ORIGINAL ARTICLE

GEOEPIDEMIOLOGICAL ANALYSIS OF COVID-19 CASES IN PREGNANT WOMEN: A DESCRIPTIVE STUDY

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Highlights: (1) Pregnancy is a period of susceptibility to COVID-19 infection. (2) Mixed-race pregnant women aged 18 to 35 were the most affected. (3) Higher number of cases in census tracts with low socioeconomic status.

http://dx.doi.org/10.21527/2176-7114.2026.51.16604

How to cite:
de Sousa EN, Santos P da S, Araújo MLV, da Silva JC, de Sousa GG da S, Santos Neto M. Geoepidemiological analysis of Covid-19 cases in pregnant women: a descriptive study. Rev. Contexto & Saúde. 2026;26(51):e16604

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ABSTRACT

Objectives: To describe the clinical-epidemiological aspects and spatial distribution of COVID-19 in pregnant women in a municipality in the state of Maranhão, Brazil. **Methods:** A descriptive and ecological study with a quantitative approach, based on cases notified to the Notifiable Diseases Information System (SINAN) between May 2020 and October 2021. The variables used were: age, skin color/ethnicity, healthcare professional status, municipality of residence, street, neighborhood, signs and symptoms, comorbidities, tests performed, test completion, and case outcomes. Data were tabulated, followed by descriptive analysis, incidence calculation, and geoepidemiological analysis. The study was approved by the Research Ethics Committee of the Federal University of Maranhão under opinion No. 4,754,078. **Results:** 313 pregnant women were analyzed. The incidence was 64.40/1000 inhabitants. The age group most represented was 26 to 35 years, most pregnant women identified as mixed-race, and 8 were healthcare professionals. Symptoms such as fever, cough, sore throat, and dyspnea were prominent. The most frequent health conditions were diabetes and decompensated chronic respiratory diseases. Five census tracts with a significant occurrence of COVID-19 in pregnant women were identified in the municipality. **Conclusions:** The group most affected by COVID-19 consisted of young adult women, mixed-race, and from census tracts with low socioeconomic status. The research provides data that can assist managers in formulating prevention and assistance strategies for future health crises.

Keywords: Pregnant women; COVID-19; Spatial analysis.

INTRODUCTION

Severe acute respiratory syndrome coronavirus (*SARS-CoV-2*), the etiological agent of COVID-19, has spread rapidly worldwide. The World Health Organization (WHO) reported that as of July 5, 2023, 767,726,861 confirmed cases and 6,951,677 deaths had been recorded globally[1]. Nationally, according to the Ministry of Health Bulletin published on September 12, 2024, the number of confirmed cases reached 38,907,767[2]. Regarding pregnant and postpartum women, the Brazilian Obstetric Observatory (OOBr) confirmed 25,192 cases of COVID-19 as of September 13, 2024[3].

Characterized by various forms of progression, COVID-19 can manifest as asymptomatic, mild, moderate, or severe. In extreme outcomes, the virus can lead to multi-organ failure and death, primarily in high-risk groups, such as the elderly, individuals with

decompensated chronic respiratory diseases, obesity, smokers, immunocompromised individuals, and pregnant women[4].

Pregnancy is a period of natural immunological and physiological changes, such as the suppression of adaptive immunity and alterations in pulmonary function, which may render pregnant women more susceptible to severe complications from infections. This vulnerability is supported by evidence from previous coronavirus epidemics, such as Severe Acute Respiratory Syndrome (SARS) and Middle East Respiratory Syndrome (MERS), which were associated with concerning outcomes, including miscarriages and maternal death. Therefore, it is crucial to study the effects of COVID-19 in this group[5-7].

A study conducted in New York revealed that pregnant women with COVID-19 tend to remain asymptomatic or develop only mild symptoms, with a reduced risk of hospitalization for moderate aggravation. Despite the preliminary nature of these data, the findings are significant for guiding clinical management; it should be noted that this population, even if not the most critical, requires continuous attention, especially when they present with other comorbidities[8].

An international multicenter study compared countries and regions to evaluate global regional differences in the burden of SARS-CoV-2 infection on maternal and perinatal outcomes, observing substantial differences between world regions regarding disease burden and gestational outcomes. It pointed out that geographical heterogeneity may be related to health systems, socioeconomic conditions, and pandemic response capacity, which would determine local variations and disease severity[9].

Studies show that intrauterine transmission of *SARS-CoV-2* is biologically possible but clinically uncommon, and the risk may be increased with the severity of maternal infection. Thus, even with studies corroborating the possibility of transmission, analyses often present methodological biases; one is the difficulty in accurately classifying whether the transmission occurred via the intrauterine or intrapartum route[5,8,10].

