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Original Article

Using Geographic Information System for Geospatial Analysis of the Measles Epidemic in Qom Province in 2024

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Abstract

Background and aims: Measles is a highly contagious viral disease that can affect susceptible individuals with a transmission probability of over 90% through close contact. Despite the availability of an effective and safe vaccine, measles remains a significant cause of morbidity and mortality among young children worldwide. This study aims to analyze the geospatial distribution of the measles epidemic using Geographic Information System (GIS) technology in Qom Province in 2024.

Methods: This cross-sectional descriptive-analytical study utilized data from all clinically and laboratory-confirmed measles cases in Qom Province registered on the Ministry of Health portal. A total of 129 cases were analysed using ESRI ArcGIS 10.8.2 to map and model the spatial distribution of measles cases. Demographic data, including age, gender, nationality, and residence, were collected and analysed using SPSS software.

Results: Among 129 suspected measles cases, 72 (55.8%) were males, and 86.04% lived in urban areas. Laboratory tests confirmed 16 (12.4%) measles-positive cases, of which 11 (68.75%) were unvaccinated and more than half (65.1%) were in the age group under 5 years. Spatial analysis showed significant clustering (z-score = 1.69) in Districts 3 (Imam Khomeini Street) and 6 (Imamzadeh Ebrahim Street) of Qom city, which were identified as high-risk areas.

Conclusion: GIS technology highlighted spatial clusters of measles in Qom's central urban areas, enabling real-time mapping and hotspot detection for continuous monitoring. These findings underscore the importance of targeted vaccination campaigns and continuous monitoring using GIS analyses to prevent future outbreaks.

Keywords: Measles, Geographic information system, Epidemics, Qom

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Introduction

Measles is an extremely contagious respiratory disease caused by a single-stranded RNA virus from the Morbillivirus genus (Paramyxoviridae family). Over 90% of susceptible individuals become infected after close contact with an infected person.[1,2] Despite the availability of a safe and effective vaccine, measles continues to be a major global cause of morbidity and mortality in children, especially in low-income settings with poor vaccination coverage.[1-3] The virus is transmitted via respiratory droplets and can survive for up to two hours in the air or on contaminated surfaces.[3,4] Its incubation period is 10–14 days, and infected individuals are contagious from four days before to four days after rash onset.[1]

Recent years have witnessed a global resurgence in measles. According to WHO, global incidence rates increased significantly from 16.4 per million in 2021 to 90.5 in 2023.[5] Concurrently, the first-dose vaccine coverage decreased to 83% in 2023, down from 86% in 2019.[6] In Iran, confirmed measles cases have also risen, with incidence rates of 1.2, 2.6, and 7.2 per million in 2021, 2022, and 2023, respectively.[7] Measles poses a high risk of complications such as pneumonia, encephalitis, blindness, and severe diarrhea, particularly in young children, pregnant women, malnourished individuals, and those with immunodeficiency.[1-3]

In 2023, Iran identified 8,491 suspected cases of fever and rash, of which 612 (14%) were laboratory-confirmed measles cases, spanning 21 provinces. Among these, 556 were Iranian, 55 Afghan, and one Pakistani.[4] The ongoing circulation of the virus is linked to factors such as reduced routine immunization during the COVID-19 pandemic, the presence of unvaccinated migrants and refugees, and vaccine hesitancy.[8] As of 2024, Iran hosts approximately 3.7 million refugees mostly Afghan nationals many of whom lack adequate vaccination coverage.[9] This situation threatens Iran's measles elimination certification, obtained in 2019.

Given the spatial nature of infectious disease transmission, Geographic Information System (GIS) offer powerful tools for disease mapping, spatial pattern identification, and resource allocation.[10-13] GIS can assist public health authorities in detecting hotspots, monitoring trends, and guiding effective control strategies. While several studies have applied GIS to measles outbreaks in Iran, no study to date has specifically analyzed spatial distribution in Qom Province an area at heightened risk due to high population mobility and increasing case reports. Accordingly, this study aims to conduct a GIS-based geospatial analysis of the measles epidemic in Qom Province in 2024 to support data-driven public health interventions.

