Transient Ischemic Attack (TIA) Incidence with Geographic Information Systems (GIS) Mapping for Stroke Prevention Interventions

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Abstract

Objectives: GIS mapping as a public health tool has been increasingly applied to chronic disease control. While evaluating TIA incidence from an existing regional stroke registry in Ludhiana city, India, we aim to apply the innovative concept of regional TIA GIS mapping for planning targeted stroke prevention interventions. **Methods:** TIA patient data was obtained from hospitals, scan centers and general practitioners from March 2010 to March 2013 using WHO-Stroke STEPS based surveillance as part of establishing a population-based stroke registry in Ludhiana city. From this registry, patients with TIA (diagnosed by MRI image-based stroke rule-out, or clinically) were chosen and data analyzed. **Results:** A total of 138 TIA patients were included in the final analysis. The annual TIA incidence rate for Ludhiana city was 7.13/100,000 (95% confidence interval: 5.52 to 8.74) for 2012-2013. Mean age was 58.5 ± 13.9 years (range: 22-88 years) and 87 (63%) were men. Majority of the TIA cases had anterior circulation TIAs. Hypertension (87.4%) was the most common risk factor. Using Geographic Information System (GIS) mapping, high TIA incidence was seen in central, western, and southern parts and clustering of TIA cumulative incidence was seen in the central part of Ludhiana city. **Conclusion:** Incidence rate of TIA was lower than that expected from a low- and middle-income country (LMIC). TIA GIS mapping, looking at regional localization, can be a novel option for developing targeted, cost-effective stroke prevention programs.

Keywords: GIS mapping, India, LMICs, stroke, TIA

Introduction

Mapping has been used in public health since the time of Hippocrates to understand geo-environmental influence on residents' health.[1] John Snow used "disease diffusion mapping" to study the cholera epidemic in London in the 1850s.[2]

Geographic Information Systems (GIS) mapping is an advanced cartographic technique which digitally synthesizes geographic information obtained from health records, satellite data etc., The spatial data therefore represent the source descriptive data, such as subject attributes. The spatial and associated descriptive data, pertaining to a specified geographic region, therefore can be manipulated by the user to address targeted questions.[1] Epidemiologists can use GIS mapping for studying incidence and prevalence or surveillance of diseases, amongst other things.[3]

GIS mapping has been traditionally used for communicable diseases, but its application in non-communicable diseases is evolving. Surveillance in chronic diseases can be challenging, hence, GIS mapping is a time and resource efficient modality for this need. GIS mapping can be used to study spatial patterns of incidence of a cardiovascular disease such as stroke by looking at distribution patterns and clustering. The regional maps can also contrast disparities across local boundaries.[4]

Transient ischemic attack (TIA) is considered a harbinger of future stroke. A systematic review and meta-analysis of several prospective studies on early stroke risk following TIAs showed that the pooled risks of stroke were 3.1% [95% confidence interval (CI) 2.0-4.1] at 2 days and 5.2% (3.9-6.5) at 7 days.[5] Another meta-analysis of longer-term risks put calculated pooled risks of 8.0% (5.7-10.2%) and 9.2% (6.8-11.5%) at 30 and 90 days, respectively.[6] Identifying high incidence areas of TIA using GIS mapping, and resultant preventive planning

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could be useful to avert major strokes and resultant disability. The relevance of TIA GIS mapping is starting to be recognized internationally[7] but a GIS-based study on TIA has not been done in India yet. Our study can, therefore, potentially pave the way for Indian technological advancements to be utilized in the prevention of major stroke.

The stroke registry in Ludhiana city had previously provided us with a valuable opportunity to study regional stroke incidence using GIS mapping.[8] This database also equips us with a valuable tool to capture the incidence of TIA and visualize the spatial distribution of TIA cases in the city.

