Spatial Distribution of Maternal Mortality in Ethiopia: Further Analysis of Ethiopian Demographic and Health Survey

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Abstract

Background: Maternal mortality is one of the major public health problems challenging the medical community, especially in developing countries. In Ethiopia, despite great emphasis to reduce maternal mortality, it is still high indicating progress in improving maternal health is inadequate. Identifying hotspot areas with a high prevalence of maternal mortality is important to design evidence-based interventions and reduce maternal mortality. Despite this fact, the geographical distribution of maternal mortality in Ethiopia remains unclear. Therefore, this study aimed to explore the spatial distribution of maternal mortality in Ethiopia.

Methods: Community-based cross-sectional study design was employed in the 2016 Ethiopian Demographic and Health Survey. A total of 12790 women were included in this analysis. The distribution of maternal mortality across the country was observed by ArcGIS software. Getis-Ord Gi* statistics were used to identify the hot and cold spot areas for maternal mortality.

Results: The spatial distribution of maternal mortality in Ethiopia was found to be clustered with Global Moran's I = 0.031 [p value < 0.0001]. Hotspot areas with high clustering of maternal mortality were identified in five administrative zones of Tigray regional states, four zones of Afar regional state, one South Nations Nationalities and Peoples zone of Amhara regional state, two zones of Oromia regional state, one zone of the Somali region, and one zone of SNNP. Cold spot areas with low significant clustering of maternal mortality were identified in Addis Ababa, three zones of the Amhara region, five zones of the Oromia regional state, five zones of SNNP, and two zones of the Gambella region.

Conclusion: Spatial distribution of maternal mortality in Ethiopia is non-random and varies from region to region. The clustered hot spot areas with high clustering were identified in Tigray, Afar, Amhara, Somali, SNNP, and Oromia regions whereas cold spot areas with low clustering of maternal mortality rates were detected in Oromia, SNNP, Gambella, and Amhara regions. Therefore, this study recommended strengthening maternal health programs by targeting Tigray, Afar, Amhara Somali, SNNP, and Oromia regions.

Keywords: *Maternal mortality; Spatial Analysis; Ethiopian demographic and health survey; Ethiopia,*

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Introduction

Maternal mortality is the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes. It is one of the major public health problems challenging the medical community, in developing countries (CDC, 2003). Globally, approximately 585,000 women die each year as a result of pregnancy and childbirth-related complications. Every minute, one mother "dies in childbirth" around the world majority of which are in Africa (Annan, 2010, Kassebaum *et al.,* 2014, WHO, 2015). In sub-Saharan Africa, women face a 1-in- 13 chance of dying in childbirth. Ethiopia reports the fifth-highest maternal mortality from sub-Saharan countries.

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According to the 2016 Ethiopian Demographic Health Survey (EDHS), the maternal mortality ratio was estimated to be 412 per 100,000 live births. Maternal death accounts for around a quarter of all deaths in women aged 15-49 years (CSA, 2016; Berhan and Berhan, 2014).

The majority of maternal deaths are due to direct causes including hemorrhage, infection, unsafe abortion, hypertensive disorders of pregnancy, and obstructed labor. In Ethiopia, maternal mortality rates are around 65.1% during the postpartum period (Tesfay, Neamin, *et al,* 2022). Lack of accessibility and availability of maternal health care services and the low level of skilled birth attendants worsen the condition (WHO, 2014). Maternal mortality contributes a lot to infant and child mortality related in inadequate care, inefficient management of delivery, and lack of essential care for a newborn (WHO and UNICEF, 1999).

In Ethiopia, despite a greater emphasis on the need to address the health of childbearing mothers, maternal mortality is still high indicating the progress of improving maternal health is inadequate (Tsegay *et al.*, 2013). As per the authors' knowledge and search strategy, no study was done to identify geographical variations and hotspot areas with a high prevalence of maternal mortality in Ethiopia previously.

Identifying hotspot areas with a high prevalence of maternal mortality is important to design evidence-based interventions and reduce maternal mortality. Despite this fact, the geographical distribution of maternal mortality in Ethiopia remains unclear. Therefore, this study aimed to explore trends and spatial distribution of maternal mortality in Ethiopia. The findings of this study are helpful for policymakers in identifying high-risk geographical areas within a community, which is crucial for designing evidence-based intervention in those areas thereby reducing maternal deaths.