National studies on pregnant women with COVID-19 in Brazil investigate how the saturation of the healthcare system during the pandemic hindered access to prenatal care, aggravating maternal and neonatal outcomes[11]. These studies analyze everything from the profile and racial disparities of the affected women[10,12] to the clinical and psychological impacts of the pandemic on this group[13,14].

Within the context of Maranhão, a qualitative investigation analyzed the social representations of pregnant women who underwent prenatal care during the disease outbreak in

São Luís, MA[15]; another study showed the progression of maternal deaths during this period in the southern part of the state; and a study verified deaths related to maternal obstetric causes in Maranhão between 2011 and 2020, in which, although it does not specifically observe COVID-19, it concludes that there was an increase in maternal mortality between 2019 and 2020 during the pandemic, but it does not provide a specific analysis of COVID-19 as a cause or associated factor, nor did it evaluate spatial changes in the mortality pattern during the pandemic[16]. However, no research was found that conducted ecological studies including the spatial distribution of pregnant women notified with COVID-19 in the state of Maranhão.

The Geographic Information System (GIS) has been widely used since the beginning of the COVID-19 pandemic, as it is possible to deduce areas of high or low risk for virus morbidity[17]. Spatial distribution aids in understanding how COVID-19 spread among pregnant women and, thus, assists in formulating planning, implementations, and strategies that can contribute to future health crisis situations[18]. According to Ordinance 1,631/201 of the Ministry of Health, epidemiological studies can assist in the distribution of the minimum number of beds and resources to be offered[19].

Furthermore, the study is justified by the gap in investigations focusing on pregnant women affected by the disease based on regional contexts, which, in this case, is the Southwest of Maranhão. The scarcity of published investigations on the epidemiological profile of pregnant women notified with COVID-19 in Maranhão cities is interesting to verify to what extent local data approach the national scenario, thus exploring the dynamics of the disease in the region and improving the understanding of the geoepidemiological context in which the disease is inserted.

Given the above, the present study aimed to describe the clinical-epidemiological aspects and the spatial distribution of COVID-19 in pregnant women in a municipality in the state of Maranhão, Brazil.

METHODS

This descriptive, ecological, quantitative study used data collected from notified COVID-19 cases among pregnant women in the municipality of Imperatriz, Maranhão, from May 2020 to October 2021. Data collection was carried out from November to December 2021. The study followed the recommendations of the STROBE Statement (Strengthening the Reporting of Observational Studies in Epidemiology)[20].

The municipality of Imperatriz, located in the state of Maranhão, has a land area of 1,369.039 km², is situated on the banks of the Tocantins River, and is 629.5 km from the capital, São Luís. With an estimated population of 259,980 inhabitants, it is considered the second-largest city in the state and the second-largest political, cultural, and population center, also serving as a university, commercial, and health hub (Figure 1).

According to data from the Imperatriz Municipal Government, the city has about 160 neighborhoods. The municipality has 218 census tracts (CT) in the urban area, according to the distribution of the last census[21].

Figure 1 - Map of the State of Maranhão, highlighting the municipality of Imperatriz-MA.

Source: Adapted from geographic database

Data were obtained from the municipal epidemiological surveillance via the Notifiable Diseases Information System (SINAN) (COVID-19 notification forms), which contains information on notified pregnant women. The variables used were: age, skin color (yellow, white, mixed-race, black, not reported), healthcare professional status (yes, no), municipality of residence, street, neighborhood, signs and symptoms (coryza, dyspnea, diarrhea, headache, sore throat, taste disorders, olfactory disorders, fever, cough, others, asymptomatic), comorbidities (yes, no), types of comorbidities (diabetes, chronic heart disease, decompensated chronic respiratory disease, advanced chronic kidney disease [stages 3, 4, or 5],

immunocompromised, chromosomal diseases or immune fragility, obesity), tests performed (rapid antigen test, antibody test, RT-PCR), and case outcomes (death, recovery, not reported).

COVID-19 notification parameters are distinguished based on clinical-epidemiological, laboratory, and clinical-imaging criteria. Clinical criteria were considered based on the assessment of acute respiratory conditions, characterized by the presence of at least two (2) of the following signs and symptoms in the last 7 days: fever (even if referred), chills, sore throat, headache, cough, coryza, olfactory disorders, or taste disorders.

