

Spatially Enabled Web-Based Renal Registry System for Nigeria

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ABSTRACT

Lack of electronic renal registry has resulted to a non-reliable statistics about Chronic Kidney Disease, So, there is a need to have a better understand of the national distribution of ESRD registries which will assist in clinical and policy decisions which is the focuses of this paper. In order to develop the renal registry, Structured Query Language (SQL), PHP, Google Map API, CSS and HTML technologies were used. The digital map which was provided by the Google Map API. The result of the application shows that users can view renal distribution details of any location on the map within the area of study with ease. This will help policy makers in making decisions regarding building renal related health facilities and distribution of renal equipment to the affected location. In conclusion, nephrologists, policy makers, and any other stakeholders would be able to query, analyse, view and generate renal distribution information based on renal patient disease stages within the country.

Keywords: Chronic Kidney Disease, Renal, Registry, Spatial, GIS

CISDI Journal Reference Format

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1. INTRODUCTION

Chronic Kidney Disease (CKD) is a significant cause of morbidity and mortality across developed and developing nations and is associated with increased risk of death from cardiovascular disease (Okunola *et al.*, 2005). CKD is an insidious disease characterised by a clear natural history with a detectable asymptomatic period during which interventions (such as blood pressure control, diabetes control) could help prevent or delay progression to the end stage of kidney failure (Arogundade *et al.*, 2005).

Epidemic diseases have highly destructive effects around the world and these diseases have affected both developed and developing nations (Kusiak *et al.*, 2000). However, kidney disease and failure are arising globally, particularly in the developing countries where the major underlying causes, diabetes and hypertension, are on the rise. Chronic diseases place long term demands on health management systems. Patients with advanced stages of diseases need some form of renal (kidney) replacement therapy, but the increased demand is unlikely to be met in developing countries and resource constrained settings because of the complexities and high cost of such therapy. Thus, early detection of kidney diseases and managing the underlying causes are important in saving lives (Mario and Sridevi, 2008).

In the field of medicine, registries have been widely established to collect data on patient generally especially renal registries (Grimson *et al.*, 2011). Data from these registries can provide useful information to assess the effectiveness of treatment options, identify patients who could benefit from an existing or new treatment, and drive improvements in health care quality (Couchoud *et al.*, 2013). End-stage renal disease (ESRD) and its current standard of care, renal replacement therapy (RRT; which includes dialysis and/or kidney transplantation) result in substantial economic and societal costs. The rise in the incidence and prevalence of CKD in both developed and developing countries has resulted in a renewed interest in global CKD prevention because many countries now regard CKD as a public health threat (Akinsola *et al.*, 2004). In Nigeria presently, there is no existing electronic means of capturing and monitoring CKD or any electronic national database for the disease neither is there any existing ICT infrastructure to capture renal information electronically, monitor the spread based on geographical location and using this to effectively manage CKD in Nigeria. In order to have a better understand of the national distribution of renal disease, there is a need to have a renal registries required for tracking and monitoring of the spatial distribution of renal diseases by public health officers and patients alike efficiently and effectively in any community in Nigeria. This paper focuses on functional national database for reporting of CKD in Nigeria that is Nigerian Renal Registry.

2. SPATIAL DATA IN DISEASE REGISTRY

A disease registry is a tool for tracking the clinical care and outcomes of a defined patient population (Hall *et al.*, 2016). Most disease registries are for the management patients with one or more chronic diseases such as diabetes, coronary artery diseases or asthma. Spatial Data are data that have some form of spatial or geographic reference that enables them to be located in 2- or 3-dimensional space (Hall *et al.*, 2004). There are five (5) main spatial data types namely; Points, Lines, Regions, Partitions (maps) and Graphs (networks). Applications of Spatial Data include; Geographic Information Systems (GIS), Computer-Aided Design/Manufacturing and Multimedia Databases. Providing analysts and decision-makers with timely access to reliable epidemiological, social demographic measures and environmental health measures at a high spatial resolution is a key priority to facilitate evidence-based decision-making (Brownson *et al.*, 2009; Gudes *et al.*, 2010; Jacobs *et al.*, 2012). Various studies have been undertaken that used GIS technology and spatial data analysis in evaluating health data (Levene *et al.*, 2009; Rushton *et al.*, 2006). Spatial analysis is a useful tool to explore health data, map and identify patterns, generate new hypothesis, and provide evidences about existing hypothesis (Boscoe *et al.*, 2004).