METHODS

Study site and study period

A population-based stroke registry was initiated in Ludhiana city, for The Indian Council of Medical Research (ICMR)'s WHO-STEPS-based surveillance. We did data analysis for TIA patients from this existing registry. Ludhiana city covers an area of 159.37 km^2 between the latitude 30° 51' 10'N and 30° 57' 20'N and longitude 75° 46' 00'E and 75° 56' 20'E and is divided into 75 wards by its Municipal Corporation. The population of Ludhiana city is 1,618,879, as per 2011 census, and 1,065,127 of them are over 18 years of age.

The stroke registry was formed between March 2, 2010 and March 25, 2013. Following the registry feasibility study from March 26, 2010 (with data collection from August 2010 to March 25, 2011), we included data that were collected from March 26, 2011 to March 25, 2013.[8,9]

TIA definition and inclusion criteria

Inclusion criteria for TIA was: "all patients equal to or over 18 years of age who resided in Ludhiana for more than 6 months, with a focal (or at times global) neurological impairment of sudden onset, and lasting <24 hours".[10] The newer definition of TIA, that is, normal diffusion weighted image (DWI) sequence in MRI, was used wherever MRI was available. In cases where imaging was not done (as is still quite common in India especially within the initial 24 hours), it was not insisted upon, but the non-imaging-based traditional definition was used.

Data collection

The WHO STEPS methodology was used for data collection of stroke and TIA patients.[10] The detailed methodology of data collection, and the incidence of stroke is previously reported.[8,9] Validation of the incident data was done using door-to-door surveillance in three selected areas in the city, based on the third-year (March 2012 to March 2013) data from the registry. For TIA patients, whether hospitalized or non-hospitalized, the institutional data sources were multiple overlapping entities (public hospital, private hospital, scan centres, general practitioners, physiotherapy centres). We used both imaging and clinical criteria for TIA diagnosis, based on how the institution diagnosed it. For minor strokes and TIA, we had also placed regular advertisements in newspapers and patients were asked to contact us. Through this, we captured a few patients who had not been tracked earlier.

As a first step, our research staff contacted all public hospitals, private hospitals, scan-centers, general practitioners, physiotherapy centers, neurologists, and neurosurgeons in Ludhiana city and obtained data using patient-load questionnaire. Based on information provided by them, 34 major centers (2 public hospitals, 15 private hospitals, 8 physiotherapy centers, 9 private scan centers) and 14 general practitioners were identified (but only 6 general practitioners eventually participated in the study.[9] Detailed information (demographic details, imaging modalities, symptoms, risk factors, Modified Rankin Score at discharge) was collected from hospitals, general practitioners and physiotherapy centers but only limited information (demographic details, imaging modalities) was available from scan centers.

At each site, one staff member was trained for data collection using three workshops and additional training programs during the feasibility phase. The site staff were trained on scientific definitions, study methodology, and data collection through these workshops and training programs.

A few city residents who travelled outside Ludhiana city for treatment were captured by newspaper advertisements given as part of the study.

All the completed forms were reviewed by the principal investigator (J.D.P) and data queries were resolved by the research staff by contacting the nodal persons in each centre.

Site of lesion

The site of lesion was classified as anterior or posterior circulation using the definition from a previous study.[11] TIA patients with focal motor or sensory symptoms affecting one side of the body or with aphasia/dysphasia, amaurosis fugax (retinal ischemia), or any combination of these symptoms were considered to have TIA in the carotid system (anterior circulation). Those TIA patients who had motor and/or sensory symptoms on both sides of the body, a combination of unilateral motor/sensory symptoms with any brain stem symptoms (such as vertigo, diplopia, dysphagia, ataxia, or dysarthria), ataxia of gait, bilateral clumsiness of the arms and/or legs, diplopia, dysarthria, bilateral homonymous hemianopsia, or any combination of these symptoms were regarded as patients with vertebrobasilar TIA (posterior circulation).

Ethics approval

Ethics approval was taken from Christian Medical College and Hospital, Ludhiana and Dayanand Medical College and Hospital, Ludhiana. Permission was also granted by all other participating centers.