Therefore, all pregnant women who met the notification criteria were included. After extraction, the database was analyzed by two researchers from the team, and a decision was made to exclude notifications with incomplete data and those in duplicate.

Variables were tabulated and organized in an electronic spreadsheet using Microsoft Excel 2019 software (Version 2208 Build 16.0.15601.20072), which was also used to perform the proposed descriptive analyses. Initially, the database consistency stage was performed, including the identification and exclusion of duplicate records, verification of mandatory fields, standardization of categorical variables, and checking for possible inconsistencies between related variables. Records with missing essential information for analysis, chronological discrepancies (such as incompatible or invalid dates), and values outside expected ranges for numerical variables were considered inconsistent. When possible, inconsistencies were corrected by verifying against the original epidemiological surveillance database; in cases where the inconsistency persisted, the record was excluded from the respective analysis.

After data quality verification, descriptive statistical analysis was performed by calculating absolute and relative frequencies of the patients' sociodemographic, clinical, and laboratory characteristics.

To calculate incidence, the number of pregnant women monitored monthly in the municipality during the study period was retrieved via the Health Information System for Primary Care (SISAB), using the indicator “Pregnant women with the first prenatal care visit.” The total number of pregnant women monitored monthly in the municipality of Imperatriz-MA between May 2020, and October 2021 was 4,860. The formula used was: the number of pregnant women with COVID-19 divided by the number of pregnant women in the municipality, multiplied by 1,000.

The survey of cases notified during the proposed period was performed via remote mapping, in which addresses were geocoded using the online platform BatchGeo (https://pt.batchgeo.com/). Prior to geocoding, addresses from the municipal epidemiological

surveillance underwent a textual standardization process, correcting orthographic inconsistencies, standardizing street names, and verifying information completeness to reduce location errors. Only records containing sufficient minimum information to identify the residence spatially were used. In cases where the street number was absent or ambiguous, the location was assigned to the centroid of the street or the reported reference area, with such situations subjected to manual verification. Records whose addresses remained indeterminate after verification were excluded from the spatial analysis.

The generated geocodes were exported to QGIS (version X.X), free software used for visualization, management, editing, and analysis of spatial data, as well as for creating thematic maps. The SIRGAS 2000 geodetic reference system was adopted, ensuring compatibility with official cartographic bases. Visual validation of point positioning was performed, identifying potential spatial discrepancies and making adjustments, when necessary, as a form of quality control for georeferencing.

Geocoded cases (represented by points) were distributed within the census tract (CT) grid of the municipality of Imperatriz, based on the 2010 Demographic Census from the Brazilian Institute of Geography and Statistics (IBGE). This spatial unit was chosen because the municipality lacks an official division of neighborhoods and, above all, because it is a territorial division with well-defined boundaries and a smaller area compared to neighborhoods, which provides greater analytical precision and reduces the spatial aggregation effect in rate calculations.

In compliance with Resolutions 466/12 and 510/2016 of the National Health Council (CNS), the research protocol was approved by the Research Ethics Committee of the Federal University of Maranhão under opinion No. 4,754,078.

RESULTS

During the analyzed period, 681 pregnant women with COVID-19 were notified in Imperatriz-MA, with 176 cases in 2020 and 505 cases in 2021. Using the adopted criteria, 342 pregnant women (50.2%) were excluded from the analysis because they presented non-reactive/non-detectable laboratory results and/or did not meet the confirmed clinical criteria, in addition to 26 (3.8%) duplicate notifications. No imaging exams were used as a notification criterion. Therefore, considering the adopted criteria, the analysis corpus is composed of 313 pregnant women (45.9%) notified with COVID-19 (Table 1).

Table 1. Number of pregnant women by year of notification for COVID-19 via SINAN. Imperatriz, Maranhão, Brazil, May to December 2020 and January to October 2021.

	2020		2021	
Variable	**N**	**%**	**N**	**%**
Reagent/Detectable tests	31	17.6	125	24.7
Non-reagent/Non-detectable tests	63	35.8	279	55.2
Clinical criteria	70	39.7	87	17.2
Discarded cases	12	6.8	14	2.7
Imaging criteria	0	0	0	0
Total	**176**	**100**	**505**	**100**

Source: Research data. Municipal epidemiological surveillance and SINAN. Imperatriz – MA, Brazil, May 2020 to October 2021.

Table 2 highlights the sociodemographic characteristics, indicating that the predominant age group was 26 to 35 years (41.5%) and 18 to 25 years (37.1%). Results show that 2.5% of the pregnant women were minors, and 1.60% were aged 56 years or older.