Materials and Methods

Study Design and Objectives

This study was a cross-sectional descriptive-analytical investigation aimed at analyzing the geospatial distribution of the measles epidemic in Qom Province, Iran, in 2024 using GIS technology. The primary objective was to identify spatial patterns and high-risk areas (hotspots) of measles cases. The secondary objective was to examine demographic characteristics (age, sex, nationality, and residence) and vaccination status among suspected and confirmed cases.

Study Setting

Qom Province, located in central Iran, is bordered by Tehran Province to the north, Semnan to the east, Markazi to the west, and Isfahan to the south. Administratively, the province is divided into five districts, with Qom city serving as the central hub. The city is segmented into eight urban districts: District 1 (Bajk), District 2 (Nirogah), District 3 (Imam Khomeini Street), District 4 (Zanbil Abad-Salariyeh), District 5 (Jamkaran), District 6 (Imamzadeh Ibrahim Street), District 7 (Holy Shrine), and District 8 (Pardisan).[12]

Selection and Description of Participants

Between January and June 2024, the study included all clinically and laboratory-confirmed measles cases (n = 129) registered on the Iranian Ministry of Health portal, with data obtained from the Qom Province Health Deputy. Suspected cases had already been documented by the Health Deputy in standardized national measles reporting forms. These cases were identified either through active case finding conducted by health centers and rural health houses or through self-referral of individuals presenting with clinical signs suggestive of measles—namely, fever and a maculopapular (non-vesicular) rash accompanied by at least one of the following symptoms: cough, coryza (runny nose or red eyes), or conjunctivitis.[14] Laboratory confirmation was performed via serological testing, and only those with measles-specific IgM antibodies were classified as confirmed and included in the study. The source population comprised residents of urban and rural areas in Qom Province. Demographic data, including age, sex, nationality of all patient including (Iranian, Afghan, Iraqi, Pakistani), and residence (urban or rural) and residential address, were extracted from the measles registration forms.

Data Collection

Data were obtained from the epidemiological information system of the Communicable Diseases Unit at Qom Health Center. Collected variables included demographic characteristics, hospitalization history, vaccination status, and laboratory test results. Spatial data were recorded based on patients' residential addresses and mapped using ArcGIS 10.8.2 (Environmental Systems Research Institute, Redlands, CA, USA). No chemicals or drugs were used in this study, and no direct risks to participants were present due to the use of secondary data. Data collection adhered to ethical guidelines, ensuring patient confidentiality by omitting personal identifiers and reporting data in aggregate form.

Spatial Analysis Methods

In order to determine whether the spatial distribution of cases is random, clustered, or uniform, hotspot analysis in GIS was used. Spatial data were analyzed using ArcGIS version 10.8.2. Individual cases were geocoded by extracting precise geographic coordinates (latitude and longitude) from residential addresses using Google Maps. These coordinates were systematically recorded in Microsoft Excel and subsequently imported into ArcGIS for spatial analysis. To visualize the spatial distribution of suspected and laboratory-confirmed measles cases, point density analysis was performed on digital maps representing both urban and rural areas of Qom Province. Spatial autocorrelation was then assessed using the Global Moran's I statistic to quantify the overall spatial pattern—whether clustered, dispersed (regular), or random. The Global Moran's I index ranges from -1 to + 1, where values approaching + 1 indicate significant clustering, values near -1 suggest dispersion, and values around zero imply randomness. Furthermore, Local Moran's I and Getis-Ord Gi* statistics were applied to identify local spatial clusters and spatial outliers. These methods allowed the detection of statistically significant high-incidence (High-High) and low-incidence (Low-Low) clusters, in accordance with standard practices in spatial epidemiology.[15-17]

Statistical Analysis

Measles cases Descriptive statistics, including means, standard deviations, and 95% confidence intervals, were calculated using SPSS version 26 (IBM Corporation, Armonk, NY, USA). Quantitative variables (e.g., age) were reported as means with standard deviations, and qualitative variables (e.g., sex, nationality) were presented as frequencies and percentages. Spatial analysis results, including Moran's I and Getis-Ord G* statistics, were reported with z-scores and p-values to indicate precision and uncertainty. Statistical methods were supported by references to standard works,[15-17] and all statistical terms and abbreviations were defined.