In developed nations, data from renal registry can be fully used to find association between occurrence of renal incidents with geographical and demographic factors (Higgs *et al.*, 2005; Moore and Carpenter, 1999). In order for the modelling of single objects, the fundamental abstractions are point, line, and region while for modelling spatially related collections of objects, the two most important instances are partitions (of the plane) and networks.

2.1 GIS in Disease Mappings

Geographical Information Systems (GIS) is an automated set of functions that provides professionals with advanced capabilities for the storage, retrieval, display and analysis of geographically located data (Kumar, 2016). GIS is a tool with the ability to bring together, exploit and analyse data from a variety of sources. By using data from diverse sources such as renal registries, local authorities, environmental and sociological agencies, in a cohesive and spatial manner, the geographical distribution of renal incidence and mortality can be explored in relation to the geographical distribution of external, social and environmental factors (Benach *et al.*, 2001). Since renal risk, incidence, prevalence, mortality, and survival have been shown to vary geographically, Geographic Information Systems (GIS) are uniquely suited tools for analysing these patterns (Brewer, 2006; Jacquez, 2004; McLafferty, 2002; Pickle *et al.*, 2006; Rushton *et al.*, 2004). For example, GIS have been used to demonstrate how renal rates cluster in space-time (Alexander *et al.*, 1998; McNally *et al.*, 2011; Mosavi *et al.*, 2007; Steliarova-Foucher *et al.*, 2004).

Beyond their abilities to manage, display, and synthesise spatial data, GIS are capable of revealing relationships between renal cases, clusters, and other spatial phenomena; for example, many studies use GIS to examine the spatial relationship between renal incidence and environmental risks (Boscoe *et al.*, 2004; McEntee and Ogneva-Himmelberger, 2008; Polstrup and Hansen, 2004).

GIS applications have been used to improve researches and services of healthcare. The integration of these applications with health data could bring many benefits, such that GIS analytical functions could be used to combine data from various sources and format, visualise and analyse spatial pattern of incident of diseases, develop and model a risk map, and generate report which identify areas for improvement of health services and diseases prevention with all kinds of support decision making (Richards *et al.*, 1999). Information technology continues to change the landscape of what is possible in the display and communication of spatial data. Richards *et al.* (1999) suggested that with time, each community will have the capability to link together health information from a variety of different data sources and to recognize spatial data patterns that suggest where cost effective public health interventions can be applied. The Internet has gone a long way in helping make data available and accessible to the general public. Numerous web applications have been developed that incorporate GIS. This is in order for geographical data to be easily converted into easy-to-access maps and information. In addition to ease of access of data, distributing data over the Internet is more efficient than transmitting data through disks.

2.2 Renal Registry

Registries provide an organized and standardized method to systematically collect observational data about specific groups of patients managed in routine clinical practice for a predetermined objective (Gliklich *et al.*, 2010). Registry data can help describe the natural history, epidemiology, and burden of a disease; and capture treatment site, regional, or national variations in treatment and outcomes to help evaluate safety, quality, and value of patient care (LaBresh *et al.*, 2003). In the field of ESRD care, registries some with long standing histories have been widely established to collect data on patients undergoing RRT. Data from these registries can provide useful information to assess the effectiveness of treatment options, identify patients who could benefit from an existing or new treatment, and drive improvements in health care quality (Couchoud *et al.*, 2013). Registries of patients with ESRD receiving dialysis were initially identified through a systematic literature review using Cochrane Renal Group standard search strings (Willis *et al.*, 2013) to identify publications on renal registries through publicly available resources such as Medline/PubMed, Embase, the Cochrane Library, and the Centre for Reviews and Dissemination databases.

3. METHODS

The system was developed using Web 2.0 development tools which include: HTML (Hypertext Markup Language) used to design the interface and outlook of the website, CSS (Cascading Styling Sheets) for the web layout and styling to the contents of the HTML code, ADOBE Fireworks for designing the interface and ADOBE Flash for developing animations required by the graphical user interface. All these software tools were used for implementing the client-side development of the system using the Dreamweaver IDE (Integrated Development Environment) software. The database was implemented using SQL (structured Query Language) and PHP (Hypertext Pre-processor) for handling data which are filled into forms on the GUI and may be either entered or retrieved to the database for effective management. The system was deployed on a local host using the WAMP (Web-Apache-MySQL-PHP) Server – a local host domain hosting service for testing implemented web-based applications before final deployment.

The map services provided by Google were used to capture information about the distribution of renal disease patients while the coordinates of the hospitals located within wards of State local government areas (LGAs) were captured using the longitude and latitude. Markers were created and used to display the locations at which renal patients' data are available across the nation.