Data for spatial distribution

The patients' residential addresses were taken from the registry, which was then converted into geocoded data based on the spatial data provided by Punjab Remote Sensing Centre. Only ward wise spatial data was available in Ludhiana city and so

we calculated the ward wise cumulative incidence rate using the population of each ward.

Statistical analysis

For the calculation of incidence, census data is obtained from ORGI Data Dissemination Unit, New Delhi, India. The descriptive statistical measures were calculated using SPSS version 21 (IBM, Armonk, NY) and spatial analysis was performed by using ArcGIS 10.3 (ESRI, Redlands, CA).

Spatial statistics

The ward wise TIA incidence/100,000 was shown using dot density map. To see that data is clustered, dispersed or random Global Moran's I index (spatial autocorrelation tool) was calculated. In the next step, for hot and cold spots (hot spots: high values are clustered together; cold spots: low values are clustered together) of TIA cases, Getis-Ord G_i^* was calculated.

Global Moran's I index

The spatial pattern of TIA cases was studied by using Global Moran's I statistic. It is similar to Pearson correlation coefficient, but it measures correlation among spatial observations. To study whether the TIA cases were clustered or dispersed, spatial autocorrelation was calculated using Global Moran's I index.

$$ I = \frac{n \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\left(x_i - \bar{X}\right)\left(x_j - \bar{X}\right)}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij} \sum_{i=1}^{n}\left(x_i - \bar{X}\right)^2} $$

Where

i and j denotes the wards

x_i = TIA incidence rate for i^{th} ward

x_j = TIA incidence rate for j^{th} ward

$\bar{X}$ = the mean of TIA incidence rate for all of the wards in the study areas

n = number of wards = 75

w_{ij} = Spatial weight matrix (connectivity matrix), which defines spatial interaction across study regions

In general

w_{ij} = 1 if ward i and ward j are neighbouring (share a common boundary)

otherwise w_{ij} = 0

The value of this index ranged from -1 to +1. The positive values indicate that similar values are spatially clustered (positive autocorrelation) whereas negative values indicate that similar values are dispersed (negative autocorrelation). If I index is zero, it indicates that spatial observations have random patterns.[12]

Hot spot analysis

Hot spot analysis shows the type of cluster that exists in the spatial data. If the higher values are clustered together, then it is a 'hot spot' whereas if the lower values are clustered together, then it is a "cold spot". By using Getis-Ord G_i^* statistic we were able to find out the hot and cold spots of TIA incidence in 75 wards in Ludhiana city. In our analysis, input feature class were wards, and for each ward the G_i^* was computed using the following formula:

$$ G_i^* = \frac{\sum_{j=1}^{n} w_{i,j}x_j - \bar{X}\sum_{j=1}^{n} w_{i,j}}{S\sqrt{\dfrac{\left[n\sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2\right]}{n-1}}} $$

Where

$$ \bar{X} = \frac{\sum_{j=1}^{n} x_j}{n} $$

$$ S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - \left(\bar{X}\right)^2} $$

Notations have same meaning as defined above in autocorrelation formula.

The G_i^* statistic is a Z-score. For each ward, we got a Z-score and a P value. For the statistically significant ($P < 0.05$) positive Z score, the larger the value of Z-score, the more intense the clustering of high values. In a similar way, for the statistically significant ($P < 0.05$) negative Z score, the smaller the value of Z score, the more intense the clustering of lower values. Z score near zero indicates no clustering. In our analysis, we have used red color to show hot spots and blue color for cold spots. Three additional shades of each color are used, with the darkest color indicating a Z score of 99% CI, medium one indicating 95% CI and the lightest one representing 90% CI.