Results

Descriptive Statistics

Data on 129 suspected measles cases were collected at Qom Health Center, of which 72 (55.8%) were boys and 57 (44.2%) were girls. The ages of cases ranged from 1 month to 34.92 years and were categorized into three groups: less than 5 years (65.1%), 6–18 years (31%), and more than 18 years (3.9%).

Regarding nationality, 78 (60.47%) were Iranian, 49 (37.98%) Afghan, 1 (0.77%) Iraqi, and 1 (0.77%) was Pakistani. Furthermore, 111 (86.04%) lived in urban areas, and 18 (13.96%) lived in rural areas. Of the suspected cases, 101 (78.3%) were referred to health centers, 24 (18.6%) to the Children's Hospital, and 4 (3.1%) to the city physicians' offices for testing at the reference laboratory. A history of hospitalization from fever and rash was noted in 19 (14.72%) cases, while 91 (70.54%) had a vaccination history.

Laboratory testing confirmed 16 positive measles cases (12.4%) among the suspected cases. Of these confirmed cases, 11 (68.75%) had not received routine vaccinations, and 11 (68.75%) individuals had a history of hospitalization. Among the laboratory-confirmed measles cases, 13 individuals (81.25%) were Iranian, 2 (12.5%) were Afghan, and 1 (6.25%) was Iraqi. Regarding sex distribution, 9 cases (56.25%) occurred in females and 7 cases (43.75%) in males. Only 3 of the infected individuals were below the age for the MMR vaccine, with the mean age of infected individuals being 4.5 years (Table 1). In present study, all positive cases were either imported or related to imported cases.

Spatial Statistics

The spatial distribution of clinical and confirmed measles cases in Qom Province in 2024 was examined using GIS. The results of spatial autocorrelation analysis using the global Moran's I method are shown in Table 2. Based on the results, the spatial distribution pattern of measles cases is clustered. This means that measles cases tend to aggregate in specific areas and are not randomly distributed across the province (Figure 1). Figure 1 illustrates the geographic distribution of measles cases across Qom Province. The majority of cases are concentrated in central urban areas. According to the results of the Global Moran's I statistic (Moran's I = 0.17, z-score = 1.69, P value = 0.09), the spatial distribution of cases shows a tendency toward clustering, although the pattern does not reach conventional levels of statistical significance ($P < 0.05$).

Maps of the spatial distribution of clinical and confirmed cases in Qom Province show that as the largest population of Qom is concentrated in the central area, most clinical and confirmed cases were in the central