3.1 Data Flow Diagram (DFD) of Renal Registry System

DFD is a way of giving a description of the structural requirements of the system based on data flow. This was the preliminary step taken in order to create an overview of the renal registry system by showing the kind of input, storage and output information required by the system. A DFD cannot give information about the timing of process or information about whether processes will operate in sequence or in parallel within the renal registry system. However, DFDs are generally used as technical descriptors because they are easily understood by technical and non-technical audiences, to provide a high level system overview, complete with boundaries and connections to other systems and to provide a detailed representation of system components.

The Data flow diagram shown in figure 3.1 shows the overall description of the flow of data through the renal registry system based on the actions performed by the system users.

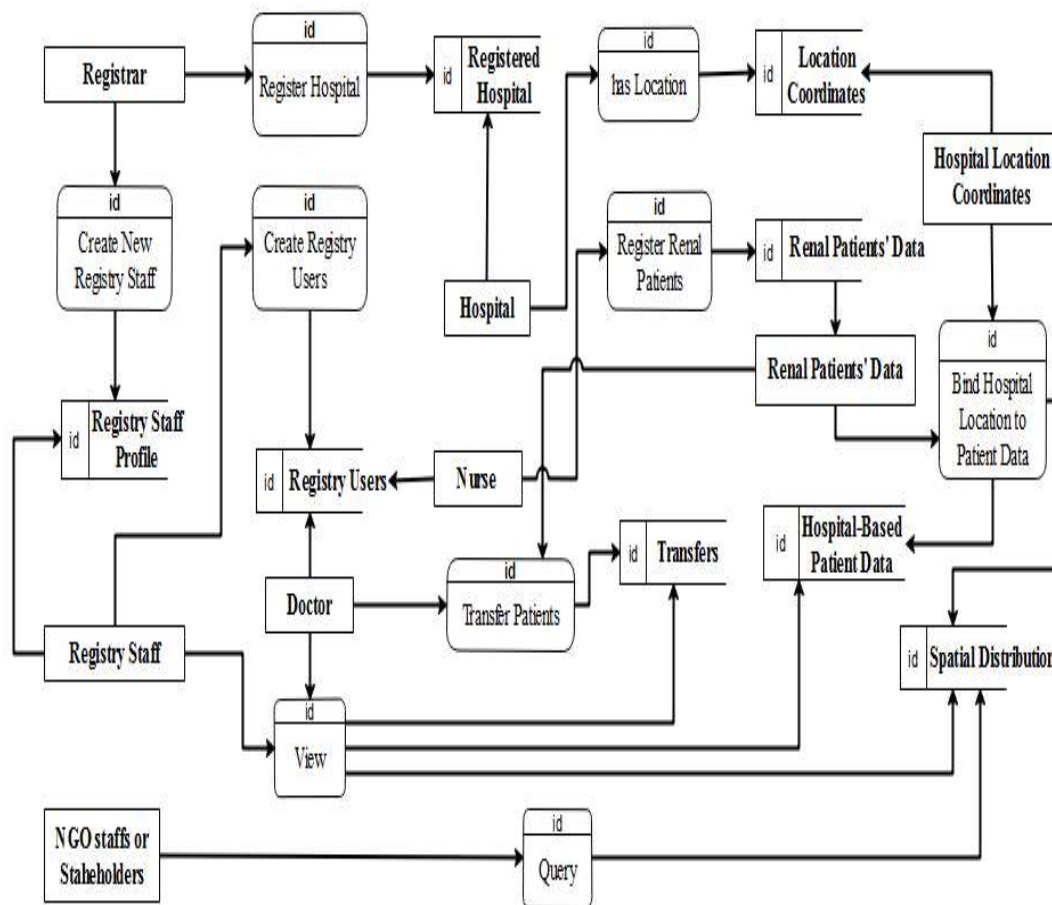


Figure 3.1: Data Flow Diagram of Renal Registry System

3.2 System Architecture for Renal Registry System

The design of the proposed system architecture for renal registry system is presented in Figure 3.2. It was developed in order to create a clearer picture of the structure of the prototype system. The architecture of the renal registry system consists of a set of hardware that are defined in accordance with the requirements and specifications of the proposed system. The architecture gives a description of the relationship that exists between the different hardware that makes up the system's architecture. The architecture is characterized majorly by the system components comprising of the hardware and system users alongside the relationship that exists between them.

