Original Article

Pakistan Journal of Public Health
https://doi.org/10.32413/pjph.v13i4.1259
www.pjph.org

GIS Environment Based Study of Acute Myocardial Infarction Incidence and Associated Risk Factors at a Major Referral Cardiac Center in Twin City of Rawalpindi and Islamabad, Pakistan

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Kanwal Latif[1], Athar Hussain[2], Marium Soomro[1]

[1] Health Research Advisory Board, Karachi, Pakistan
[2] COMSATS University Islamabad

Correspondence:
Athar Hussain
athar.hussain@comsats.edu.pk

Abstract

Background: Acute Myocardial Infarction (AMI) is a critical cardiac condition characterized by sudden blood flow blockage to the heart. Previous research indicates associations between AMI risk and factors such as age, gender, lifestyle habits, and preexisting medical conditions.

Methods: This cross-sectional spatial analysis study aims to explore the geographically diverse incidence of AMI and associated risk factors in the twin cities of Islamabad and Rawalpindi. Data from 500 AMI patients, collected in April 2022 from a major cardiac center, were analyzed using the Chi-square test to assess associations between AMI risk factors.

Results: Significant associations were identified between the lifestyle of AMI patients and diabetes ($p = 0.002$), and a highly significant association of age was found with diabetes, hypertension, and smoking ($p = 0.000$). This pioneering spatial analysis of AMI incidence provides valuable insights for developing national health interventions in Pakistan.

Conclusion: This study addresses the significant concern of AMI incidence and associated risk factors in data-sparse Pakistan. Utilizing Geographical Information System (GIS), it offers a spatial understanding of AMI distribution and patterns, paving the way for future cardiovascular health research in the country.

Keywords: AMI, cardiovascular disease, diabetes, gender, geo-spatial analysis.

Introduction

The Cardiovascular disease (CVD), a leading cause of death worldwide, is characterized by Acute Myocardial Infarction (AMI) or heart attack, which occurs when the blood flow to the heart muscles is blocked thus causing tissue damage. Non-ST-Segment Elevation Myocardial Infarction (NSTEMI) accounts for over 15% of annual deaths and is more common in men. The AMI is a major cause of heart disease, affecting over 30% of population aged 45 years or above. The CVD is responsible for 82% of all deaths in low- and middle-income countries, causing 17.9 million deaths in 2019 according to the World Health Organization. It is projected that CVD will cause 23.6 million deaths by 2030 and it remains a leading cause of death (1,2).

The CVD continues to be a major cause of death worldwide, with high mortality rates seen in developing countries (3). Lifestyle changes driven by technological advancements have contributed to an increase in heart disease. Ischemic heart disease, a major cause of death and illness, particularly affects men more than women (4). Heart attacks can be classified as STEMI or NSTEMI, with STEMI being a more severe form caused by a complete blockage of a coronary artery and NSTEMI being a milder form caused by partial blockage (5). Elevated blood sugar levels contribute to atherosclerotic changes in the coronary arteries, making it a significant risk factor for heart attacks (6). The main risk factors for AMI include smoking, diabetes, hypertension (HTN), obesity, high cholesterol, and a sedentary lifestyle (7). Age was also found to be a significant causative factor for diabetes (8).

Spatial analysis and Geographic Information System (GIS) play an important role in identifying high-risk areas for AMI and in understanding the impact of environmental factors on its occurrence. GIS technology collects, manages, analyzes, and presents geospatial information, creating new opportunities for health research and improving our understanding of healthcare systems (9,10). Health geography, the study of how the spatial organization of health services affects access to care, health outcomes, and well-being, is also aided by GIS-based spatial analysis tools (11).

Studies have shown that the geographical distribution of AMI is associated with environmental factors, as well as individual and neighborhood socioeconomic conditions. A study in Calgary, Canada found AMI hotspots in older and low-income areas between 2004 and 2013 (12). Another study in Denmark evaluated the geographical pattern of fatal and non-fatal outcomes of AMI and found a significant association between the absence of a connection to a general practitioner and fatal outcomes (13). A study in Trinidad found that stress, physical inactivity, alcohol consumption, smoking, diabetes, HTN, and family history of ischemic heart disease were associated factors of AMI (14). Another study in Sweden found that the rates of CVD were concentrated in certain regions with disparities between sexes, having hotspots and clusters in central and northern Sweden and cold patches in the vicinity of major cities (15).

