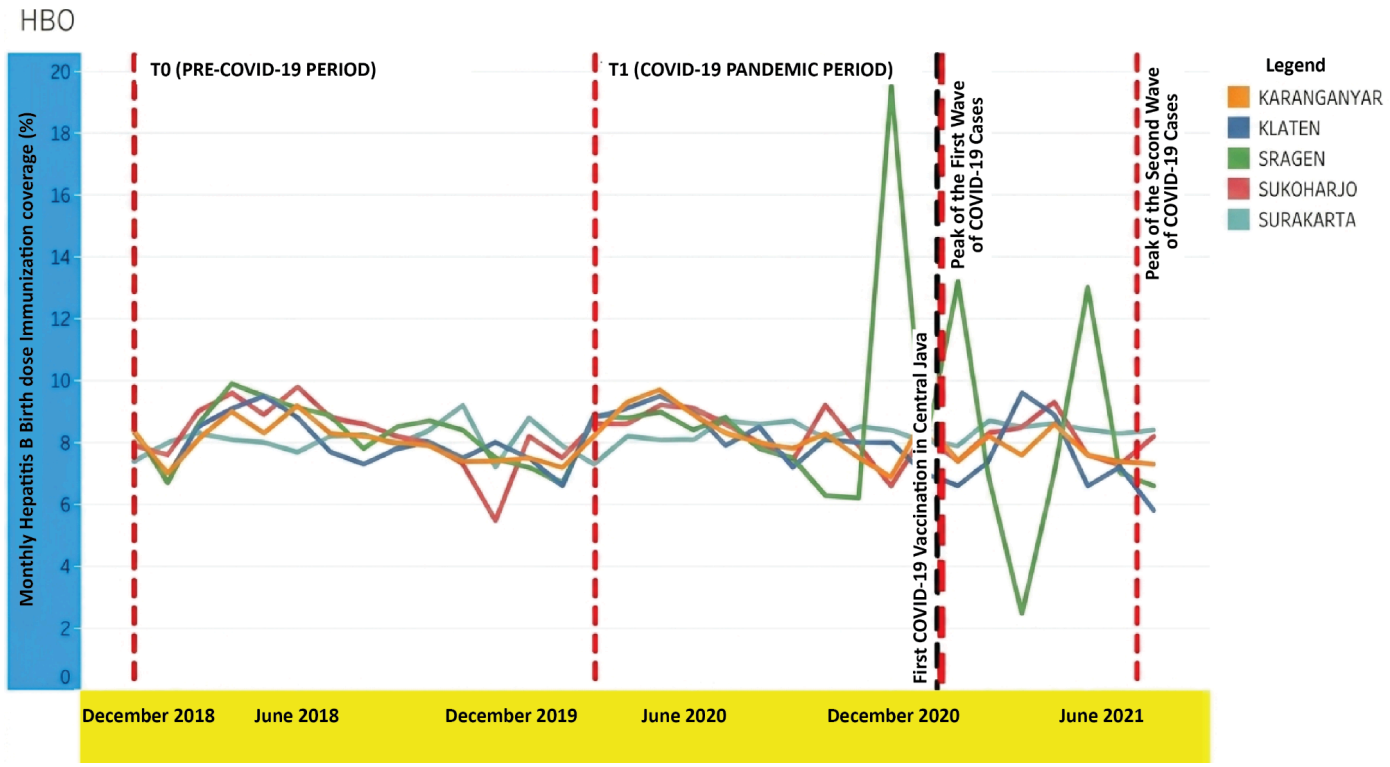
Source: Processed secondary data

Figure 1. Monthly coverage of the BCG immunization program in Solo Raya before and during the COVID-19 pandemic