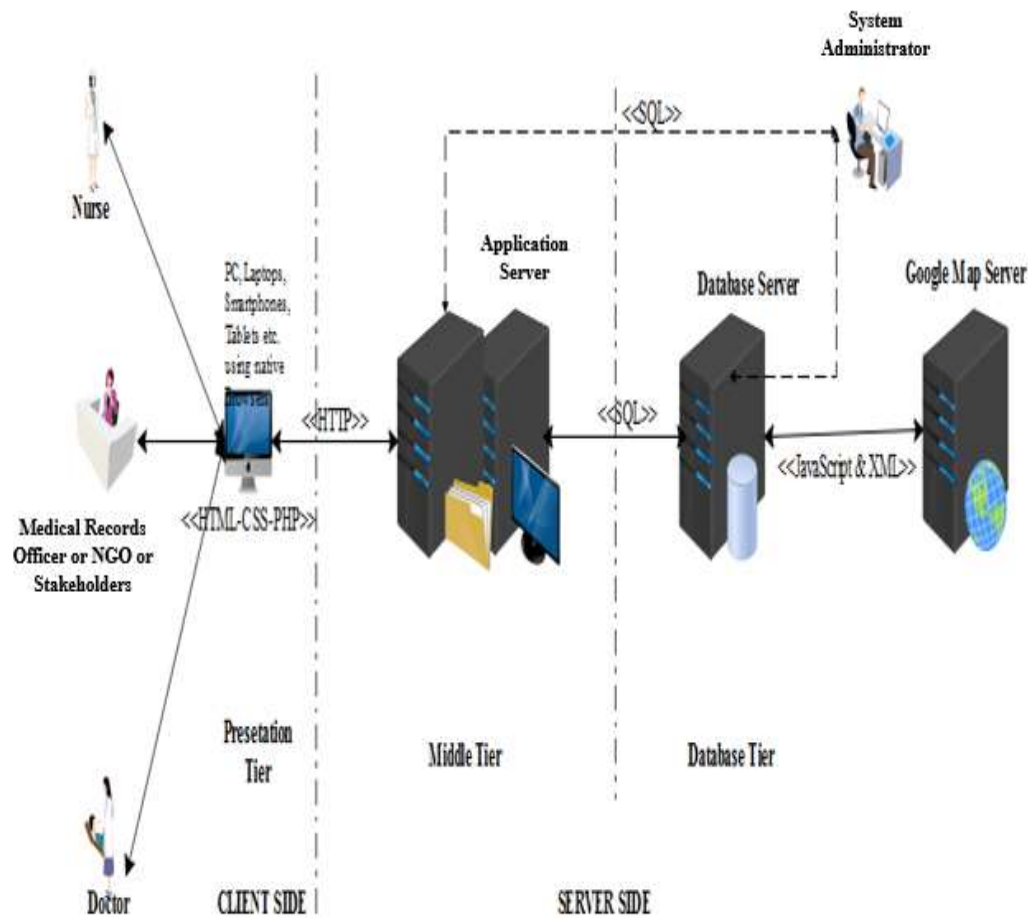


Figure 3.2: System Architecture for Renal Registry

The system architecture is a 3-tier architecture, which is divided into three (3) main parts. They include; the client side, middle tier and the server side. The client side is the part of the system where the users of the system will interact with the application via a Web browser application interface as long as there is active Internet connection. The web application will provide (as usual) a user interface and data can be transferred to and from the Web server using Hypertext Transfer Protocol (HTTP). This will happen via the Uniform Resource Locator (URL), which points activities to the application directory residing in the application server.

The middle-tier is where the application server that manages the renal disease stored within the renal registry system's services resides. It is integrated with the business logic, which describes the different types of activities to be performed by the users of the registry system, such as: registration of system users, registration of new patients and the update of existing patients' data, transfer of patients and the verification of transfers, viewing and querying of renal patients' data and viewing of the spatial distribution of renal patients cases across hospitals using the digital map provided using the Google Map API. The middle tier is also embedded with the server side which will contain the database server, the application server and the Google Map API for managing the provision of the spatial features required by the renal registry system. In this paper, Object Oriented Programming technique was used to model the real world entities that are involved in the system. In order to hide the most of the internal workings of the renal registry system from users, the object oriented concept of encapsulation was leveraged. Based on this, an interface was provided to allow users perform data capture and other processing activities.

4. IMPLEMENTATION OF THE RENAL REGISTRY SYSTEM

This section of the paper presents the implementation of the renal registry for Nigeria. The renal registry information system allows for information relating to renal patients to be stored, accessed, retrieved and monitored. As a result, distribution of renal disease gender, ethnic groups and occupation is evaluated or monitored and preventive measures are taken.

4.1 User Interface

(a) The system user interfaces

The interfaces of the system are those components which allow for interaction between the users (medical record officers, doctors, nurses NGOs and government agencies) and the system without the user knowing the underlying functions, workings, and operations of the system.