Materials and Methods

Study Setting and Period

The study was conducted based on EDHS records in Ethiopia. Administratively, Ethiopia is divided into regions and the region is divided into zones, and zones, into administrative units called weredas (districts). Each district is further subdivided into the lowest administrative unit, called kebele. Kebeles are also subdivided into census enumeration areas (EAs), which are convenient for the implementation of census. In Ethiopia female population constitutes nearly half of the total population and these close to a quarter of all populations are in the reproductive age group.

Study Design

A community-based cross-sectional study design was employed on 2016 EDHS data.

Study Population and Sample Size

The data for the spatial analysis part was extracted from the 2016 EDHS. For showing the trend, we used EDHS data from 2000 to 2016. The data sets were downloaded in SPSS format with permission from the Measure DHS website (http://www.dhs program.com). The cluster number and related data sets were joined to the Global Positioning System (GPS) coordinates of EDHS.

Sampling Procedure

The 2016 EDHS sample was selected using a stratified, two-stage cluster design using Enumeration Areas (EAs) as primary sampling units and households as the secondary sampling units. The sample included 645 EAs, 202 in urban and 443 in rural areas. In the first stage of selection, 645 EAs (202 in urban areas and 443 in rural areas) were selected with probability proportional to EA size. In the second stage of selection, a fixed number of 28 households per cluster were selected with an equal probability of systematic selection from the newly created household listing.

Data Processing and Management

After extracting the 2016 EDHS data SPSS software was used for further cleaning and recoding. Descriptive statistics in form of frequencies and percentages were used to describe the study population. ArcGIS 10.1 software was used for spatial analysis.

Spatial Analysis

The spatial autocorrelation (Global Moran's I) statistics measures were used to evaluate whether maternal death is dispersed, clustered, or randomly distributed in the study area. A positive value for Moran's Index indicates a clustered pattern of maternal mortality, while a negative value for Moran's Index indicates a dispersed pattern. Local Moran's I which measures whether there were positive correlation (high-high and low-low) clusters or negative correlation (high-low and low-high) clusters of high values (high-high) and clusters of low values (low-low) was used to investigate the local level cluster locations of maternal mortality.

The spatial interpolation technique was applied to predict the un-sampled from sampled measurements. Kriging spatial interpolation method was also used for predictions and to produce smooth surfaces of maternal mortality. The aggregate rates of maternal mortality rate at the regional level were exported into ArcGIS version 10.1 to see the spatial patterns. Gettis-OrdGi* statistics were computed to measure how spatial autocorrelation varies over the study location and to identify hot and cold spot areas by calculating the Gi* statistic for each area. Z-score was computed to determine the statistical significance of clustering. The Ethiopian map was projected using the Adindan4 WGS84 world coordinate system.

Results

Socio-demographic Characteristics of the Study Participants

A total of 12,790 reproductive age group women were included in the analysis. The majority of them 10327 (80.7%) were rural residents and the mean age of respondents ranged from 15 to 49 with a mean (± SD) of 30.35 (±8.56) years. About 1925 (15.1%) of the respondents were from SNNP and only 590 (4.6%) are from the Harari region (Table 1).

Table1: Socio-demographic characteristics of reproductive age group women in Ethiopia, 2016, (N=12,790)

Variables	Categories	Frequency (n=12790)	Percentage (%)
Place of residence	Rural	10327	80.7
	Urban	2463	19.3
Region	Tigray	1438	11.2
	Afar	1170	9.1
	Amhara	1335	10.4
	Oromia	1608	12.6
	Somali	1892	14.8
	Benishangual Gumuz	767	6.0
	*SNNP	1925	15.1
	Gambela	752	5.9
	Harari	590	4.6
	Addis Ababa	651	5.1
	Dire Dawa	662	5.2
Husband educational status	Uneducated	4781	42.1
	Primary	4100	36.1
	Secondary	1305	11.5
	Above Secondary	1102	9.7
	Don't know	68	0.6
Categorized age	15-19	2850	22.3
	20-24	2369	18.5
	25-29	2326	18.2
	30-34	1808	14.1
	35-39	1578	12.3
	40-44	1066	8.3
	45-49	793	6.2
Women's educational status	Uneducated	6791	53.1
	Primary	3568	27.9
	Secondary	1445	11.3
	Technical/ vocational	538	4.2