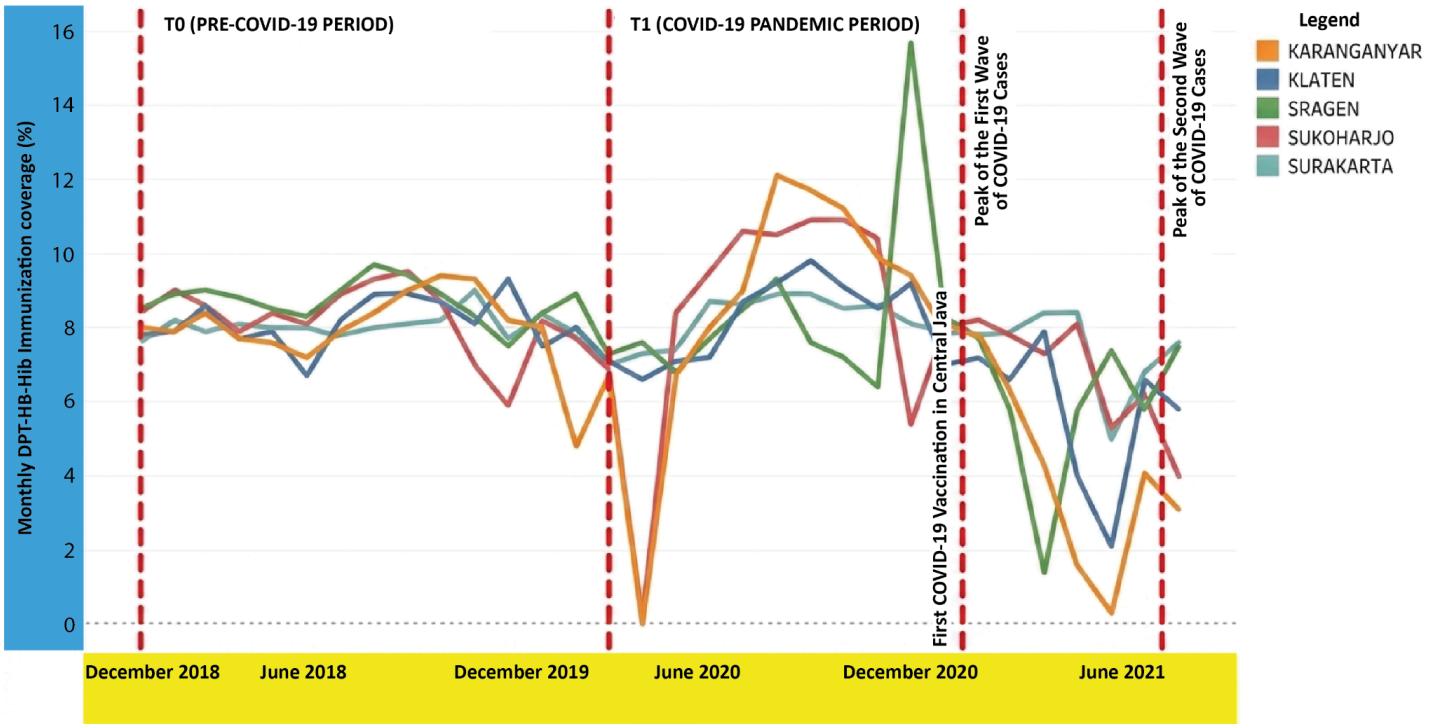
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Figure 2. Monthly coverage of the measles immunization program in Solo Raya before and during the COVID-19 pandemic