Furthermore, studies conducted in New York State, and Southern West Virginia in USA, and in Denmark found associations between AMI and factors such as stress, physical inactivity, alcohol consumption, smoking, diabetes, HTN, and family history of heart disease (16-18). Research in France found higher AMI mortality rates in poorer socioeconomic areas (19), and a Libyan study revealed a significant difference in smoking rates and HTN between male and female AMI patients (20). Above studies show that the incidence of AMI varies in different regions, with factors such as HTN, smoking, and spatial accessibility to hospitals impacting the occurrence of the disease.

A study conducted in neighboring Iran found that HTN and smoking were highly associated with AMI occurrence (21). Another study in Shijingshan District, Beijing, China, showed that accessibility to hospitals for AMI patients varied based on distance and traffic congestion (22). A study in the Zanjan province of Iran found a 30% increase in the age-adjusted incidence rate of AMI from 2014 to 2018, with the highest incidence rate seen in the Golabar area. Spatial analysis techniques identified five hot spots and one high cluster of AMI cases (23). A study in India found that the majority of young AMI patients had an anterior wall STEMI (24). A case-control study in Gujarat, India identified several risk factors for AMI, including illiteracy, upper socioeconomic class, positive family history of AMI, HTN, type A personality, diabetes, obesity, low intake of fruits and leafy vegetables, and a history of acute life event (25). A geographical analysis in Iran showed a link between environmental exposures and cardiovascular death (26). Another study in Iran found close proximity of AMI incidence cluster to industrial sites, including a steel factory and congested highways (27). A study in Afghanistan found that nearly 10% of the population had CVD and identified risk factors such as older age, current cigarette use, and elevated total cholesterol (28). A patient survey based study in Pakistan found that males were more likely to have AMI between the ages of 41 and 60 and had a higher prevalence of sedentary lifestyle, smoking, and HTN compared to females (29).

Generally speaking, the GIS technology enhances vector-borne disease surveillance by offering a spatial and temporal perspective on disease incidence. Utilizing GIS, one can map the distribution of illnesses across time and location, identifying disease hotspots or clusters (30).

Thus, to our knowledge there has been no attempt to document the spatial distribution of AMI disease in Pakistan. In this case study, based on data acquired from 500 patients, a spatial distribution of patients with selected causative factors of AMI is presented in twin cities of Rawalpindi and Islamabad to highlight the relevance of GIS environment in determing the spatial distribution including the proximity of AMI patients to a major referral cardiac center.

Methodology

Study Area and Data Source

Islamabad Capital Territory (ICT) covers an area of 906 square kilometers (350 sq mi) in the city of Islamabad and an additional 2,717 square kilometers (1,049 sq mi) in the Margala Hills to the northeast. The district of Rawalpindi is located in Pakistan's Punjab province, with a total area of 5,286 square kilometers and a total area of tehsil Rawalpindi is 16,32 square kilometers. Rawalpindi is located at 33.626057°N latitude and 73.071442°E longitude. Islamabad is located at 33.738045°N latitude and 73.084488°E longtude (Figure 1).

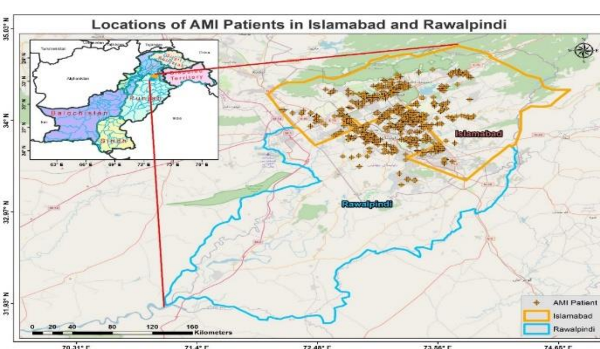

Figure 1: Geographical display of district Rawalpindi and Islamabad in Pakistan with a density of AMI patients. The inset displays the location of countries neighbouring Pakistan in south Asia

In Pakistan, a national census is conducted every 10 years by the government, the last one was in 2017. For this study, population data was obtained from door-to-door surveys during the polio eradication program and rubella and measles campaign from the health department government of Punjab (district Rawalpindi), during year 2022, for Rawalpindi and from the Federal health department for Islamabad (private communication).