**SNNP; South Nations Nationalities and Peoples*

Spatial Analysis for Maternal Mortality IQ

Spatial autocorrelation of Maternal Mortality Rate (MMR) based on feature locations and attribute values was calculated using the Global Moran's I statistic. From this analysis, the z-score and p-values showed that there is statistically significant autocorrelation at 0.1, 0.05, and 0.01 levels of significance (Figure 1).

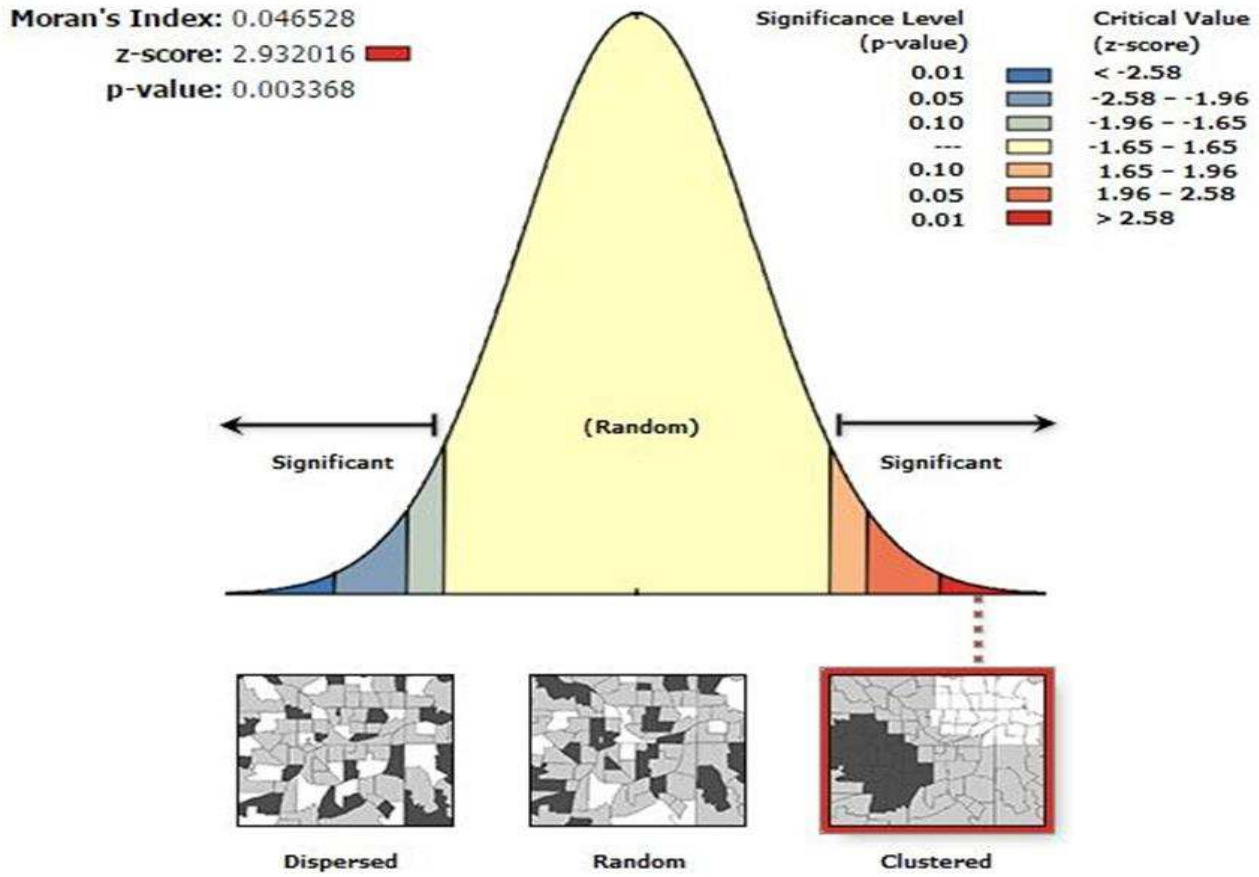

Figure 1: Spatial autocorrelation of MMR based on feature locations and attribute values using the Global Moran's I statistic in Ethiopia, 2016

Incremental Spatial Autocorrelation

The Incremental spatial autocorrelation of MMR showed that the maximum peak, where spatial clustering is highly significant is at a distance of 151378.55 meters, with a corresponding Z score of 4.23 (p-value<0.001) (Table 2).