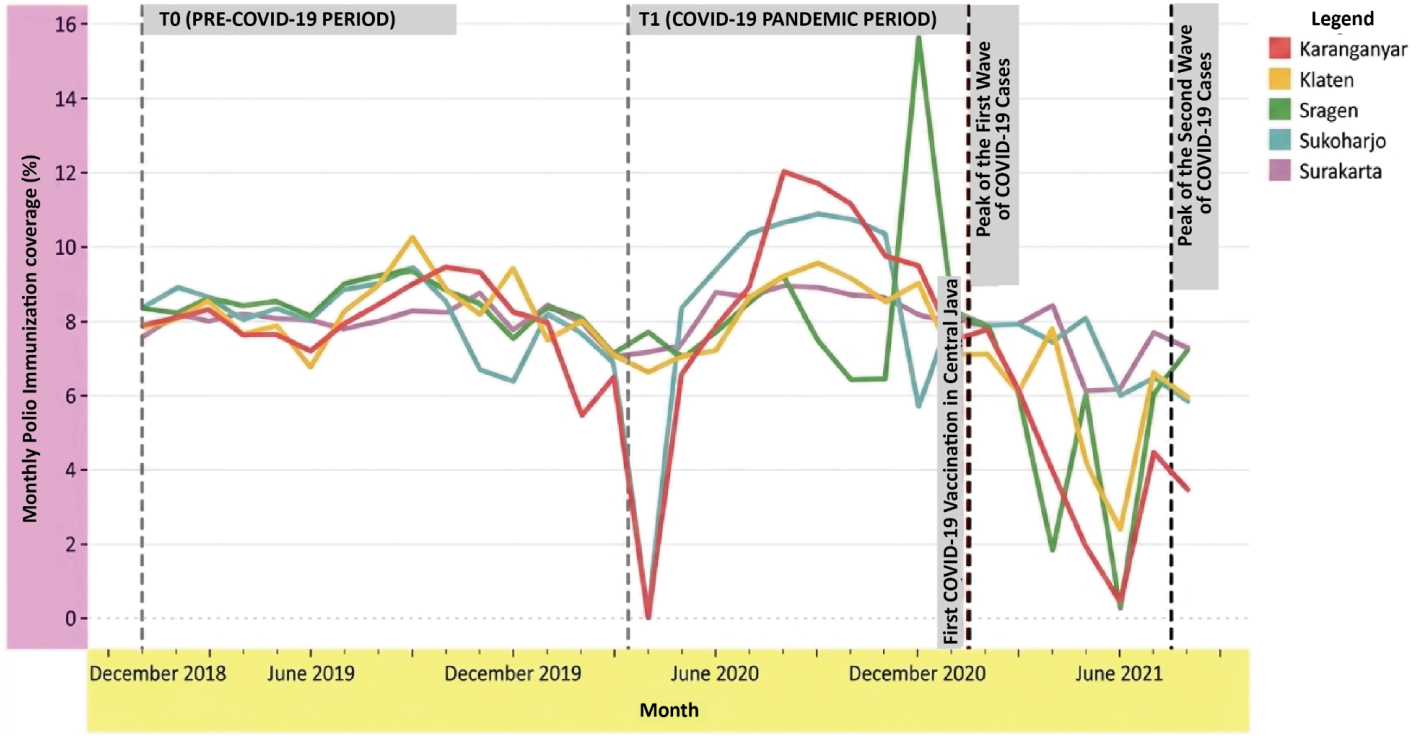
Source: Processed secondary data

Figure 3. Monthly coverage of the HB0 immunization program in Solo Raya before and during the COVID-19 pandemic



Source: Processed secondary data

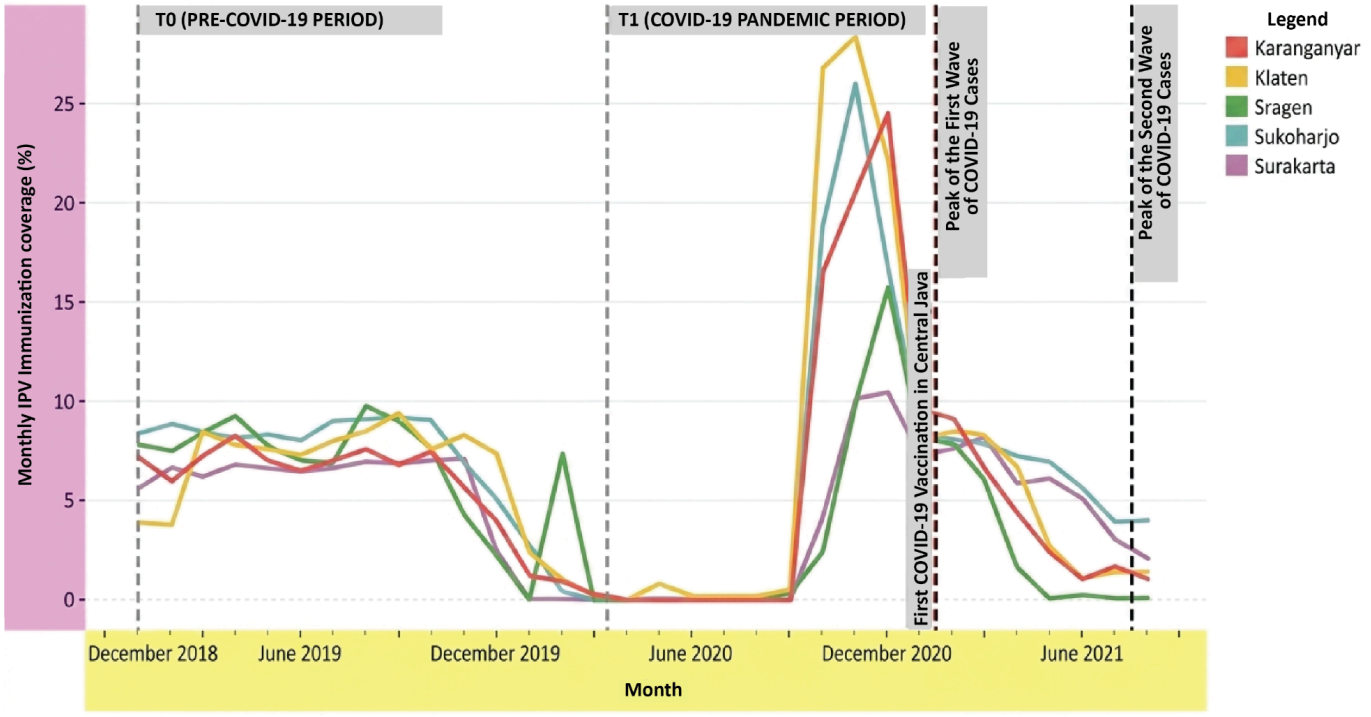
Figure 4. Monthly coverage of the DPT-HB-HiB immunization program in Solo Raya before and during the COVID-19 pandemic