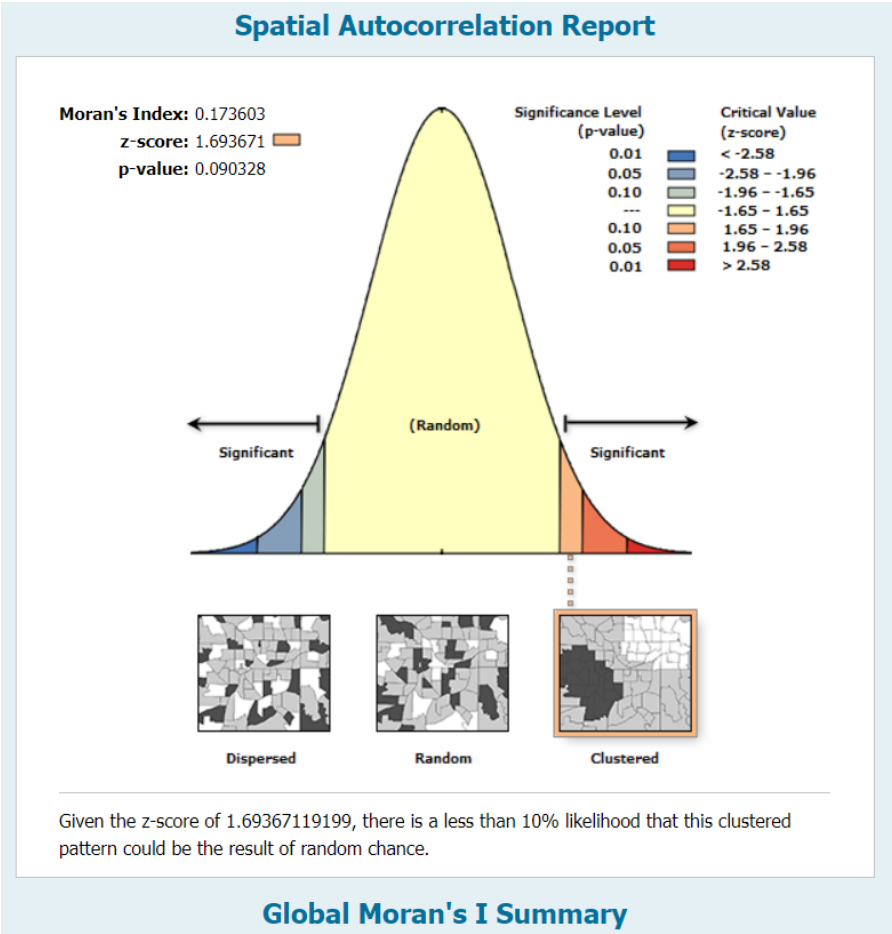

Figure 1. Spatial distribution of clinically suspected and laboratory-confirmed measles cases in urban and rural areas of Qom Province

Table 1. Demographic and clinical characteristics of suspected measles cases

Variable	Frequency	
	Number	%
Gender		
Male	72	55.8
Female	57	44.2
Age (year)		
Less than 5 years	84	65.1
6-18	40	31
More than 18 years	5	3.9
	Mean 5.62 ± 6.12 (std)	
Nationality		
Iranian	78	60.47
Afghan	49	37.98
Iraqi	1	0.77
Pakistani	1	0.77
Residence		
Urban	111	86.04
Rural	18	13.96
Referral Source		
Health Centers	101	78.3
Children's Hospital	24	18.6
Private Clinics	4	3.1
History		
Hospitalization History	19	14.72
Non-Hospitalization History		
Vaccination History	91	70.54
Non-Vaccination History		
Positive Measles Cases	16	12.4
Hospitalization Positive Cases	11	68.75
Non-Hospitalization Positive Cases	5	31.25
Vaccinated Positive Cases	5	31.25
Non-Vaccinated Positive Cases	11	68.75

part and the city of Qom, with few cases reported from other sections (Figure 2). Figure 2 displays the spatial distribution of clinical and confirmed measles cases across Qom Province. The majority of cases are concentrated in the central urban areas.

The distribution of clinical and confirmed cases in urban areas shows that District 6 (Imamzadeh Ebrahim Street), District 5 (Jamkaran), and District 3 (Imam Khomeini Street) had the highest number of clinical and confirmed cases during the study period (Table 2, Figure 3). Table 2 shows the number of clinical measles cases distributed across the urban districts of Qom Province. Districts 3 and 6 reported the highest number of cases, indicating significant clustering in these areas.

Figure 3 illustrates the spatial distribution of clinical and confirmed measles cases in Qom County. The highest concentration of cases is observed in the central urban areas, with a significant number of cases reported in

Table 2. Distribution of clinical measles cases by urban districts in Qom Province

Cases	Urban districts
8	1
10	2
21	3
10	4
14	5
32	6
3	7
3	8

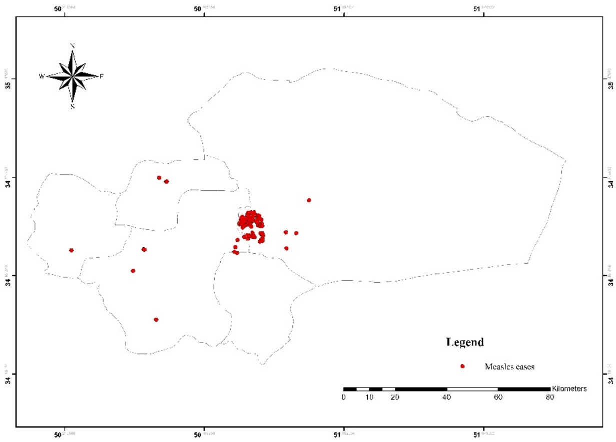

Figure 2. Spatial distribution maps of measles cases in rural and urban areas of Qom Province