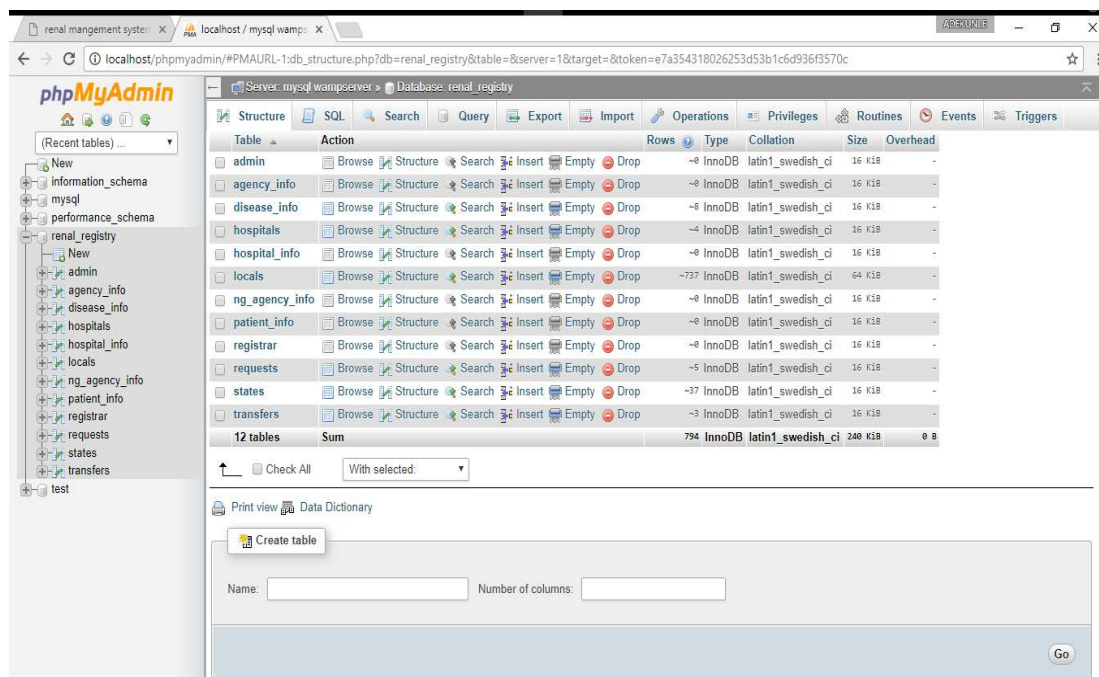


Figure 4.1: Physical Data Model for Renal Registry in Nigeria

The interfaces built include the Home page, Registration page, Login page, Patient Information page, Patient transfer page, Overview page, Admin page, Renal Distribution page and the Registration Requests page. The physical data model for the renal registry is shown in figure 4.1 and the system user interface is shown in figure 4.2.

(b) The home page module

The home page is the first interface that the user views the moment the universal resource locator (URL) of the renal registry is accessed (see figure 4.3). The home page is where the user can be able to access the buttons to navigate to every other part of the registry. For all registered users who want to perform any activity on the system, the user must click on the menu button (login) in order to log in and perform any necessary functions required.

(c) The registration module

Registration module is the module which allows all the users to send registration request to the admin (in this case the Medical Record Officer) by entering their personal details and necessary identifications indicating the type or category of user they belong to. In this module, each user is required to enter their name(s), username, password, e-mail address, agency/hospital name, user type, identification type, identification image and passport. The user then waits for his or her request to be approved by the registrar of the cancer registry. Figure 4.4 depicts the user registration module.

(d) The login module


This module is the module that enables the approved users of the cancer registry to log in to the registry to perform all authorised activities within the jurisdiction of their user type. This module has the username, password and user type boxes. It also has a provision for the users that are yet to be registered to do so. The login module is depicted in figure 4.5.

Figure 4.2: The System User Interface



Figure 4.3: Home Page Module

Hi adele paul kenny | [Logout](#)

 **RENAL**
REGISTRY SYSTEM

[HOME](#) [REGISTER PATIENT](#) [TRANSFER PATIENT](#) [RENAL DISTRIBUTION](#) [LOGOUT](#)