The trends of Karanganyar, Klaten, Sragen, Sukoharjo and Surakarta for Month. Color shows details about Karanganyar, Klaten, Sragen, Sukoharjo and Surakarta.

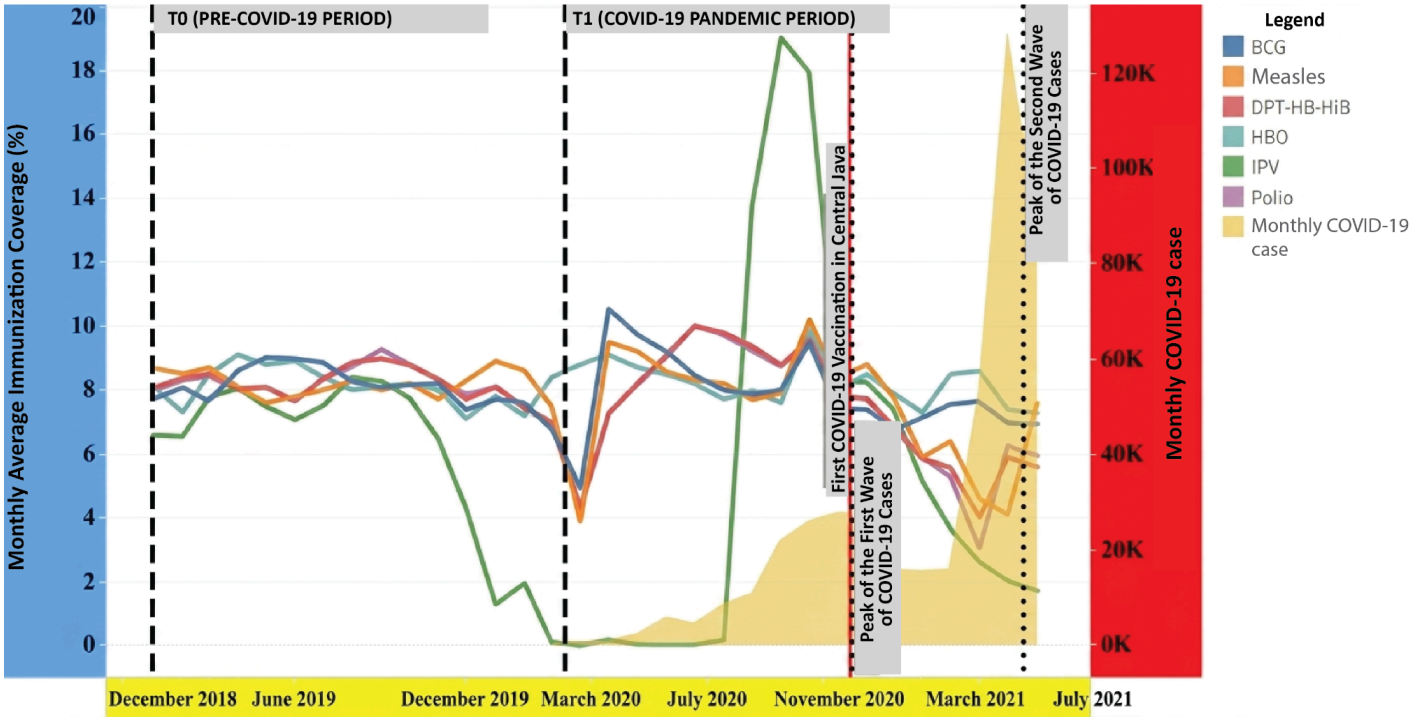
Source: Processed secondary data

Figure 5. Monthly coverage of the polio immunization program in Solo Raya before and during the COVID-19 pandemic



Source: Processed secondary data

Figure 6. Monthly coverage of the IPV immunization program in Solo Raya before and during the COVID-19 pandemic



Source: Processed secondary data

Figure 7. Average monthly coverage of the basic immunization program in Solo Raya before and during the COVID-19 pandemic with monthly COVID-19 cases

Summary statistics of monthly basic immunization coverage in Solo Raya before and during the COVID-19 pandemic