Regarding skin color/ethnicity, the research found the highest percentage of pregnant women identified as mixed-race (76.3%). As for symptoms, the most frequent were cough (59.7%), fever (46.1%), sore throat (44.1%), and dyspnea (33.2%). Asymptomatic cases represented 4.4% of the total.

In the diagnosis of pregnant women with COVID-19, serological tests for antibodies (22.7%), rapid antigen tests (23.0%), and molecular biology or RT-PCR tests (4.1%) were performed. In other words, 50.2% of the pregnant women were notified based on the assessment of signs and symptoms.

Of the 313 pregnant women notified by positive test or clinical criteria, 18 had some factor associated with a higher health risk. The most prevalent health conditions were diabetes and decompensated chronic respiratory disease (both at 1.9%).

Of the total number of pregnant women, 2.6% were healthcare professionals across various categories. Regarding case outcomes, most lacked this information (99.7%); however, one pregnant woman (0.3%) recovered, and one resulted in maternal death (a 24-year-old with obesity).

Table 2. Distribution of clinical-epidemiological and laboratory variables of COVID-19 cases notified in the municipality of Imperatriz-MA (March 2020 to January 2021). Imperatriz, Maranhão, Brazil, 2022.

Variable	N	%
Age group	-	-
≤ 17	8	2.6
18-25	116	37.1
26-35	130	41.5
36-45	49	15.6
46-55	5	1.6
≥ 56	5	1.6
Ethnicity	-	-
Asian	29	9.3
White	30	9.6
Mixed-race	239	76.3
Black	3	1.0
Not reported	12	3.8
Associated comorbidity	-	-
Yes	18	5.7
No	295	94.3
Types of comorbidities	-	-
Diabetes	6	1.92
Chronic heart disease	1	0.3
Decompesated chronic respiratory disease	6	1.9
Advanced chronic kidney disease (stages 3.4 or 5)	1	0.3
Immunocompromised	1	0.3
Chromosomal diseases or immune fragility	2	0.6
Obesity	1	0.3
Tests completed	-	-
Rapid antigen test	72	23.0
Rapid antibody test (IgM/IgG)	71	22.7
RT-PCR	13	4.1
Symptoms*	-	-
Coryza	56	17.9
Dyspnea	104	33.2
Diarrhea	12	3.8
Headache	94	30.0
Sore throat	138	44.1
Taste disorders	39	12.5
Olfactory disorders	36	11.5
Fever	146	46.6
Cough	187	59.7
Others	54	17.2
Asymptomatic	14	4.5
Healthcare professional	-	-
Community health agent	2	0.6
Nurse	2	0.6
Physiotherapist	1	0.3
Nurse technician	1	0.3
Others	2	0.6
Case outcome	-	-
Death	1	0.3
Recovery	1	0.3
Not reported	311	99.7

Source: Municipal epidemiological surveillance and SINAN. Imperatriz – MA, Brazil, May 2020 to October 2021.

The incidence of COVID-19 among pregnant women in the analyzed municipality was 64.4/1,000 inhabitants, being 47.0/1,000 in 2020 and 78.1/1,000 in 2021. Of the 313 cases of pregnant women notified during this interval, 298 were georeferenced, representing 95.2% of total cases.

Figure 2A illustrates the distribution of cases in the urban area of Imperatriz, MA, and Figure 2B represents a map with the number of cases of pregnant women with COVID-19 by census tract. The maps reveal a heterogeneous distribution of the health condition which, despite being present across nearly the entire municipality, shows a higher concentration in certain census tracts.

Figure 2A - General map of the distribution of cases of pregnant women with COVID-19 in the municipality of Imperatriz (May 2020 to October 2021). Imperatriz-MA, Brazil. 2023.