[View Registered Patients](#)

renal patient registration page

Patient personal Information

Surname: <input type="text" value="ADEDOYIN"/>	Ethnic Group: <input type="text" value="Hausa"/>
Other names: <input type="text" value="Adebola"/>	Marital Status: <input type="text" value="Married"/>
Date of birth: <input type="text" value="dd/mm/yyyy"/>	Occupation: <input type="text" value="Farmer"/>
Sex: <input type="text" value="Male"/>	Residential Address: <input type="text" value="Oromiyar Street, Ile-Ife, Osun State"/>
Nationality: <input type="text" value="Nigerian"/>	State of residence: <input type="text" value="osun"/>
State of origin: <input type="text" value="Osun"/>	Town of residence: <input type="text" value="Ile-Ife"/>

Figure 4.4: User Registration Module

(e) The patient information module

This is the module that enables any authorised user type that is Doctor or Nurse to register any one diagnosed with the renal disease. The doctor will key in the surname of the patient in the search box to verify if the patient already exist in the database and if already existing then the doctor needs not re-register the patient. However, if the patient does not exist in the database, the doctor keys in the name, residential address, occupation, ethnic group, state of origin, residential town and state, marital status, sex, date of birth, year of disease diagnose, nationality and renal stage of the patient. The disease information of the patient is also entered. This module can be accessed by the medical personnel only (in this case the doctor user type) as it is the module containing the information of the patients which is confidential and must be treated so (Figure 4.6).

(f) The patient transfer module

This is the module where the information of any renal patient that is transferred from one hospital to another for one reason or the other is being handled. Any patient that is to be transferred must have been registered in the database. See figure 4.7 for the patient transfer module.

(g) The overview module

This module shows all the tabular representation of spread of renal diseases in terms of gender, states (in south-western Nigeria), ethnic groups and renal stages. This statistical information is depicted using a table. The statistical spread of the renal disease is represented. See figure 4.8 for the renal distribution module. The distribution module can be viewed by all approved users of the renal registry.



Login page

Username:

Password:

User type:

Doctor

Not yet registered [Click here](#) to register

Submit

Figure 4.5: User Login Module

Hi adele paul kenny | [Logout](#)

RENAL
REGISTRY SYSTEM

[HOME](#) [REGISTER PATIENT](#) [TRANSFER](#) [RENAL DISTRIBUTION](#) [OVERVIEW](#)

Registered Patient

Hospital	Name	Sex	Dob	State	renal Type	Year Diagnosed	Edit
OAUTHC	Patient1 one	male	2017-02-02	Osun State	normal	2017	Edit
OAUTHC	Patient2	male	2017-02-09	Lagos State	normal	2017	Edit
OAUTHC	Patient 3 Patient 3	male	2017-02-09	Lagos State	normal	2017	Edit
OAUTHC	Patient4	male	1999-01-11	Ogun State	Acute Kidney Disease	2017	Edit
OAUTHC	Patient 5	male	1988-06-15	Adamawa State	Normal	2015	Edit
OAUTHC	Patient 6	male	1973-02-23	Ondo State	Hypertension & Diabetes	2016	Edit

Figure 4.6: User Registered Patient Module

RENAL
REGISTRY SYSTEM

[HOME](#) [REGISTER PATIENT](#) [TRANSFER PATIENT](#) [RENAL DISTRIBUTION](#) [LOGOUT](#)

Transfer Patient

patient name

Search Result

adeleke oluleye [Transfer Now](#)

Transfer Information

Patient Name:

Reason for transfer:

Transfer From:

Transfer To:

Click here to proceed transfer

7/10/2017

27

Figure 4.7: Renal Transfer Patient Module

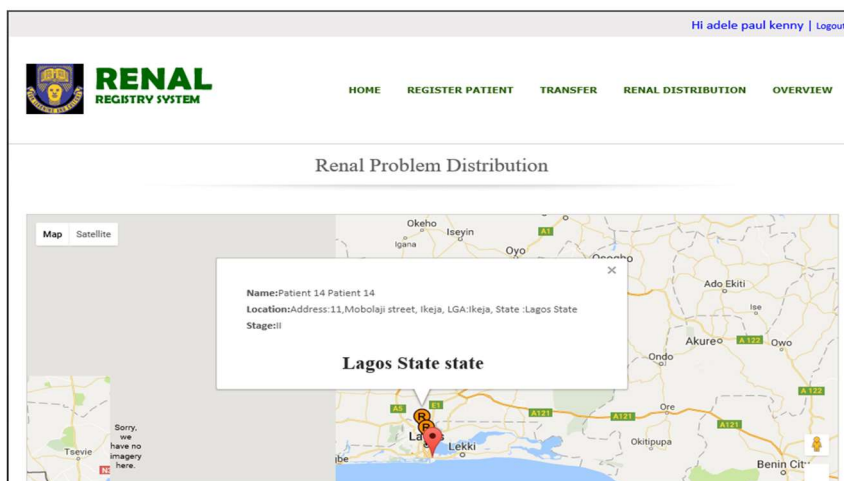


Figure 4.8: Renal Problem Distribution Module

(h) The admin module

This is the module that has to do with the granting of permission and registering of hospitals or laboratories in the nation. It is managed by the administrator (renal registrar) and used by the renal registry personnel e.g. Doctors, Nurses, Medical Record Officer. Here the renal admin in this case the registrar of the registry creates other renal registry personnel as users and these users are able to perform activities in the registry depending on their permission level. There are two levels of permission- the creating users and hospital registering permission level.