RESULTS

The Ludhiana city TIA registry had 138 TIA patients. They included 120 (87%) patients from hospitals and 18 (13%) from scan centers. TIA diagnosis was done by MRI imaging for 68.4% of the 138 patients. (24.8% only had CT imaging and 6.8% had no imaging study done). [Figure 1]

Demographic details and vascular risk factors

The mean age of TIA patients was 58 ± 14 [range: 22-88 years] and 87 (63%) were men. The majority of patients were married (96.7%) and literate (90%). About 30% were "employed" and about 35% of patients were "housewives". [Table 1]

Most of the patients 71% (85/120) had anterior circulation TIA. The common risk factors for TIA were hypertension: 104 (87.4%), diabetes mellitus: 54 (45%) and past alcohol intake: 47 (39.5%). [Table 2]

Annual incidence rates of TIA in Ludhiana city

Based on the study registry, the total number of TIA cases in Ludhiana city, from 26th March 2011 to 25th March 2012 is 62 and annual incidence rate for 2011-2012 is 5.82/100,000 (95% confidence interval: 4.37 to 7.27). The total number of
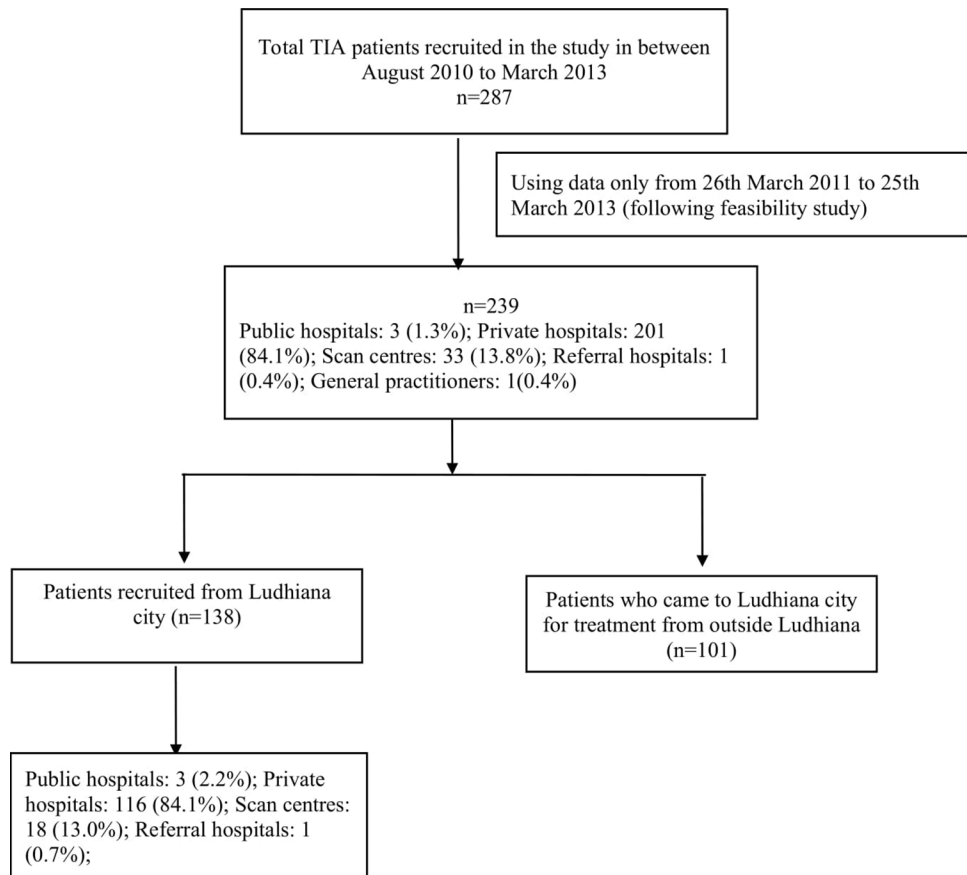
Figure 1: Flowchart depicting TIA study data collection from Ludhiana city stroke registry