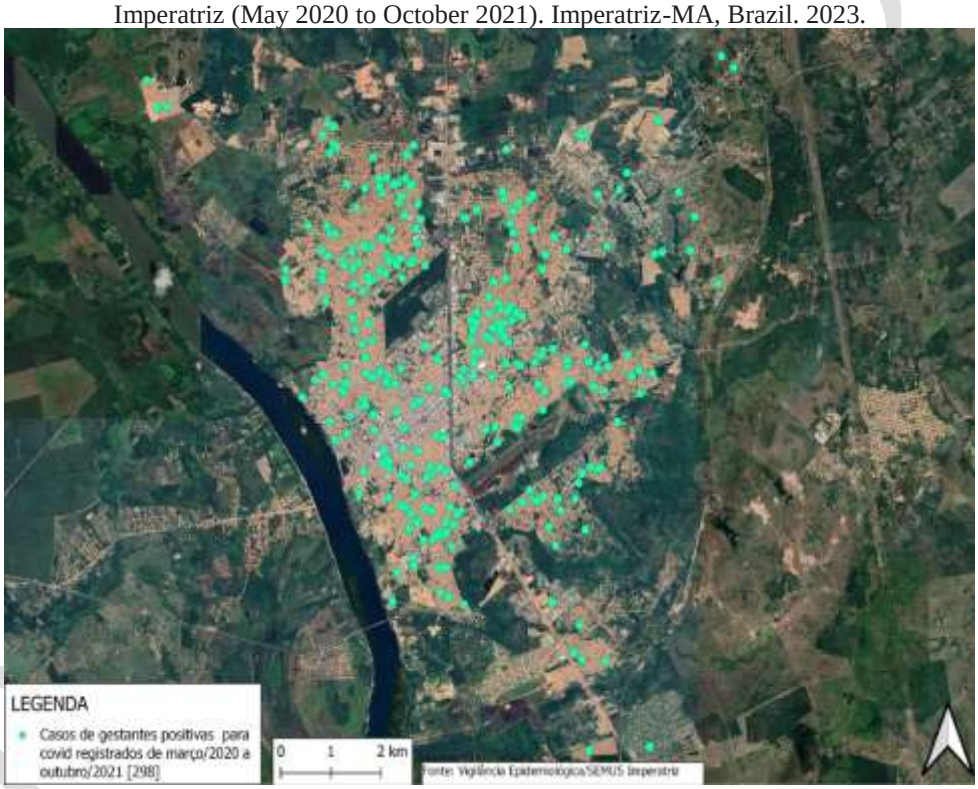
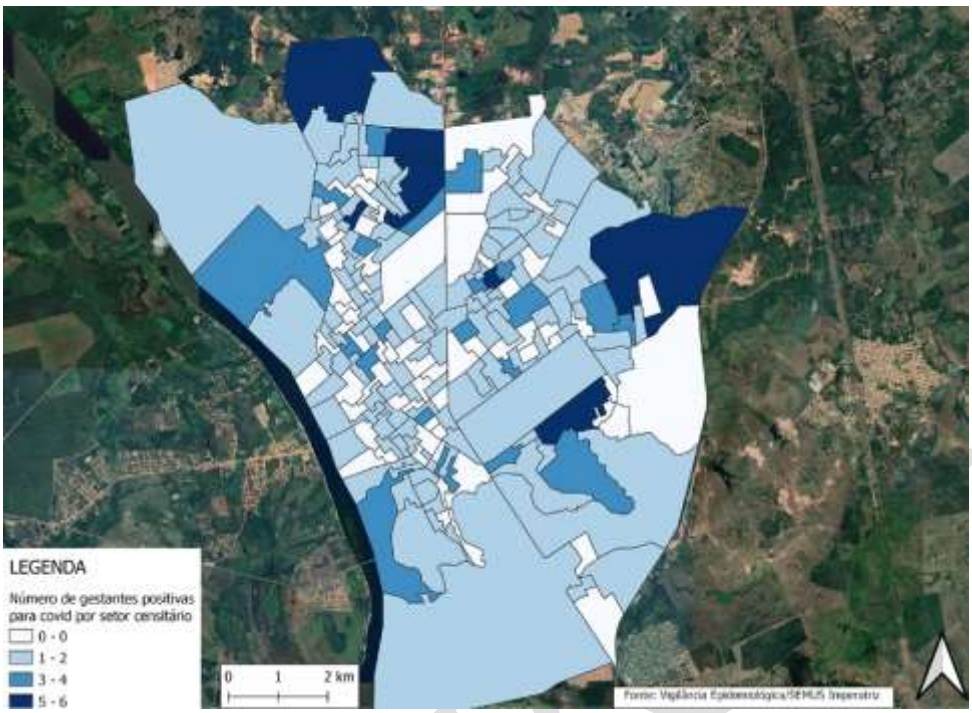


Figure 2B - Map of the distribution of cases of pregnant women with COVID-19 by census tract in the municipality of Imperatriz-MA (May 2020 to October 2021). Imperatriz-MA, Brazil. 2023.



The highest concentration of COVID-19 cases in pregnant women was found in census tracts belonging to the Bom Jesus, Parque Alvorada I, Vila Lobão, São José, and Ouro Verde neighborhoods, where five to six cases were notified. There was also an occurrence of three to four cases in some census tracts encompassing Parque Santa Lúcia, Vila Airton Sena, Vilinha, Vila Nova, and Bacuri.