(i) The renal distribution map module

The renal distribution module is simply the geographical display of the spread of renal disease in a map of the area of study. The map as shown in figures 4.9 and figure 4.10 displays the various towns in south-western states of Nigeria that have any record of persons living with renal diseases and the stages of renal disease patients registered in the database of the renal registry. The renal distribution module can only be functional or available as long as there is internet connection on the device being used to access the renal registry. All authorised users of the renal registry can access this module.

(j) Registration requests module

This module can be accessed only by the registrar or any other authorised personnel of the renal registry; this module enables the approval of the request sent in by anyone registering to become a user of the system. The registration requests module consist the user ID, names of the users, the username, the user type, the hospital or organization name, the date of registration, the registration status of the user, action performed by the registrar as shown in figure 4.11.

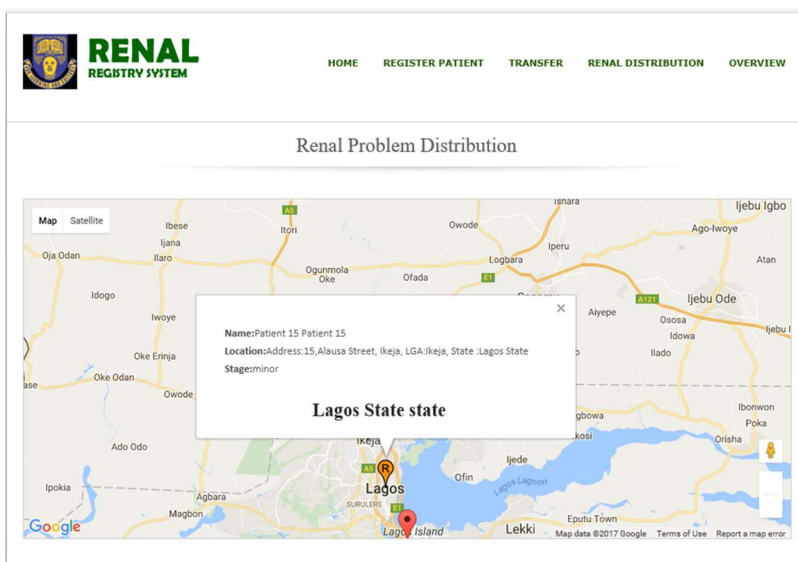


Figure 4.9: Renal Problem Distribution Module

<div> <div>RENAL REGISTRY SYSTEM</div> <div>HOME RENAL DISTRIBUTION OVERVIEW REQUESTS HOSPITALS</div> </div>									
Registration Requests									
ID	Surname	Othernames	Username	User Type	Hosp/Org Name	Date	Status	Action	
1	adele	paul kenny	adele	doctor	OAUTHC	01/29/2015	approved	No more action can be performed	
2	alaba	jone jane	alaba	doctor	OAUTHC		rejected	No more action can be performed	
3	adedini	paul	leke	doctor	OAUTHC		pending	Approve	Reject
4	asimiyu	titi mary	mary	doctor	OAUTHC		pending	Approve	Reject
5	adedini	jone jane	jone	doctor	OAUTHC		pending	Approve	Reject

