

Geospatial analysis of end-stage renal disease among patients attending hemodialysis units in Alexandria, Egypt

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Background/aim

End-stage renal disease (ESRD) is increasing worldwide and renal replacement therapy is inevitable to prevent death. Geographic information system (GIS) analysis is particularly suitable for chronic kidney disease (CKD) and ESRD. Spatial analysis is an important tool for better decision-making and planning. The aim of this study was to utilize geospatial analysis of ESRD in Alexandria for understanding the interplay between geography and other risk factors and for guiding resource allocation.

Patients and methods

A cross-sectional study was adopted, 950 ESRD patients were interviewed during the period from November 2021 to December 2022. Data were collected using predesigned structured interview questionnaire, which included sociodemographic information and the patient's medical history. This information was then used for the development of the spatial representation of data and cluster analysis for ESRD patients attending hemodialysis units in the districts of Alexandria governorate.

Results

The results of the study showed that the mean age of ESRD patients ($n=950$) was 49 ± 16.2 years. 538 of studied patients (56.6%) were males. Hypertension was the most frequent main etiology of ESRD (31.3%). It was found that 100–150 hypertensive patients were in Al-Ameria and Sharq district. Moreover, greater than 150 hypertensive patients were in Al-Muntazah district. Although Al-Muntazah district had the highest number of ESRD cases ($no.=247$), it was not a significant cluster ($P=0.15$). On the other hand, Al-Ameria district had a significant cluster of ESRD cases ($no.=177$, $P=0.002$).

Conclusion

It is recommended to target future screening programs and awareness campaigns in Almeria district to raise public awareness about early detection and prevention of chronic kidney disease this will help to prevent further progression to ESRD. Further studies are required to assess the accessibility to renal dialysis units in Egypt.

Keywords:

end stage renal disease, geospatial analysis, hemodialysis

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Introduction

There is an upsurge in the prevalence of End-stage renal disease (ESRD) worldwide associated with increased burden on health system due to renal replacement therapy (RRT) and kidney transplantation. This condition is mostly serious in developing countries where health resources are insufficient [1]. ESRD is defined as 'the progressive and irreversible impairment of kidneys functions which represents the final stage of chronic kidney disease (CKD)' [2].

There are five stages for chronic kidney disease. The ESRD is the fifth stage of the progression of chronic kidney disease, and it is identified by glomerular filtration rate (GFR) less than 15 ml/min for three months [3]. Globally, in 2020, it has been reported

that ESRD affects two million people with a rising rate of 5–7% per year [4].

In the United States, in 2015 there were 687,093 people with ESRD described in the US Renal Data System and patients formally registered to receive maintenance dialysis or transplantation [5].

In Egypt, the estimated annual incidence of ESRD is around 74/million and the total prevalence of patients on dialysis was 264/million in 2016 [3]. Nearly \$32 billion has been spent on ESRD patients each year in

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the United States [6]. The Egyptian Ministry of Health spends \$100 million on RRT which is ~28% of the total healthcare budget [7].

ESRD has several causes that differ from one patient to another. The known risk factors for ESRD can be categorized into four categories (demographics, comorbidities, lifestyles, and environmental factors). Demographics include old age over 75 years and having family history of chronic renal diseases. Comorbidities include diabetes, hypertension, glomerulonephritis (GN), heart failure, hyperuricemia, hyperlipidemia, and anemia. Lifestyle habits such as smoking, drinking alcohol heavily and use of analgesics regularly over long durations of time. Environmental factors such as exposure to organophosphorus herbicides in water [8]. A Study conducted from 54 countries showed that 80% of ESRD cases are due to complications of hypertension, diabetes, or both [9].

Geospatial analysis is a technique that transforms raw data into information that may be used to make effective decisions. The primary benefit of spatial analysis is its capacity to reveal patterns that were previously unknown as in the case of using it to detect disease clusters and establish prevention programs. This makes spatial analysis an important tool for better decision-making and planning [10].