DISCUSSION

The physiological and immunological changes that occur during pregnancy may lead to functional impairment when pregnant women are infected by upper respiratory tract pathogens, such as the COVID-19 virus, where there is a tendency to progress to more severe clinical conditions[7,10].

In Brazil, there is no universal testing policy; however, the Recommendations Manual for Assistance to Pregnant and Postpartum Women facing the COVID-19 Pandemic (2021) states that all women at the time of clinical or surgical admission, or for vaginal delivery, should undergo an RT-qPCR test for SARS-CoV-2, provided they have not had a previous positive diagnosis. If the result is delayed, a rapid test is recommended[13,22].

In the analyzed municipality, there was a significant increase in the total number of cases of pregnant women notified with COVID-19 between May 2020 and October 2021. This increase may be attributed to the phase in which COVID-19 had high transmissibility, but it is also important to highlight the greater availability of diagnostic tests, which may increase the number of notifications and reactive/detectable cases[6].

Despite this, a portion of the pregnant women was excluded from the proposed analyses after applying the study's inclusion/exclusion criteria. Early in the pandemic, pregnant women with characteristic signs and symptoms of COVID-19 would seek healthcare, but they did not meet the defined clinical criteria or were not within the timeframe of at least 7 days from the onset of symptoms for serological testing to be performed and infection confirmed. Some returned to the health service for post-symptomatic testing, which may be one of the reasons for the exclusion of some pregnant women at the onset of infection. It is important to highlight that structural and care-related weaknesses may have contributed to failures in case identification and notification, as well as influencing maternal outcomes[13].

During data analysis and considering the exclusion criteria, a number of duplicates was observed, similar to a study conducted in Wuhan, China[23]. Occasionally, duplications in this study's notifications are due to the fact that reactive/detectable pregnant women sought the same or another health service on the same day or 12 days after the first test. Another factor is that some pregnant women tested non-reagent/non-detectable in one location and repeated the exam in another service to confirm the previous result.

It is also interesting to note the high number of pregnant women who obtained a non-reagent/non-detectable laboratory result (342; 50.2%) or who did not present clearly established clinical criteria. In this sense, the exclusion of data in the analysis is justified by the inclusion and exclusion criteria previously established in the study, yet they may indicate a limitation in the sample's representativeness. Data analysis indicates great concern among pregnant women regarding COVID-19, as they are part of one of the disease's risk groups[6].

Regarding the age group variable, a predominance of notifications for young adult pregnant women aged 18 to 35 was observed in the municipality of Imperatriz. This result is expected, as this is the peak reproductive age group, and aligns with national research that has evidenced the prevalence of pregnant women affected by COVID-19 between the ages of 20 and 39 years[10,12,24]. This finding was also verified in the international scenario, where an investigation in China, Italy, and Iran found a higher frequency of infection in pregnant women in the age group between 25 and 34 years[7].

Regarding ethnicity, the majority of pregnant women identified as mixed-race (76.36%), a result similar to national studies. The population of Imperatriz, MA, is predominantly mixed-race according to IBGE data, which points to a racial characteristic of the region[10-12].

Despite these results, the National Health Council (CNS) has recognized that the Black population experiences greater vulnerability to COVID-19 exposure. In Recommendation No. 004, of March 30, 2021, the CNS highlights that Black individuals may face unfavorable socioeconomic conditions that hinder social isolation and access to healthcare services. Furthermore, they face precarious working conditions, contributing to higher susceptibility to the disease[24]. Another essential point refers to the prevalence of pathologies more common to this racial group, which increase the chance of aggravation by COVID-19, such as arterial hypertension, diabetes mellitus, and kidney disease, which worsen the clinical picture, resulting in a hospitalization and death rate nearly twice as high among Black pregnant women compared to White pregnant women[14-16].

According to research data, the most prominent comorbidities were Diabetes Mellitus and decompensated chronic respiratory disease. A study conducted in Iran highlights that pregnant women with comorbidities had more severe outcomes, demonstrating that the presence of these conditions worsens pregnancy outcomes in women infected with COVID-19[26].

The overload of health systems during the pandemic hindered access to prenatal care, especially for women with habitual and high-risk pregnancies, contributing to worse maternal and neonatal outcomes[11]. Therefore, it is essential that pregnant women be monitored appropriately to ensure access to necessary care within the Unified Health System (SUS), especially in sanitary crisis situations.