Average Nearest Neighbor

The average nearest neighbor ratio was calculated using EUCLIDEAN distance. Accordingly, the ANN ratio is less than one, and the p-value associated with it is significant indicating that there is a significant clustering pattern (Figure 2).

Table 2: Spatial Incremental Autocorrelation of MMR by distance, in Ethiopia, 2016

Distance	Moran's Index	z-score	p-value
121812.89	0.031264	2.796050	0.0051731
136595.72	0.038800	3.924838	0.000087
151378.55	0.038345	4.225990	0.000024
166161.37	0.030000	3.684660	0.000229
180944.20	0.020760	2.824674	0.004733
195727.02	0.019927	2.938135	0.003302
210509.85	0.014785	2.411953	0.015867
225292.68	0.009113	1.677961	0.093355
240075.50	0.004167	0.956410	0.338865
254858.33	0.001079	0.479367	0.631677

First Peak (Distance, Value): 1.50, 2.744776, Max Peak (Distance, Value): 1.50, 2.744776, Distance measured in meters

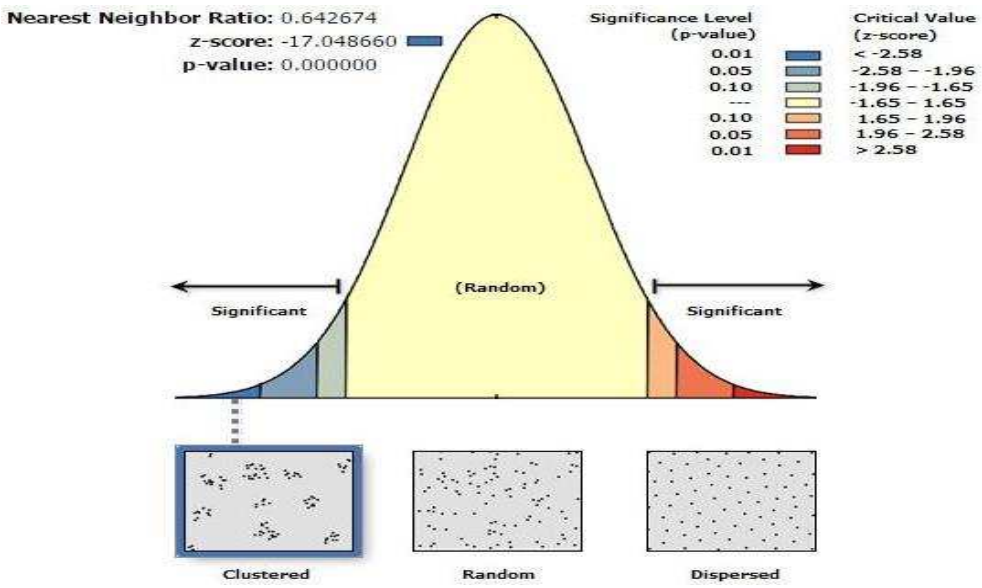

Figure 2: Average neighbor index of MMR based on average distance from each feature to its nearest neighboring for maternal mortality in Ethiopia, 2016

Cluster Analysis

Cluster Analysis by Region and Zone

Hot spot areas with a high cluster of maternal mortality and cold spot areas with low-level clusters were identified. Hotspot areas with high clustering of maternal mortality at a 99% confidence level were seen in two administrative zones of Afar regional state (Zone 3 and Zone 5), one administrative zone of Amara region (North Shewa), and one zone of Oromia regional state (Bale). Areas with hot spot clusters at a 95% confidence level include one zone of the Tigray region (Southern Tigray), one zone of the Amhara region (North Shewa), and one zone of the Oromia region (Bale), and one zone of SNNP (Bench Maji). Hot spot areas at a 90% confidence level were identified in four zones of the Tigray region (Western Tigray, North Tigray, Southern Tigray, and Central Tigray), two zones of the Afar region (Zone 1 and Zone 4), and one zone of Somali regional state (Shebale).