Geographic information system (GIS) analysis is particularly suitable for CKD and end-stage renal disease (ESRD). Proper management of CKD needs time, adequate resources, and intense care. Inadequate management of CKD can result in higher expenses, accelerate progression of disease, and greater death rates [11].

Understanding socioeconomic disparities in CKD has benefited greatly from the geographic linking of United States Census data to renal databases. GIS tools have been used to calculate distances between health care providers and patients as well as to investigate the obstacles to renal care in rural areas [11].

In the light of uprising prevalence of ESRD nationally and internationally in addition to financial burden, direct and indirect cost as well as disability, the present study aims to clarify the geospatial analysis of ESRD in Alexandria for understanding the interplay between geography and other risk factors and for guiding resource allocation.

Patients and methods

Study design

The present study is a cross sectional study which was carried out to collect data from all ESRD patients attending governmental hemodialysis units in Alexandria, Egypt during the period from November 2021 to December 2022 by direct interviewing of the patients using pre-designed structured interview questionnaire.

Inclusion criteria

All ESRD patients who were attending hemodialysis units in Alexandria University Hospitals (AUH), Hospitals of Ministry Health and Health Insurance Hospitals during field work from November 2021 to December 2022.

Exclusion criteria

Patients who refused to participate in the study, Patients who were living outside Alexandria and comatose patients were excluded from the study.

Ethical consideration

The present study was conducted with the Code of Ethics of the World Medical Association, according to the principles expressed in the Declaration of Helsinki. This study has been approved by the local Ethics Committee of Faculty of Medicine, Alexandria University, Egypt with approval number 0201515 on May 20, 2021. A written informed consent was provided by each participant prior to their inclusion in the study.

Methods

The questionnaire was developed in the native language of respondents (Arabic), it included sociodemographic information (age, sex, residence, education, occupation, family size, crowding index, and monthly income) and the patient's medical history (associated chronic diseases, history of the dialysis, congenital abnormality, and main etiology of ESRD). This information was then used for the development of spatial representation of data and cluster analysis for ESRD patients attending hemodialysis units in the districts of Alexandria governorate.

Statistical analysis

The collected data was coded and analyzed using the Statistical Package for Social Sciences (SPSS ver.25). The spatial scan statistic has been applied also to detect local clusters with statistically significant elevated risk of ESRD. The spatial scan statistic is a local cluster

test, which identifies the location and the statistical significance of local clusters. *P value* was considered significant at *P* less than 0.05.

Results

Regarding sociodemographic characteristics of end stage renal disease patients attending renal dialysis units in Alexandria ($n=950$), it was found that the age of studied patients ranged between 4.5 and 83 years with a mean age of 49 ± 16.2 years. More than half of the patients (56.6%) were males. Nearly two thirds of the patients (65%) were married, 20.9% were single, 10.5% were widows and only 3.6% were divorced. More than one quarter of the patients (28.5%) were illiterate while 19.2% were university graduates and higher grades. The majority of the ESRD patients were either not working (30.1%) or housewives (30.9%) or pensioner (16.8%) while minorities of the patients were technical workers (2.2%), professionals/semiprofessionals (4.6%) and manual workers (5.4%). The family size ranged between 1 and 20 members with a median family size of 4.0 members (interquartile range = 2.0). The monthly family income ranged between 400 and 40,000 Egyptian pound with a median of 1500 (interquartile range = 2100). The majority of the ESRD patients (81.7%) were living in 2–3 rooms. The crowding index ranged between 0.3 and 8 with a mean crowding index of 1.7 ± 0.9 .

Concerning the main etiology of ESRD it was found that the most frequent main etiology of ESRD was hypertension (31.3%), followed by congenital diseases which represented (16.2%). In more than one tenth of patients the etiology of ESRD was interstitial nephritis (12.8%), diabetes mellitus (12.1%) or unknown (10.9%). In 5.4% of patients the etiology was glomerulonephritis, in 4.1% of patients was Systemic lupus erythematosus and in 4.0% of patients was

obstructive nephropathy. Preeclampsia, recurrent urinary tract infections and tumors were the least common etiologies (1.6, 1.1, 0.5%, respectively) as illustrated in Table 1.