The signs and symptoms of COVID-19 in pregnant women are similar to those in the general population[4,27]. In this research, cough, fever, sore throat, and dyspnea were the most frequent. National[6,23,28] and international[26,28] studies confirm these findings, varying only in percentage. It is emphasized that the early and correct identification of symptoms, especially the most severe ones, is crucial for rapid intervention and to reduce the risk of negative outcomes.

Regarding the diagnosis of COVID-19 in pregnant women in Imperatriz, MA, it can be verified that in 2020 the percentage of notifications by clinical criteria was higher than testing, which may be related to the low quantity of tests available during that period[29]. In 2021, there

was a significant advance in the number of tests, and consequently, notifications by clinical criteria decreased.

Still regarding laboratory exams, two cases were recorded where exams were collected, but they were not completed. Furthermore, analysis of the notification form identified that 59 exams were requested but not collected. Difficulties in obtaining tests, the number of people waiting, and the testing sites may have contributed to this number of requests without collection and completion[30].

It is worth noting that there was no notification by clinical-imaging criteria in the analyzed pregnant women. It is important to emphasize that at the beginning of the COVID-19 pandemic, the Ministry of Health recommended CT scans in cases of flu-like syndrome that could not be confirmed by laboratory criteria. However, this type of exam does not present specificity in relation to COVID-19 and is also high-cost. In Technical Note No. 14/2022-CGGRIPE/DEIDT/SVS/MS of 2022, the clinical-imaging criterion was discontinued due to the low sensitivity of this parameter, since changes in imaging exams in patients with COVID-19 can be found in patients with other pulmonary conditions[4,31].

A national study conducted in 2020 identified 124 deaths of pregnant or postpartum women, a number 3.4 times higher than the total maternal deaths from COVID-19 reported globally[22]. In Brazil, in 2020, maternal deaths from COVID-19 represented about 10% of total deaths caused by the disease[6,22].

It is interesting to observe that the number of deaths among pregnant women nationwide was 1,365 from 2020 to 2022, while in Maranhão, in the same period, the number of deaths was 50 according to OOBr data (2024)[3]. In Imperatriz, MA, one death was notified, in which the pregnant woman was 24 years old, presented with sore throat, cough, fever, and dyspnea, and had a comorbidity.

According to the study's findings, a small portion of the pregnant women presented some comorbidity, among which Systemic Arterial Hypertension, Obesity, and Diabetes Mellitus stood oct. National[32] and international[33] literature also highlights these comorbidities as more prevalent, even if not following the same percentage sequence. According to Hantoushzadeh et al.[26], in a study conducted in Iran, pregnant women with comorbidities had more severe outcomes, showing that the association worsens pregnancy results in women with COVID-19.

During the COVID-19 pandemic, hospitals, basic health units, and clinics became centers of high demand for diagnosis and treatment, which represents a significant risk of

contagion, both for the pregnant women seeking these services and for the professionals working in these environments[6]. The research highlighted the healthcare professionals most affected during the pandemic, evidencing the need for public policies that protect them in sanitary emergency situations.

It is worth noting that during the analyzed period, COVID-19 vaccinations were being integrated gradually in Brazil. Following the determination by the Ministry of Health, pregnant women were not included in the first stage of vaccination in the state of Maranhão, which justifies the absence of this data[35]. Only in July 2021 did the Ministry of Health include pregnant women as a priority group in the National Immunization Program in Brazil[36]. Siqueira et al.[37], in a study of maternal mortality from COVID-19, highlights the need for vaccination in the obstetric population due to the group's high mortality rates.

Census tracts can be used to plan, collect, and disseminate the results of Censuses and Statistical Surveys and thus direct health actions that can benefit the population at highest risk and prevent complications[21,38]. Thus, despite the heterogeneous distribution of cases in the urban area, on the map of cases of pregnant women with COVID-19 by census tract, a higher concentration was observed in some tracts of the Bom Jesus, Parque Alvorada I, Vila Lobão, São José, Ouro Verde, Parque Santa Lúcia, Vila Airton Sena, Vilinha, Vila Nova, and Bacuri neighborhoods.

It is highlighted that the previously cited neighborhoods have a higher number of residents per household, which favors the dissemination of the disease through interpersonal contact. Furthermore, they are characterized by intense socio-spatial inequalities, accompanied by a lack of care from public administrations. It is also noted that the Vila Lobão and Bacuri neighborhoods, besides having low socioeconomic indicators, have open-air markets/fairs, which may have contributed to the virus's circulation, as they presented gatherings of people[39-41].