Figure 4.10: Registration Request Module

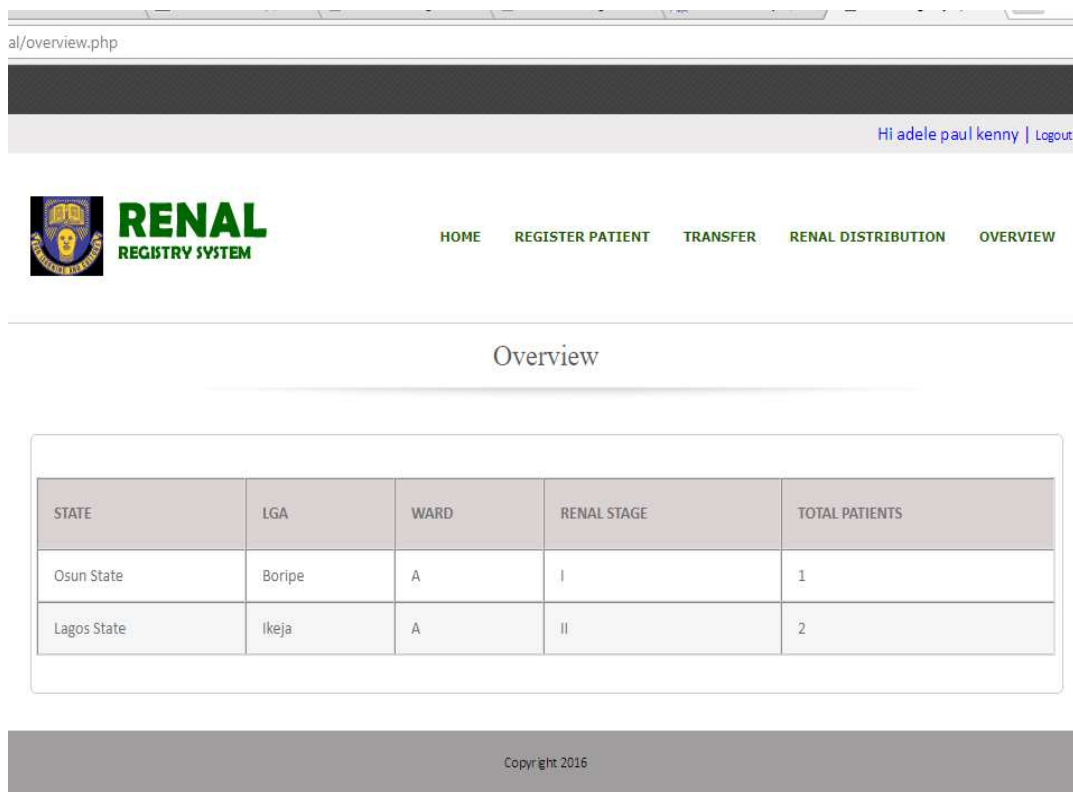


Figure 4.11: Overview at Ward Level

4.2 Discussion

The renal registry information system which was developed would gather information comprehensively about renal patients which will help monitor and control the widespread of the disease and provide a database for monitoring and controlling of renal diseases generally in Nigeria. This will also help in determining the distribution rate of renal disease in Nigeria and the prevalence rate of renal diseases in this region of the country. The proposed system allows for the users to register information, view renal distribution map in different towns of south-western Nigeria based on their user type.

The results of the implementation showed that the tables and maps support easy-to-understand and easy-to-interpret information viewing. Users can view renal distribution details of any location on the map within the area of study with ease. The results of the response of the testers selected among the intended users showed that at least 76% of the testers strongly agree that the system implementation of the data model for renal registry met both operational factors and the UI/UX factors used to evaluate the user acceptance test (UAT) required for system evaluation.

This will help policy makers in making decisions regarding building renal related health facilities and distribution of renal equipment to the concerned patients. The model in future may give rise to a comprehensive and robust renal registry for Nigeria as a whole. Also, nephrologists, policy makers, and any other authorised users would be able to query, analyse, view and generate renal distribution information based on renal patient disease stages, town/city and state level and this will enhance proper and wide renal disease prevention awareness campaign.

This system will hopefully aid effective and efficient intervention in the rate at which renal disease is claiming lives of Nigerian citizens. This will improve the standard of health care system especially those related to renal diseases generally. This system will also serve as way of having uninterrupted access to genuine information on renal disease distribution (either hard copy or on the internet) in the nation since there is no automated system currently.

5. CONCLUSION

The system would be able to capture renal patient's information such as the name, gender, occupation, marital status, ethnicity, renal stage(s), renal level, nationality, residential address, ward and state of origin. The system can display the renal distribution of the various types of renal diseases in various locations on the map in terms of residential address of the patients, wards and the local government area. It is also capable to display the renal statistic in terms of gender, state, ethnicity and renal disease types. The system will go a very long way in helping government and non-governmental agencies (NGOs) in providing necessary, proper and adequate renal health care facilities in the nation that will help improve the life of people living with renal diseases. It will also enhance the channelling of campaigns on how to combat renal diseases to the right areas in the nation.

The renal registry system is a spatially enabled web-based system that allows users to access their information needs via the internet with the aid of an internet service provider. This means that the system can be accessed from client computers via the use of a native web browser (such as Mozilla Firefox, Internet Explorer, Torch and Chrome). Thus, the service can be made available via a web server which serves every client computer's request via the internet to the web browser on each individual client computer.

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