Table 2 reveals that most of the studied patients (89.5%) were dialyzed three times per week, while the minority dialyzed either once (0.2%) or twice (6.0%) or four times weekly (0.7%). The majority of the patients (95.8%) were dialyzed for 4 h/session while a small percentage was dialyzed either for 3 h (3.9%) or 5 h (0.3%)/session. The duration of the hemodialysis among the studied patients ranged between 0.25 to 43 years with a median duration of 4 years (IQR=7 years). Concerning co-morbidities, more than two thirds (70.6%) of studied patients suffered from hypertension and more than half (54.8%) of the patients were anemic. Nearly one fifth of the patients (20.6%) had cardiovascular diseases, while less than one fifth of the patients (18.5%) were diabetic. More than a tenth of the patients (14.5%) had a medical history of hepatitis C virus. Less than a tenth of the patients (9.1%) had gout. The least frequent comorbidities were systemic lupus erythematosus (4.1%) and hepatitis B virus (2.2%).

Figure 1 illustrates the number of the studied ESRD patients who had hypertension during the period from

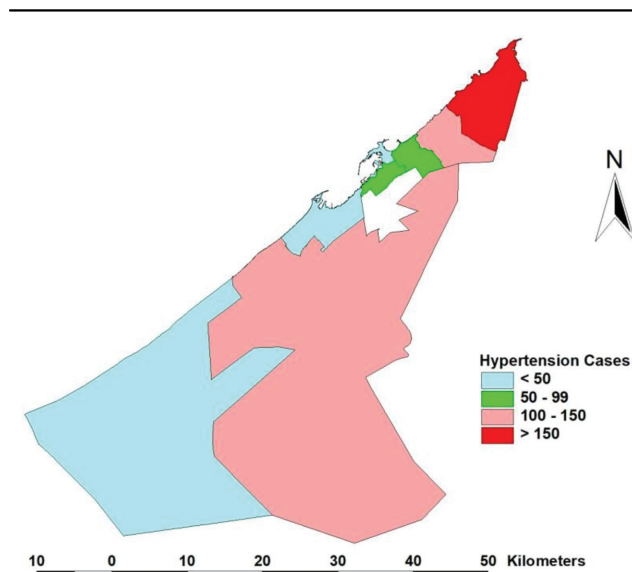
Table 1 Distribution of studied end-stage renal disease patients in Alexandria from October 2021 to November 2022 according to the main etiology

Main Etiology of ESRD	Total number (950)	%
Hypertension	297	31.3
Congenital diseases	154	16.2
Drug/toxin (Interstitial nephritis)	122	12.8
Diabetes mellitus	115	12.1
Unknown etiology	104	10.9
Glomerulonephritis	51	5.4
Systemic lupus erythematosus	39	4.1
Obstructive nephropathy	38	4.0
Preeclampsia	15	1.6
Urinary tract infection	10	1.1
Tumors	5	0.5

Table 2 Medical history of studied end-stage renal disease patients in Alexandria during the period from October 2021 to November 2022

Medical history of studied patients	Total number (950)	%
Number of renal dialysis sessions/week		
Once	2	0.2
Twice	57	6.0
Three times/week	850	89.5
Four times/week	7	0.7
Variable	34	3.6
Hemodialysis duration (y)		
Mean $\pm$ SD	6.3 $\pm$ 5.9	
Median (IQR)	4 (7)	
Minimum – maximum	0.25– 43.0	
Number of hours/dialysis session		
3 h	37	3.9
4 h	910	95.8
5 h	3	0.3
Associated chronic diseases†		
Hypertension	671	70.6
Anemia	521	54.8
Cardiovascular disease	196	20.6
Diabetes mellitus	176	18.5
Hepatitis C virus	138	14.5
Gout	86	9.1
Systemic lupus erythematosus	39	4.1
Hepatitis B virus	21	2.2

†: categories are not mutually exclusive. IQR, interquartile range.