Study Design

This study was conducted at a major referral cardiac center in twin city of Rawalpindi and Islamabad and included 500 patients. A structured questionnaire was used to gather information on participant profile, type of AMI (STEMI or NSTEMI), and risk factors such as HTN, diabetes, and lifestyle. The study included patients with symptoms of AMI such as chest pain, shortness of breath, and ST elevation on ECG, with ages between 35 and 85 years. Patients with a previous history of AMI, coronary artery bypass grafting (CABG) and percutaneous interventions (PCI), age above 85 or below 35, or other complicated heart diseases were excluded from the study (Figure2).

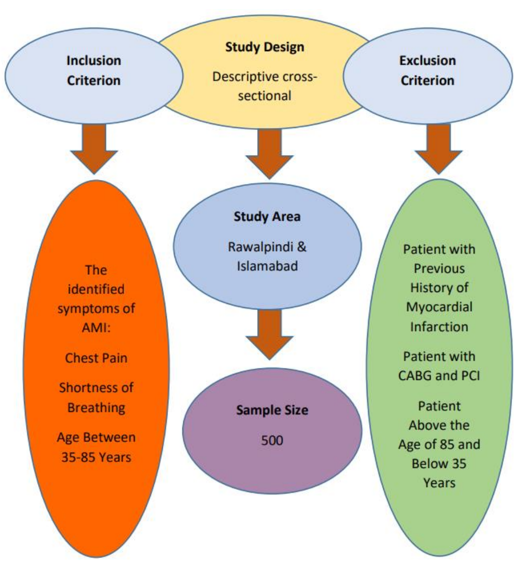

Figure 2: Methodology design for AMI Patients in Rawalpindi and Islamabad with a sample size of 500 patients. See text for more details.

Informed consent was taken from the study participants. A structured questionnaire was used to gather data on patients with a history of AMI. The physician's documents and hospital records were used to confirm the patient history of AMI. The use of a validated questionnaire ensured the reliability and validity of the data collected, allowing for accurate analysis and presentation of findings (31). Mean, Chi square test and Global Moran's index are used to quantify the findings (10).

Results

Statistical Overview

Out of 500 patients studied, 297 (59%) were male and 203 (41%) were female. The mean age of AMI patients was 63 years among both genders in Islamabad and Rawalpindi. The study found that AMI was more common in male patients than in females, including risk factors and AMI types (Table 1).

The study found that 202 of the male patients were smokers, while none of the female patients were smokers. Also, 319 patients were diagnosed with STEMI and 182 with NSTEMI. The study analyzed AMI risk factors such as age, gender, lifestyle, and smoking as independent variables and HTN, diabetes, and AMI types as dependent/outcome variables.

Table 1: AMI types and associated risk factors in population of Rawalpindi and Islamabad during study period

Variables	Frequency	Percentage
STEMI	318	64%
NSTEMI	183	36%
Smoking		
Smokers	202	40%
Non-smokers	298	60%
Gender		
Male	297	59%
Female	203	41%
Lifestyle		
Sedentary	291	58%
Active	209	42%
Other risk factors		
Diabetes		
Diabetic	318	64%
Non-diabetic	183	36%
Hypertension		
Hypertensive	394	79%
Non-hypertensive	106	21%
Mean Age	63 years	

The study found that between the ages of 60 and 79, there was a higher frequency of HTN among both genders. For example, the prevalence in AMI patients was 76% for men and 82% for women, indicating no significant gender difference and no association of gender with HTN ($p = 0.117$), and the association of gender with diabetes and AMI is statistically insignificant ($p = 0.664$, $p = 0.334$).