Based on Table 1, the mean monthly coverage decreased for five of the six indicators during the pandemic period compared with the pre-pandemic period. IPV coverage showed the largest decrease, with a mean difference of 1.36 percentage points.

Table 1. Summary statistics of average monthly immunization coverage before and during the COVID-19 pandemic

Basic immunization coverage	Mean ± SD	
	Before the COVID-19 pandemic	During the COVID-19 pandemic
BCG	8.16 ± 0.53	7.82 ± 1.30
Measles	8.29 ± 0.35	7.45 ± 1.79
HB0	8.10 ± 0.62	8.2 ± 0.66
DPT-HB-HiB	8.23 ± 0.45	7.37 ± 1.86
Polio	8.23 ± 0.47	7.32 ± 1.95
IPV	6.38 ± 2.27	5.02 ± 6.25

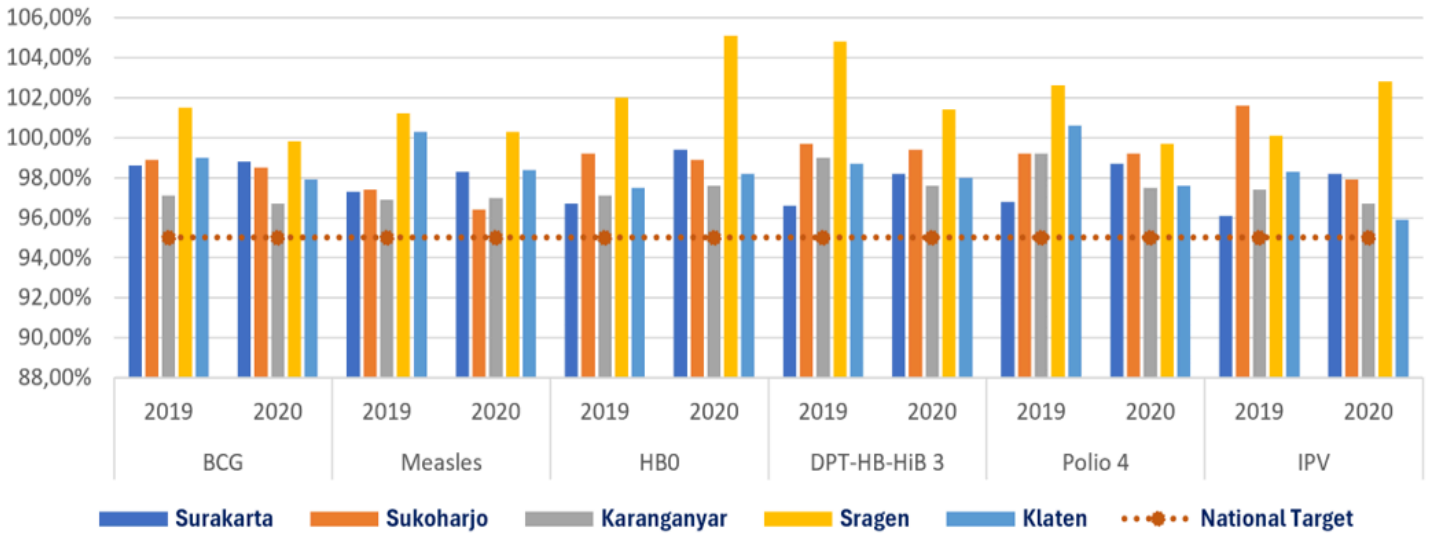
Source: Processed secondary data

In contrast, the mean HB0 coverage increased from 8.10 to 8.20. In addition to changes in the mean, the standard deviations were higher during the pandemic period for all indicators than during the pre-pandemic period, particularly for IPV, indicating greater variation in monthly coverage during the pandemic period.