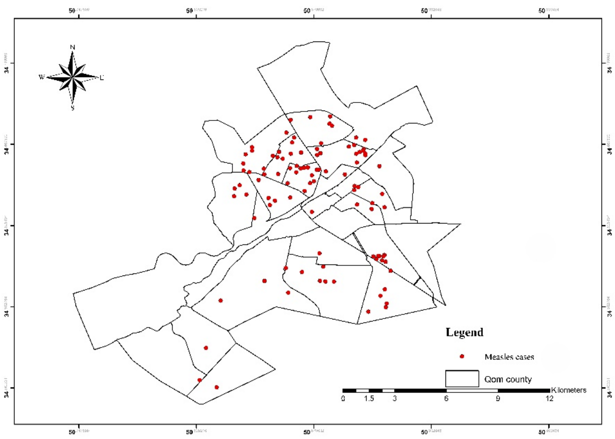

Figure 3. Spatial distribution maps of measles cases in Qom County

Districts 3, 5, and 6.

According to the results of the Getis-Ord G* analysis, the highest number of clinical and confirmed cases were in District 6 (Imamzadeh Ebrahim Street) and a part of District 3 (Imam Khomeini Street), was classified as HH areas. Therefore, based on the results, these areas namely, Imam Khomeini Street and Imamzadeh Ebrahim Street, were identified as two measles hotspots in Qom Province (Figure 4). Figure 4 identifies the hotspots of measles cases in Qom County based on the Getis-Ord G* analysis. Districts 6 (Imamzadeh Ebrahim Street) and parts of District 3 (Imam Khomeini Street) are highlighted as significant hotspots with high concentrations of

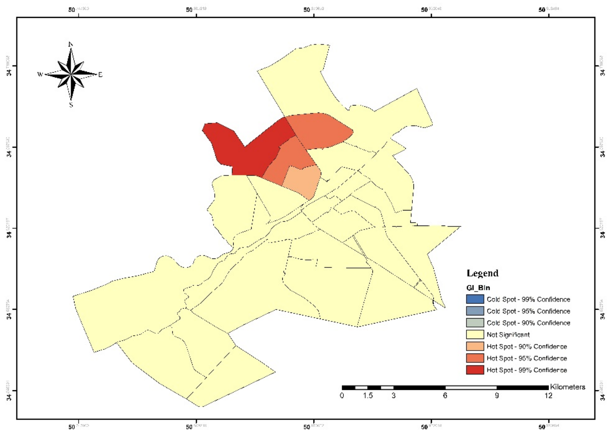

Figure 4. Map of measles hotspots in Qom County

measles cases.

Discussion

In this study, 12.4% (16 out of 129) of the suspected measles cases tested positive. The most of the suspected measles was observed in the age group less than 5 years. Before the implementation of the Expanded Program on Immunization, measles was common in children, and over 90% of people contracted the disease by the age of 20.[18] It was rare for someone to go their entire life without contracting the disease.[19,20] The highest percentage of confirmed measles cases in the age group of 1 to 4 years aligns with the findings of Zahraei et al. and Moshayekhi Mazrae et al.[21,22]

In this study, the majority of confirmed measles cases were male (55.8%), which is consistent with other studies in Iran such as Mokhtari Azad[23] (63.4%), Behjati[24] (64.2%), Javadi[25] (62.9%), Kelishadi[26] (64.1%), Moshayekhi Mazrae [22] (61.3%), and Sadeghi-Pour Roudsari[27] (82.3%). The higher incidence in males may be due to boys participating more in group games and outdoor activities, which increases personal contact, while girls have fewer contacts outside the home due to cultural reasons.

The results showed that 11 individuals (68.75%) did not have a history of measles vaccination. In the study by Moshayekhi Mazrae et al., it was found that 66.39% of confirmed measles cases had no history of receiving the measles vaccine, while 8% had received one dose and 7.30% had received two or more doses.[22] In a study by Behjati in Yazd, 40% of the cases had a history of one dose of vaccination.[24] Along the same lines, Mokhtari Azad found that 61% of confirmed measles cases had no history of vaccination.[23] According to these studies, it can be concluded that vaccination is effective in preventing measles, and in cases where vaccination has not been performed or been incomplete, the incidence of the disease increases.