The study found that patients with HTN are at a high risk of developing AMI. The study found a highly significant association between HTN and these age categories ($p = 0.000$). A total of 62% of participants under the age of 49 had HTN, 74% of those aged 50 to 59, 86% of those aged 60-69, 85% between the ages of 70 to 79, and 65% aged ≥ 80.

The study found that the risk of developing CVD, including MI, is significantly increased by diabetes. The results showed a very significant difference in diabetes between age groups, indicating that AMI patients who were older had a higher probability of developing diabetes. Diabetes increased substantially with age, from 36% in adults aged ≤ 49 years, to 60% in adults aged 50 to 59 years, 74% of participants aged 60 to 69, 66% between the ages of 70 to 79 years, and 59% aged ≥ 80 years respectively. The association of age with diabetes is also significant ($p = 0.000$) as shown in Table 2. The study found a significant statistical association between age and AMI types ($p = 0.047$).

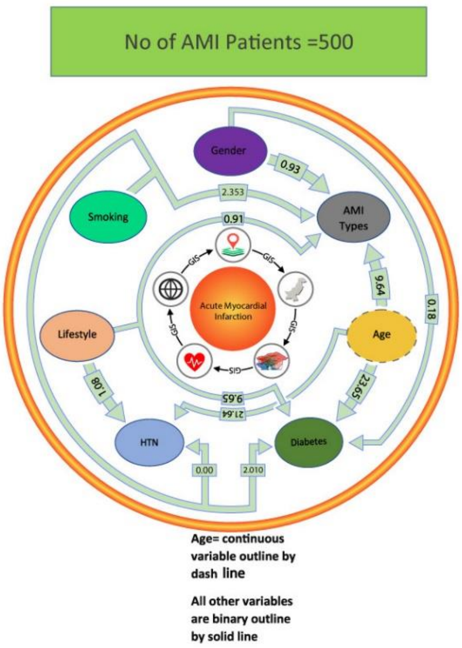

Figure 3: The association of AMI risk factors in Rawalpindi and Islamabad patients is displayed in outer circle with Chi-Square result. The GIS environment development is displayed in inner circle

The lifestyle of AMI patients shows a significant association with diabetes ($p = 0.002$). It was noted that 70% of diabetic patients had a sedentary lifestyle with an outcome of AMI. The association of lifestyle with HTN and AMI types is statistically insignificant (Figure 3).

Spatial Variations

The study obtained the latitude and longitude coordinates of the patient's residence addresses through the use of Google Maps, using information obtained from the questionnaire. It is noted that the population density in Rawalpindi and Islamabad covaried with the density of AMI patients. The high density areas of AMI patients are located in highly populated areas in Rawalpindi such as Girga, Chak Jalal Din, Lakkah, Rawalpindi Cant-10, and Islamabad Zone I, Zone IV. These findings were illustrated via a GIS environment-based map (Figure 4).

The study used a spatial autocorrelation tool to examine the spatial pattern of AMI patients in the study area (Figure 5). The results of the analysis suggest that the pattern of AMI patients' location is clustered, with a Moran's Index of 0.032, a z-score of 2.391, and a p-value of 0.016. This indicates that there is less than a 5% likelihood that this clustered pattern could be the result of random chance. Additionally, the study found that the pattern of specifically male and female AMI patients with a history of diabetes (23), hypertension, lifestyle, and AMI types was random, as shown in Table 3.