Achievement of basic immunization targets in 2019 and 2020

As shown in Figure 8, overall immunization indicators achieved the annual targets in the observed areas. However, compared with 2019, annual coverage decreased in Klaten, Karanganyar, Sukoharjo, and Sragen Regencies in 2020. In contrast, Surakarta City showed an increase in coverage in 2020. HB0 showed a greater tendency toward increased coverage compared with the other indicators. Despite variations in monthly coverage, annual coverage in most areas remained above the national target of 95%.

Informal operational consultations identified operational challenges during the pandemic, including temporary suspensions of immunization services, vaccine shortages, reassignment of health personnel to COVID-19 services, and parental concerns about COVID-19 transmission, which coincided with periods of reduced or fluctuating immunization coverage. Documentary evidence was reviewed to corroborate information concerning changes in health-service policies and immunization service delivery during the pandemic. Health authorities implemented targeted catch-up activities to recover missed doses. These included reopening *Posyandu* under strict health protocols and decentralizing delivery to auxiliary health centers (*Puskesmas Pembantu*), clinics, and independent midwife practices. These interventions compensated for temporary drops and scaled up final annual coverage above the 95% target.



Source: Processed secondary data

Figure 8. Annual immunization coverage by vaccine type in all district (2019-2020)

DISCUSSION

This study highlights an important distinction between overall annual immunization performance and the continuity of immunization services at the monthly level during the COVID-19 pandemic. Although annual immunization coverage remained at the expected program level, monthly coverage became more variable during the pandemic, with some indicators showing more observable fluctuations than others. IPV showed the greatest reduction and variability, suggesting that some vaccine-specific services may have been more vulnerable to disruptions in routine service delivery. These findings indicate that annual coverage alone may not fully reflect temporary interruptions in access to immunization services. Monitoring monthly coverage is therefore important for identifying periods of reduced service delivery and enabling timely corrective actions before immunization gaps accumulate.

The observed patterns align with evidence from other settings showing that the COVID-19 pandemic disrupted routine immunization services. In India, lockdown policies substantially interrupted routine immunization activities early in the pandemic, followed by a gradual resumption of services as restrictions eased [5]. Similar disruptions were reported in both low- and middle-income and high-income countries. In Pakistan, substantial proportions of children missed routine vaccinations during the lockdown period [4], while vaccination rates in the United States declined following the declaration of the national COVID-19 emergency [3]. These findings suggest that disruptions to routine immunization were not limited to a particular health-system context. In Solo Raya, the observed fluctuations should therefore be understood within the broader context of changes in healthcare access, service delivery, and health-system priorities during the pandemic. Available contextual information from health workers indicated adjustments to *Posyandu* operations, temporary service restrictions, resource constraints, and subsequent catch-up immunization activities. However, these observations should be interpreted as contextual information rather than as evidence that any single factor caused the observed changes in coverage.

The findings have direct implications for routine immunization programs. Maintaining high annual coverage should be complemented by continuous monitoring of monthly service delivery, particularly for vaccines or doses showing greater variability. Health authorities should strengthen mechanisms to identify declining coverage early and promptly implement catch-up activities when service interruptions occur. Maintaining immunization services during public health emergencies also requires flexible service-delivery arrangements. Previous evidence and national guidance emphasize strategies such as appointment-based services, separating sick and healthy children, ensuring adequate ventilation and hand hygiene, maintaining physical distancing, and implementing appropriate screening procedures to reduce infection risks while sustaining immunization services [6,17,18]. Other approaches reported internationally include increasing the number of immunization clinics, reorganizing patient flow, extending service hours, and providing vaccination through alternative models such as drive-through services [15]. These approaches may be considered according to local feasibility and health-system capacity. Solo Raya's experience also underscores the importance of maintaining service continuity through alternative healthcare facilities when community-based services are temporarily restricted.