Figure 1

Distribution of studied end-stage renal disease patients ($n=950$) in Alexandria during the period from October 2021 to November 2022 according to hypertension.

October 2021 to November 2022 in each district. It was found that from 100–150 hypertensive patients were in Al-Amreia and Sharq district. Moreover, greater than 150 hypertensive patients were in Al-Muntazah district.

Table 3 depicts the spatial distribution of ESRD patients attending hemodialysis units in Alexandria governorate regarding census population in 2017, number of cases in each district, Area- km^2 , population density and P value. Although Al-Muntazah district had the highest number of the ESRD cases (no.= 247), it was not a significant cluster ($P= 0.15$). On the other hand, Al-Amreia district had a significant cluster of ESRD cases (no.= 177, $P=0.002$) in relation to its population (no.= 755239), (Fig. 2).

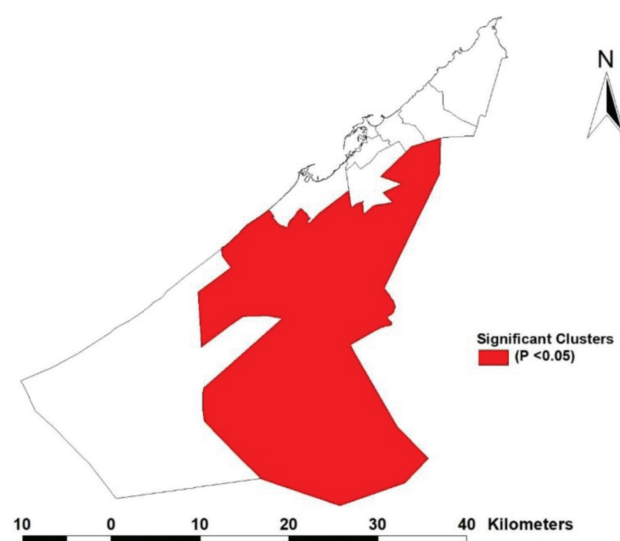
On studying the distribution of governmental renal dialysis units in Alexandria governorate with a buffer

5 km around each unit, it was revealed that nearly most of the cases lying inside this buffer except for some cases in Al-Amreia district (Fig. 3).

Discussion

The present study showed that the mean age of ESRD was 49 ± 16.2 years and 56.6% of them were males this is similar to result reported by El-Ballat *et al.* [12] who revealed that mean age of the ESRD patients were 52.80 ± 13.82 and 60.4% were males and this is less than what is reported by Collins *et al.* [13] in USA in 2015 who showed that mean age was 59.2 years.

In the current study, hypertension (HTN) was the main etiology of ESRD (31.3%). This result is consistent with the results of many studies in different governorates in Egypt. El Zorkany *et al.* [14] stated that in Menoufia the main known cause of ESRD was HTN (33.4%). El-Ballat *et al.* [12] reported that in Beheira the HTN was the main cause of ESRD (31.7%).

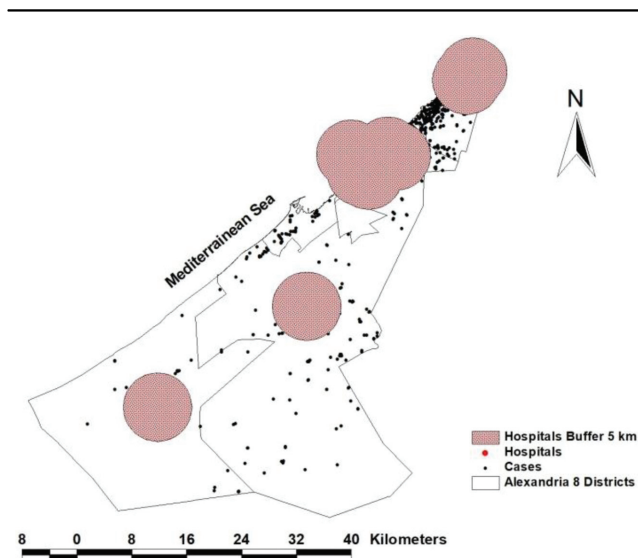
Figure 2

Significant cluster of studied end-stage renal disease patients attending renal dialysis units in Alexandria.