Cold spot areas with low significant clustering of maternal mortality at a 99% confidence level were identified in Addis Ababa, two-zone of the Oromia region (North Shewa and South West Shewa), and one zone of the Gambella region (Nuer). Areas with low significant clustering of maternal mortality at a 95% confidence level were identified in two zones of the Oromia region (Guji and East Shewa), three-zone of SNNP (Gamo Gofa and Gedio), two-zone of the Gambella region (Nuer and Agnuak) and one zone of Amhara region (North Shewa). Cold spot areas with low clustering of maternal mortality at a 90% confidence level were identified in two-zone of the Amhara region (North Shewa and East Gojjam), two zones of the Oromia region (Arsi and East Shewa), three zones of SNNP (Segen people, Wolaita and Gurage) and one zone of Gambella region (Agnuak) (Figure 3 & Figure 4).

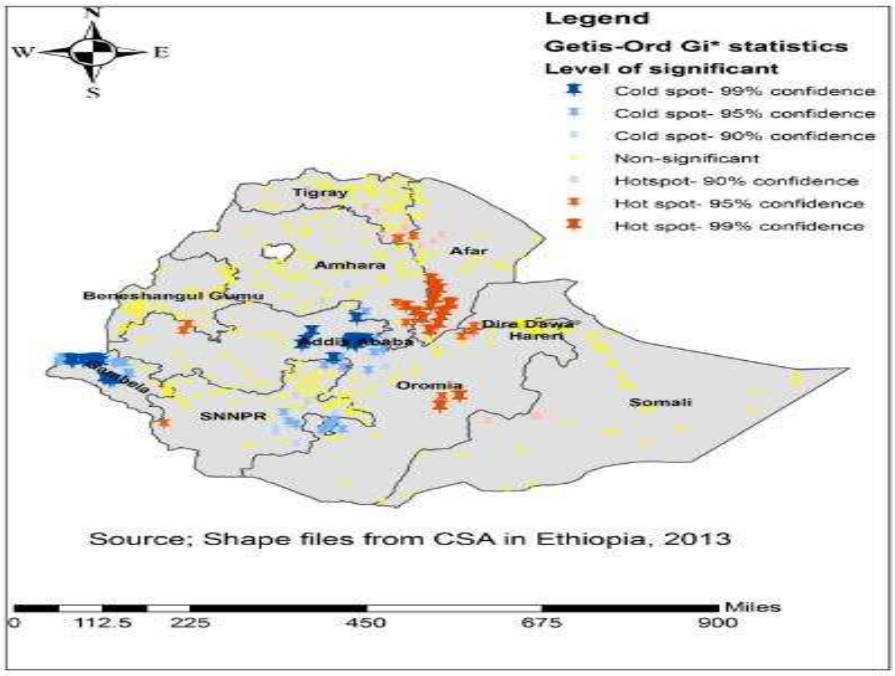

Figure 3: Hot spot and cold spot clustering of maternal mortality in Ethiopia by region, 2016