From a broader public health perspective, interruptions in routine childhood immunization can create temporary gaps in protection even when annual program indicators appear satisfactory. Delayed vaccination may leave children susceptible to vaccine-preventable diseases during periods when routine services are disrupted [15,16,19]. This is particularly relevant for diseases such as measles and diphtheria, where declining or delayed vaccination can increase outbreak risk when population immunity is insufficient [1,5]. This study shows that immunization resilience should not be assessed solely by whether annual targets are achieved, but also by health systems' ability to maintain equitable, continuous access to vaccination during emergencies. Strengthening community-based services, maintaining alternative vaccination sites, and ensuring timely communication with caregivers may help reduce temporary barriers to immunization. At the policy level, emergency preparedness and response systems should incorporate routine immunization indicators to detect and address disruptions to essential preventive services alongside managing acute health threats.

Future research should investigate the mechanisms underlying the temporal variation in immunization coverage using more robust analytical approaches. Interrupted time-series or segmented regression analyses could formally assess changes in level and trend before and after the pandemic's onset while accounting for underlying temporal patterns. Future studies should also examine seasonality, reporting delays, changes in target-population denominators, and differences between districts. Individual-level studies

would further help determine whether reductions in service coverage translated into delayed or incomplete vaccination among children and identify which population groups were most affected. In addition, qualitative studies involving health workers, caregivers, and community stakeholders could systematically explore barriers and facilitators to maintaining immunization services during public health emergencies. Such evidence would support the development of more targeted, context-specific strategies to maintain continuity of routine immunization during future outbreaks or other health-system disruptions.

The main limitation of this study is its descriptive, exploratory design, which does not allow causal inference about the relationship between the COVID-19 pandemic and changes in immunization coverage. In addition, the analysis relied primarily on administrative data that may have varied in completeness, reporting practices, and reporting delays across districts and months. The study did not cover all areas that might be considered part of the broader Solo Raya region, and the analytical approach did not formally account for seasonality or autocorrelation. Finally, the lack of individual-level vaccination records prevented assessment of whether changes in aggregate coverage reflected delayed vaccination, missed vaccination, or reporting differences. Therefore, interpret the findings as descriptive evidence of changes in immunization coverage patterns rather than causal effects.

CONCLUSION

Basic immunization coverage fluctuated during the COVID-19 pandemic, increasing and decreasing compared with the pre-pandemic period, when coverage patterns tended to remain stable. During the pandemic, IPV immunization coverage declined the most. For all immunizations other than IPV, coverage remained relatively stable, ranging from 7.32% to 8.20%.

During the first wave of COVID-19, patterns in each basic immunization coverage indicator did not change. However, during the second wave of COVID-19, patterns in each basic immunization coverage indicator changed. Comparing the pre-pandemic and pandemic periods showed a decline in summary statistics. These findings suggest that the COVID-19 pandemic may have affected immunization coverage. In 2019–2020, annual basic immunization coverage in all observed areas of Solo Raya successfully achieved the national target. Health institutions are expected to maintain and optimize Indonesia's existing immunization implementation system and apply it across regions to sustain stable monthly basic immunization coverage.

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Authors' contributions
I.A.: Conceptualization, Methodology, Supervision, Writing—original draft; S.N.R., D.K., V.D.H., E.T.C.: formal analysis, Data curation, Writing—review & editing; all authors approved the final manuscript.

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This research was self-funded.

Data availability
The corresponding author can provide the data supporting the findings of this study upon reasonable request.

Ethics statements
This study used anonymized, aggregated secondary administrative data prior to analysis. The study involved no direct interaction with human participants, and it did not access or analyze any individually identifiable patient information. In accordance with applicable institutional policies and regulations, this study did not require formal ethical approval or informed consent. Nevertheless, we maintained strict data confidentiality and privacy throughout the research process and used the data exclusively for the stated research purposes.

Conflicts of interest
The authors declare no conflict of interest regarding the publication of this article.

Use of artificial intelligence (AI)
The authors refined portions of this manuscript using ChatGPT, Gemini AI, and QuillBot to improve linguistic clarity and sentence structure. The authors have reviewed and validated all AI-assisted outputs and take full responsibility for the accuracy, integrity, and originality of the final manuscript.

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