Table 1: Demographic characteristics of TIA patients collected from hospitals and scan centres (*n* = 138)

Demographic variables	N (%)*
Age (Mean ± SD)	58.5 ± 13.9
Range	22-88 years
Gender	
Men	87 (63.0)
Women	51 (37.0)
Marital status	
Married	116 (96.7)
Widow (er)	4 (3.3)
Education	
Illiterate	12 (10.0)
Literate	108 (90.0)
Occupation	
Employed	36 (30.3)
Unemployed	5 (4.2)
Housewife	42 (35.3)
Business	18 (15.1)
Retired	18 (15.1)

*percentages are calculated after excluding missing values

cases from 26th March 2012 to 25th March 2013 is 76 and annual incidence rate II for 2012-2013 is 7.13/100,000 (95% confidence interval: 5.52 to 8.74). The age adjusted incidence rate on the basis of 2012-2013 data was 8.47/100,000 (95% CI: 6.57, 10.37). Annual incidence rate for those over 49 years of age was 21.18/100,000 (95% CI: 15.51, 26.87).

GIS mapping

The highest incidence of TIA was seen in central (ward number 36 and 39), southern (ward number 48) and western parts (ward number: 28, 54) of the city. [Figure 2]

The statistically significant hot spots of TIA patients were seen in the central part of the city (ward numbers 46, 49, and 51). [Figure 3]

Discussion

TIA incidence in this study was found to be lower when compared to that of high-income countries.[13,14] This is most likely due to patients not presenting themselves to a provider or a scan center due to low resources/low access to resources, in a condition like TIA where symptoms resolve quickly. Symptom recognition may also be low as evidenced by another study report from the same city that only 27% of stroke patients had self-recognized their stroke symptoms.[15] Since we did have MRI images for almost 70% of subjects, it is also possible that many would now get classified as stroke and not TIA, thus lowering TIA incidence rates compared to older studies done prior to the tissue-based definition.
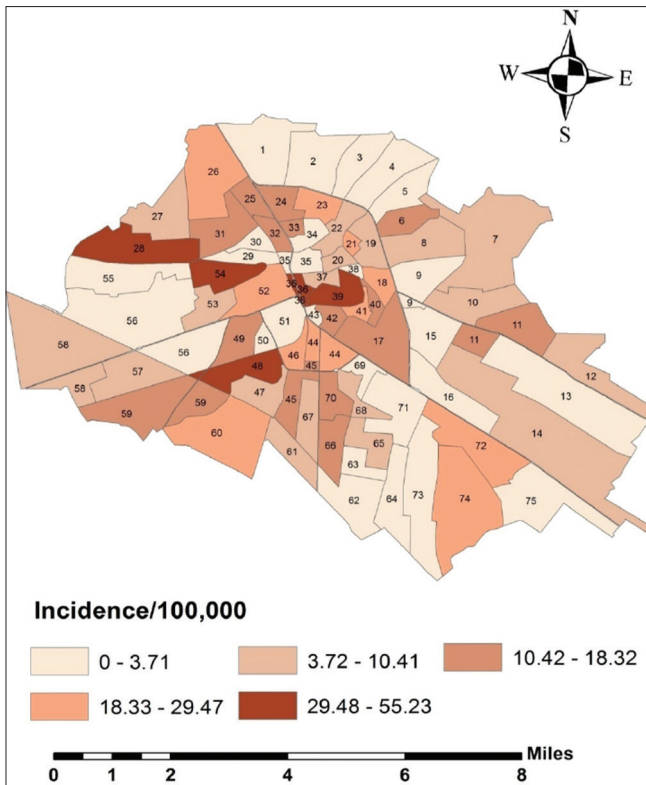
Figure 2: Spatial distribution of transient ischemic attack (TIA) incidence