An ecological study using spatial analysis techniques and time series carried out in the state of Maranhão brought findings that corroborate those of this research, emphasizing that during the first wave of COVID-19, space-time clusters of deaths from the disease were detected in the western region of Maranhão, where the Imperatriz Health Region is located, the city with the highest number of deaths. They also highlight that the fact that Imperatriz has reference hospitals for the treatment of COVID-19 patients may increase the risk of infection due to the overload of health services and equipment[42].

Another relevant piece of information refers to the fact that the municipality of Imperatriz has a High-Risk Maternity (MARI), which is the largest medium and high-complexity maternity hospital in the region and has the capacity to attend to 650 to 700 women per month, offering support to 42 municipalities in the states of Maranhão, Pará, and Tocantins[43]. This data justifies the significant number of pregnant women with COVID-19 who were attended to in the municipality during the highlighted period.

Although the World Health Organization declared the end of the public health emergency of international concern related to COVID-19, marking the transition from the emergency pandemic scenario to a phase of continuous disease management in health systems, there is still no consensus on the best approach to deal with COVID-19 during pregnancy and childbirth44. In addition to clinical and epidemiological factors, it is crucial to consider organizational, social, and political aspects. It is also fundamental that health professionals remain updated on studies addressing the health of pregnant women, in order to offer complete care to the mother and newborn, implementing evidence-based strategies to promote, recover, and qualify assistance[5,45]. Thus, the study brought pertinent information on sociodemographic and clinical characteristics, transmission, and distribution of COVID-19 in a risk population, highlighting the importance of spatial analysis within a geographical region with different realities.

Nevertheless, it is important to point out that this research has limitations, especially regarding the completion of notification forms[16], such as reported outcomes and case progression. It is emphasized that failures in the quality control of epidemiological information can make results subject to ecological fallacy[36]. The presented results and the pointing out of such limitations indicate the need to allocate resources to census tracts and neighborhoods with higher risk, that is, those that showed a higher number of cases, especially when involving diseases transmitted via respiratory routes.

Although these problems did not directly compromise the results, they highlight the need to implement training for health professionals, in order to guarantee accurate information, which will benefit both research and the formulation of public health policies.

Another limitation to be highlighted consists of the denominator used for the incidence calculation, which was based on data from the Health Information System for Primary Care (SISAB), which records predominantly the follow-up carried out within the scope of the Unified Health System. As there is no public database that integrates in a systematic way the prenatal care of the private network in the municipality, it was not possible to estimate with precision

this portion of the population. Such a characteristic may lead to the underestimation of the total number of resident pregnant women; results were interpreted in light of this limitation inherent to national health information systems. Still, the use of SISAB ensures methodological standardization, data traceability, and comparability with similar epidemiological investigations conducted in the context of Primary Care.

Furthermore, for future studies, we point out the need to include strategies that can improve data completeness and thus enable the inclusion of more robust inferential and spatial analyses, which explore associations, causalities between factors, or temporal trends.

CONCLUSIONS

Pregnant women belong to one of the high-risk groups for COVID-19. Therefore, this research is relevant for contributing to national results by deepening the discussion on the profile of pregnant women most affected by the disease and for better understanding the pathology's behavior in the analyzed municipality.

Regarding the behavior of COVID-19 among pregnant women in the municipality of Imperatriz-MA, the incidence was 64.40 per 1,000 inhabitants, being 47.04 per 1,000 in 2020 and 78.14 per 1,000 inhabitants in 2021. The group of women most affected was aged 18 to 35, identified as mixed-race, and resided in census tracts with low socioeconomic profiles.

As a proposal for future studies, it is necessary to expand analyses on COVID-19 behavior among pregnant women to all municipalities in the state of Maranhão, including more robust inferential and spatial analyses. This would contribute to a greater understanding of the associations between risk factors and the analyzed outcomes, thereby increasing the practical and scientific applicability of the study.

This study reinforces the need for public policies that strengthen territorialized epidemiological surveillance by directing resources and intensifying universal prenatal testing in these priority census tracts. Furthermore, it is necessary to invest in the training of primary care professionals for the early identification of symptoms and the qualified notification of cases. Thus, the integration of these actions with intersectoral urban planning and the formal inclusion of pregnant women as a priority group in vaccination and protection campaigns during future health emergencies constitute strategic measures to reduce inequities and protect maternal and infant health.

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Submitted: October 24, 2024

Accepted: March 16, 2026

Published: July 16, 2026

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Conflicts of interest:	There is no conflict of interest.
Funding:	This study received financial support from the Maranhão Foundation for Research and Scientific and Technological Development.
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Editor:	Matias Nunes Frizzo. PhD