Table 2: Association between predictor and outcome risk factors of AMI patients using Chi-Square test

Predictor	Outcome Variable					
	HTN		Diabetes		AMI Type	
	Yes	p-value	Yes	p-value	STEMI	p-value
Age		0.000		0.000		0.047
≤ 49	62%		36%		73%	
50-59	74%		60%		67%	
60-69	86%		74%		66%	
70-79	85%		66%		57%	
≥ 80	65%		59%		47%	
Gender		0.117		0.664		0.334
Male	76%		63%		65%	
Female	82%		65%		61%	
Lifestyle		0.298		0.002	.	0.339
Sedentary	80%		70%		62%	
Active	77%		56%		66%	
Smoking	78%	0.996	67%	0.156	68%	0.125

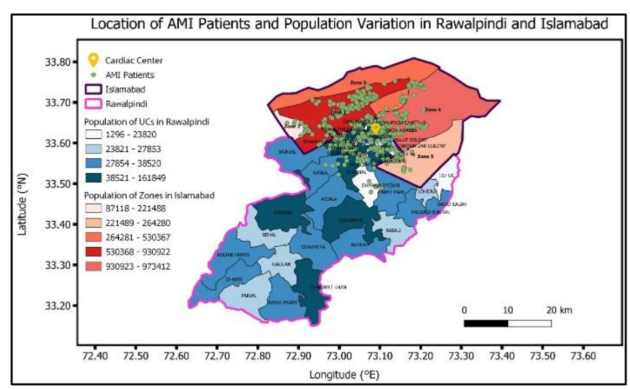

Figure 4: Population weighted spatial distribution of AMI patients in Rawalpindi and Islamabad. The UCs stands for Union Council. Autocorrelation (Global Moran's I) was used to examine the spatial pattern of AMI in the study area and to map the population and AMI patients' density

Discussion

The results of our study are consistent with other studies, indicating that men are more likely than women to experience AMI and that there may be gender-specific risk profiles.

Diabeteswas prevalent among AMI patients in Rawalpindi and Islamabad, with 318 individuals in both genders who had diabetes and 182 who did not.

A total of 392 AMI patients were hypertensive and 106 were non-hypertensive, whereas 291 patients had a sedentary lifestyle and 209 had an active lifestyle (7,14). The associations between outcome variables and AMI risk factors were examined using the chi-square test. The results of the study showed no association at all between smoking, diabetes, hypertension, and AMI types (16–18). The study found that patients with HTN are at a high risk of developing AMI. According to the study, people with HTN had a higher chance of having an AMI. As people age, the frequency of HTN rises noticeably. Five age groups comprised the AMI patients: < 49, 50-59, 60-69, 70-79, and ≥ 80 (8). It is clear that STEMI is more common among younger participants (24), with 73% for those aged 49 and older, 67% for those in the 50 to 59 age group, 66% for those in the 60 to 69 age group, 57% for those in the 70 to 79 age group, and 47% for those over 80 years old, respectively.

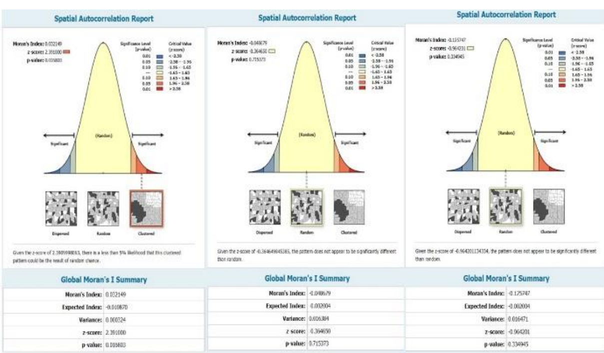

Figure 5: Graphical representation of Global Moran's I for AMI by gender. The left panel refers to total AMI patients, whereas middle (right) panel refers to male (female) AMI patients

Conclusion

Spatial analysis of AMI patients is attempted first time in selected areas of Pakistan. Preliminary studies have been performed regarding the risk factors of coronary heart disease in selected areas of Pakistan. Nonetheless, a detailed geo-spatial understanding of these factors in the twin cities of Islamabad and Rawalpindi is critical for developing national health measures to combat them. The main observations are as follows:

- AMI, and its risk factors, including HTN, diabetes, and a sedentary lifestyle are high in Islamabad and Rawalpindi.
- Smokers are fewer in number than non-smokers. Male AMI patients were comparatively high in number, according to our findings. Only male patients were discovered to be smokers, and association of gender and age with smoking is statistically significant.
- The mean age of AMI patients was 63 years among both genders in Islamabad and Rawalpindi. Age appears to be a causal factor for heart problems, as the risk of AMI or heart disorder increases as one gets older. Hypertension was discovered to be a causative factor, with most hypertensive males having a higher tendency to AMI.
- Our study showed that 64% of AMI patients were diagnosed with STEMI.
- Our findings showed 58% of AMI patients have a sedentary lifestyle, and shows an association with diabetes which was statistically significant.
- HTN is a significant risk factor for the onset of AMI (79%); its incidence is high in Islamabad and Rawalpindi. This result is consistent with the finding of a previous study, which found that hypertension is substantially more prevalent in Pakistan.
- In our study, 64% of AMI patients had diabetes. The results showed a very significant difference in diabetes between age groups. This indicates that AMI patients who were older than those who were younger had a higher probability of developing diabetes.

Table 3: Global Moran's I for AMI patients with respect to gender in Islamabad and Rawalpindi

	Variable	Moran's index	Expected index	Variance	Z-score	p-value	Pattern
Total	AMI Patients	0.032	-0.011	0.000	2.391	0.017	Clustered
Male		-0.049	-0.002	0.016	-0.365	0.715	Random
	Diabetic	-0.140	-0.002	0.016	-1.075	0.282	Random
	Non-diabetic	-0.040	-0.002	0.016	-0.299	0.764	Random
	Hypertensive	0.171	-0.002	0.016	1.346	0.178	Random
	Non-hypertensive	-0.154	-0.002	0.016	-1.188	0.235	Random
	Sedentary lifestyle	0.148	-0.002	0.016	1.173	0.241	Random
	Active lifestyle	-0.129	-0.002	0.016	-0.993	0.321	Random
	Smoking	-0.132	-0.002	0.016	-1.016	0.309	Random
	STEMI	-0.066	-0.002	0.016	-0.497	0.619	Random
	NSTEMI	0.059	-0.002	0.016	0.476	0.634	Random
Female	Hypertensive	-0.126	-0.002	0.016	-0.964	0.335	Random
	Non-hypertensive	-0.026	-0.002	0.016	-0.186	0.853	Random
	Diabetic	0.026	-0.002	0.016	0.218	0.828	Random
	Non-diabetic	-0.106	-0.002	0.016	-0.813	0.416	Random
	Sedentary lifestyle	0.063	-0.002	0.016	0.507	0.612	Random
	Active lifestyle	-0.133	-0.002	0.016	-1.025	0.306	Random
	STEMI	-0.118	-0.002	0.016	-0.907	0.364	Random
	NSTEMI	0.028	-0.002	0.016	0.238	0.812	Random

This is the first study that has been conducted in Pakistan on the use of GIS in health and healthcare, despite the fact that very little research has been conducted on the selection and training of healthcare workers in the field of GIS. Consequently, the importance of doing this research is to assist healthcare planners and decision-makers in this respect.

More specific recommendations based on private communication with senior healthcare experts in the context of GIS environment engagement, are as follows:

1. A consequence of this geospatial mapping can be the availability of mobile cardiac primary health services in high-risk areas/hotspots.
2. More detailed spatiotemporal geo-mapping of the cardiac patients needs to be executed to obtain an overview first at the city level and then a province level before approaching country-wide AMI patients density mapping.
3. Medical policymakers (health planning authorities) need to be sensitized about the significance of geo-spatial mapping of high burden diseases such as AMI.

Broadly speaking, the presented GIS environment-based research should lead to a higher scientific background for implementing policies for the control and prevention of CVD, including AMI, which is a leading cause of death. In high-risk areas, community-based awareness programs about lifestyle modifications should be arranged for AMI disease.

Declaration of Conflicting Interests

The Authors declare that there is no conflict of interest.

Acknowledgments

We thank the cardiology department for their support in data collection for this research. We also greatly thank Mr. Saifullah for his valuable guidance and supervision throughout the research. We would also like to express our appreciation to Dr. Muhammad Ilyas, Dr. Zakiuddin Ahmed, Dr. Shahzad Saddique, Dr. Jahanzaib Malik and Mr. Ashar Feroze for their helpful advice and support.

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