Table 2: Vascular risk factors for TIA patients in Ludhiana city as collected from hospitals	
Risk factors	**Number (%)***
Atrial fibrillation	9 (7.6)
Diabetes mellitus	54 (45.0)
Hypertension	104 (87.4)
Carotid stenosis	3 (2.6)
Previous TIA¶	19 (15.8)
Coronary artery disease	26 (21.9)
Drug addiction	7 (5.8)
Tobacco current	3 (2.5)
Tobacco past	18 (15.0)
Dyslipidemia	22 (19.8)
Alcohol current	15 (12.5)
Alcohol past	47 (39.5)
Pregnancy/postpartum	1 (0.8)
Neuro infections	2 (5.8)

*percentages are calculated after excluding missing values, ¶transient ischemic attack

To our knowledge, this is the first-ever reported study that used GIS mapping to study TIA incidence in India. We posit that GIS mapping of TIA incidence be used for planning strategic allocation of resources for regional stroke and resultant disability prevention. In resource-scarce settings, identification of regional clusters can enable targeted community awareness interventions in previously involved local communities.[16] The generated TIA GIS map may also be put in perspective by studying it alongside existing environmental maps such as publicly available regional transportation maps of main roads and railway lines.[17] Putting together city TIA GIS map with city transportation map may: (i) *give clues to the underlying vascular risk factors*. For instance, the TIA incidence hot spots seen in wards 46, 49 and 51 in the study, are located in the central part of Ludhiana city, which is an area where main roadways intersect. This highly crowded and industrialized area, with limited green-space for exercise, indicates a "fast-food" lifestyle of its residents. (ii) help in planning stroke care infrastructure development around existing access roads, for fast hospital access from high-risk TIA incidence hot spot regions seen in the GIS map.

Previous public health studies have used GIS mapping[7] to look at associations between environment (vertical elevation) and hypertension (in Japan)[18] or night-time light as a proxy for urbanization and hotspots of hypertension (in Thailand).[19] GIS capacity building for chronic disease surveillance and prevention through local health departments[20] has also indicated the growing relevance of GIS mapping in chronic disease prevention and policy making. Specific to stroke, GIS mapping has been used to study in-hospital stroke mortality and risk factor evaluation.[7]

Thus, the major strength of our study is that we are initiating the novel concept of GIS mapping in TIA towards planning targeted stroke prevention in India, especially in the context of an existing regional registry.

One of the limitations of the study is the potential of under-reporting of TIA by patients due to the transient nature of deficits, but this is often the challenge with any TIA incidence study. Another limitation is that we had to use both time-based and tissue-based definitions of TIA, based on how institutional diagnoses were made. No imaging study was performed on 6.8% of the TIA patients. Using a tissue-based definition for every patient could have lowered the TIA incidence further, by reclassifying some TIA patients as small stroke cases using DWI MRI. But, this goes along with our finding that total TIA incidence is low in this sample. There may also have been an environmental bias due to easier hospital access in urban areas, as opposed to more remote or mountainous rural areas. Hence, similar studies need to be repeated in diverse terrains across India, to develop larger scale national stroke prevention interventions.

Our study was not structured primarily as a TIA incidence study. We used the existing stroke registry to capture TIA incidence with GIS mapping, to showcase the value of GIS mapping in planning stroke prevention strategies. Future studies may conduct focused TIA incidence registries, in areas where GIS mapping is available, towards establishing country-wide data banks.