Table 3 Spatial distribution of end-stage renal disease patients attending hemodialysis units in Alexandria governorate

Districts	Population 2017	no. of cases	Area- km^2	Population density	P -value
1. Al-Muntazah	1589587	247	78.10	20352.4	0.150
2. Al-Amreia	755239	177	935.47	807.33	0.002*
3. Sharq	1161759	165	43.38	26776.66	0.240
4. Wasat	544785	136	19.63	27745.60	0.390
5. Gharb	357513	83	12.63	28293.21	0.250
6. Al-Gumruk	157176	56	5.74	27358.747	0.350
7. Burg al-Arab	136096	48	560.27	347.15	0.140
8. Al-Agamy	473916	38	44.61	10623.29	0.190

*: Significant P value (<0.05), using local cluster test.

Figure 3

Distribution of end-stage renal disease patients in relation to the nearest governmental renal dialysis units in Alexandria during study period from October 2021 to November 2022.

Contrary to this finding, Hassanien *et al.* [15] found that major cause of ESRD among the nations of the Gulf Cooperation Council was diabetes (17%), glomerulonephritis (13%) and hypertension (8%). Saran *et al.* [16] found that in USA diabetes was the main cause of ESRD with 38.2%, followed with HTN (25.5%). According to Kramer *et al.*, glomerulonephritis (20.4%) was the most prevalent cause of ESRD in European countries followed by diabetes (15.6%), unknown etiology (14.6%), and HTN (10.7%) [17].

The prevalence of hepatitis C virus (HCV) among ESRD patients in this study was 14.5% which is less than results reported by Megahed *et al.* in Alexandria 2019 (16.1%) and this decrease in the prevalence of HCV could be due to national program for management of HCV and isolation protocol for HCV patients in hemodialysis units. However, there were worldwide variations in the prevalence of hepatitis C among hemodialysis patients ranging from 5% to 60% [18–20].

The prevalence of HBsAg seropositivity among ESRD patients in the current study was 2.2% and this prevalence was lower than that of most of the Arab countries: HBsAg was 3.8% among Palestinian patients [21], 7% in Jordan study [22], and 48.8% in Yemen [23].

Geographic Information Systems (GIS) and spatial epidemiological approaches could provide a more

practical basis for screening programs by identifying hotspots or clusters and considering socioeconomic and demographic factors [24].

Al-Ameria district had a significant cluster of ESRD cases although its lower number of cases in comparison to Al-Muntazah district and this indicates the urgent need in Al-Ameria district for a targeted screening program for early detection of CKD and an awareness campaign about the etiologies of CKD to prevent its progression into ESRD.

Spatial planners have concentrated on how to provide healthcare services to all members of society in an equitable and efficient manner. GIS is now widely used as a tool for healthcare planning because it has improved understanding of the spatial link between health and geography. GIS can assist in achieving equal access to healthcare by analyzing and assessing healthcare demand use patterns and choosing the best sites for healthcare facilities based on population distribution, transportation and road networks, and other variables [25].

The recent work revealed that nearly most of the cases lying inside a buffer of five kilometers except for some cases in Al-Amreia district and this means the strong need of Al- Ameria district for another governmental renal dialysis unit.

Conclusion

It is recommended to target future screening program and awareness campaign in Almeria district to raise public awareness about early detection and prevention of CKD this will help to prevent further progression to ESRD. Future studies are required to assess the accessibility to renal dialysis units in Egypt. Central electronic registration system for ESRD patients in all hospitals is also recommended.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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