The current study showed that over 85% of suspected measles cases resided in urban areas. The spatial distribution maps of measles in Qom Province indicated that most cases were in the central and urban areas of Qom, with fewer cases reported from other areas. Furthermore, the spatial distribution of clinical and confirmed cases in urban areas shows that District 6 (Imamzadeh Ibrahim Street), District 5 (Jamkaran), and District 3 (Imam Khomeini Street) had the highest number of cases. Based on the Getis-Ord G* analysis, Districts 6 and parts of District 3 were identified as HH (high-high) areas, pointing to these districts as measles hotspots in Qom Province. In a study conducted in southern Kerman Province, most measles cases were from urban areas (73.3%).[22] However, in Behjati's study in Yazd, most measles cases were in urban areas (65%), which is inconsistent with the results of the current study due to the high urban population density in Yazd (69%).[24] Similarly, the majority of the population resides in urban areas of Qom, leading to higher population density and closer contact among people, which in turn facilitates easier transmission of the disease.[28] In a study by Saeed, it was also found that close contacts and the high transmission rate of the measles virus could contribute to outbreaks in a region. The impact of social conditions and environmental changes on the epidemiological characteristics of measles is greater than any potential changes in the virus itself. In addition, the spread of the disease is faster in cities than in rural areas, and children in rural areas are more likely to reach adolescence without contracting the disease.[29]

Similarly, in the study by Davoudian, most cases were Iranian (79%),[30] and Moshayekhi Mazrae et al. also reported that the majority of cases in southern Kerman occurred among Iranians.[22] Given the higher proportion of Iranians in the population of Qom Province and the significant influx of refugees, particularly from neighboring countries, the higher percentage of measles cases among Iranians is epidemiologically expected.

According to the Ministry of Health, all laboratory-confirmed measles cases in Qom were either imported or epidemiologically linked to imported cases, with no evidence of indigenous transmission. This finding is consistent with previous studies conducted in other migrant-receiving provinces of Iran, such as those by Davoudian et al. and Esmaeiloghli Amiryli et al., which reported that imported cases, particularly from neighboring countries, played a major role in measles transmission. These studies emphasized the importance of immunization efforts targeting foreign nationals and high-risk populations.[30,31]

In light of this, ensuring full vaccination coverage among refugee and migrant populations, along with strengthening active case finding for suspected measles cases, is crucial. These strategies can significantly contribute to early detection, containment of transmission chains, and ultimately, the prevention of future outbreaks.

One of the main limitations of this study is that only suspected measles cases who either referred to health centers with symptoms of fever and maculopapular rash, or were identified through active case finding by the health system, were included. Therefore, asymptomatic or mildly symptomatic individuals who did not seek care or were not captured through surveillance may have been missed, potentially leading to underestimation of the true number of cases.

Conclusion

Most confirmed measles cases in Qom Province were linked to imported transmission, primarily affecting children under five years. GIS analysis identified spatial clustering in central urban areas, highlighting hotspots for targeted intervention. Improving vaccination coverage, particularly among refugee populations, along with strengthening active case finding and integrating GIS into routine surveillance, are essential to prevent future outbreaks. These measures are critical for advancing measles elimination efforts in Qom and similar regions.

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Nil.

Authors' Contribution

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Methodology: Naser Rajabi, Mahsa Sarvi.
Project administration: Naser Rajabi.
Resources: Azam Sabouri, Reza Nafarshalamzari.
Software: Mahsa Sarvi.
Supervision: Seyed Mohsen Zahraei.
Validation: Seyed Mohsen Zahraei.
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Writing – original draft: Abedin Saghafipour.
Writing – review & editing: Naser Rajabi, Abedin Saghafipour, Seyed Mohsen Zahraei, Azam Sabouri, Reza Nafarshalamzari, Mahsa Sarvi, Alireza Omidi Oskouei.

Competing Interests

The authors declare that there is no conflict of interest.

Ethical Approval

This study was conducted in accordance with ethical guidelines and approved by the Ethics Committee of Qom University of Medical Sciences (ethics code: IR.MUQ.REC.1403.151). Patient data were anonymized, with names and surnames omitted, and reported in aggregate to ensure confidentiality. As the study utilized secondary data from the health system, informed consent from participants was not required. No experiments involving human subjects or animals were conducted, and thus, no associated risks were present.

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