Conclusions

The incidence rates of TIA and the average age of patients in Ludhiana city, India, obtained by analyzing data from an
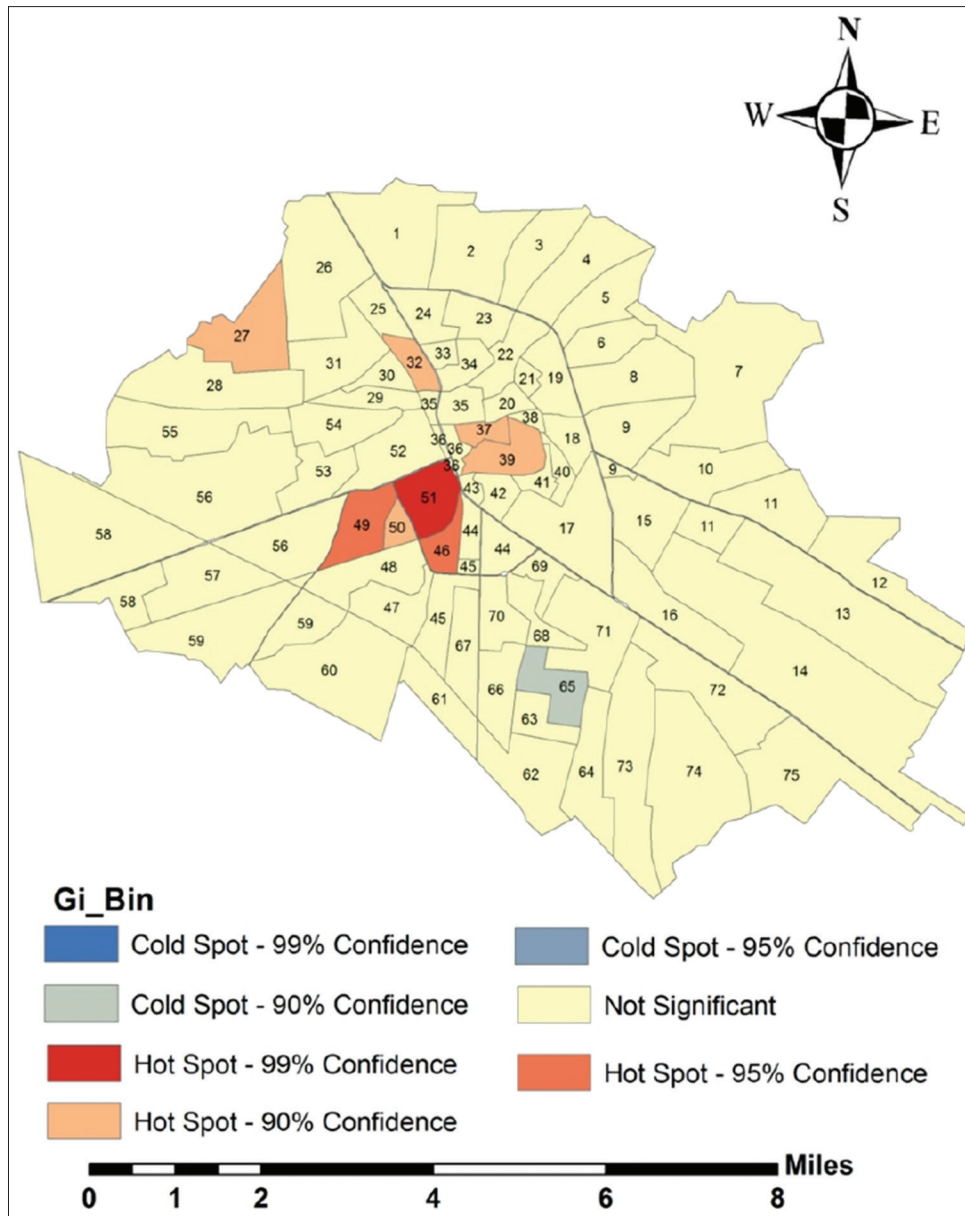
Figure 3: Hot spots of transient ischemic attack (TIA) incidence

existing population-based stroke registry, were relatively low. The findings highlight how TIA GIS mapping can be used as a valuable, novel tool for local governments in India to develop targeted stroke prevention intervention programs.

Acknowledgements

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient (s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Key messages

- TIA GIS mapping can be a valuable tool for developing targeted stroke prevention programs.
- Incidence of TIA from this registry were relatively low.
- The findings of spatial analysis are of public health significance.

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Conflicts of interest

There are no conflicts of interest.

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