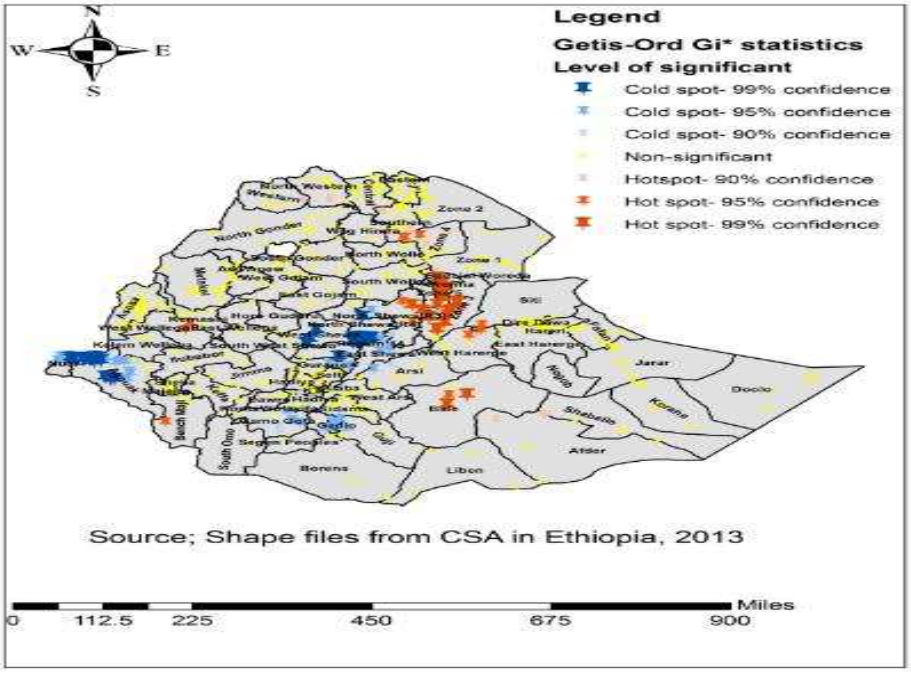

Figure 4: Hot spot and cold spot clustering of maternal mortality in Ethiopia by zone, 2016

Discussion

In this study, the overall good knowledge status of the spatial statistical techniques based on GIS provides an opportunity to clarify and identify maternal mortality within a country. Geographic visualization of maternal mortality using these tools was instrumental to understand the highest and modest rates and target interventions in high-risk areas. This study has provided a visually powerful analysis of spatial variation in maternal mortality among women in Ethiopia.

The current study finding showed that the spatial distribution of maternal mortality in Ethiopia was non-random. Geographically maternal mortality in Ethiopia showed marked heterogeneity. A clustered hot spot areas with high rates of maternal mortality were generally observed in Tigray, Afar, Amhara, Somali, SNNP, and a few zones of the Oromia region whereas cold spot areas with low clustering of maternal mortality rates were detected in some zones of Oromia region, SNNP, Gambella, and Amhara regions. The spatial variation in maternal mortality could be attributed to differences in health service accessibility and quality of healthcare. In addition, it could be the result of socio-economic as well as cultural differences during pregnancy and post natal period. This suggests that understanding other factors that may obstruct access to health care utilization, such as quality of care, cost, and social and behavioral factors are important (Sartorius *et al.*, 2010, Tessema *et al.*, 2017).

The strength of the current study was it used national data representative of the entire nation. Therefore, the findings are generalizable to all reproductive age groups of women in Ethiopia. The main limitation that should be considered when interpreting the results is the location of data values was shifted up to 2 kilometers for urban and up to 5 kilometers for rural areas to ensure respondent confidentiality and was a challenge to know the exact cases' location.

Conclusion

The spatial distribution of maternal mortality in Ethiopia is non-random and varies from region to region. The clustered hot spot areas with high clustering were identified in Tigray, Afar, Amhara, Somali, SNNP, and Oromia regions whereas cold spot areas with low clustering of maternal mortality rates were detected in Oromia, SNNP, Gambella, and Amhara regions. This study recommends strengthening maternal health programs with special attention to Tigray, Afar, Amhara Somali, SNNP, and Oromia regions.

Abbreviations and Acronyms

ANN: Average Nearest Neighbour;

EA: Enumeration Area;

EDHS: Ethiopia Demographic Health Survey;

GIS: Geographic Information System;

MMR: Maternal Mortality Rate;

SNNP: South Nations Nationalities and Peoples;

SPSS: Statistical Package for Social Sciences;

WHO: World Health Organization

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Competing Interests

The authors declare that they have no competing interests.

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Authors' Contribution

Conceptualization: ABW, BST, AME, AMA, SBA
Data extraction: ABW, BST, AME, AMA, SBA, MMS
Formal analysis: ABW, BST, AME, AMA, SBA, MMS, LDR, AT
Methodology: ABW, BST, AME, AMA, SBA, MMS, LDR, AT
Drafting manuscript: ABW, BST, AME, AMA, SBA, MMS, LDR, AT
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