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SIGNe: A Geographic Information System on the Web for End-Stage Renal Disease

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Abstract

A Web-based Geographic Information System (Web-GIS), the SIGNe (Système d'Information Géographique pour la Néphrologie), was designed for the Renal Epidemiology and Information Network (REIN) dedicated to End-Stage Renal Disease (ESRD). This Web-GIS was coupled to a data warehouse and embedded in an n-tier architecture designed as the Multi-Source Information System (MSIS). It allows to access views of ESRD concerning the epidemiology of the demand and the supply of care. It also provides maps matching the offer of care to the demand. It is presented with insights on the design and underlying technologies. It is dedicated to professionals and to public health care decision-makers in the domain of ESRD.

Keywords
Web-GIS; Multi-Source Information System; Data warehouse; End-Stage Renal Disease; Decision-making

1. Introduction

The qualitative and quantitative epidemiological changes of the last decade have shown that the incidence and the prevalence of End-Stage Renal Disease (ESRD) have increased. However, no coordinated information was available [1]. In order to increase medical, epidemiological and organisational knowledge of ESRD at a national level, a Multi-Source Information System (MSIS) has been set up as part of the Renal Epidemiology and Information Network (REIN) [2]. This program involves several organizations : Paris 5 University and Grenoble J. Fourier University, Société de Néphrologie, Société francophone de dialyse, Etablissement français des Greffes (EfG), INSERM, Institut de Veille Sanitaire, Caisse Nationale d'Asssurance Maladie, Direction de l'Hospitalisation et de l'Organisation des Soins, and representatives of patients' associations. Integrated to the MSIS application, SIGNe is a tool dedicated to dynamically visualize and analyse the ESRD data sets. Based upon new technologies such as Geographic Information Systems (GIS), Web-GIS, On-Line Analytical Processing (OLAP), SIGNe program aimed at analysing ESRD epidemiology, assessing resource allocation and improving public health decision-making.

2. Material and Methods

Data collection

The Multi-Source Information System (MSIS-REIN) is dedicated to collect all ESRD minimal patient records with their annual follow-up, the content of which were defined by a national consensus.The main variables of these records concern both epidemiological informations and description of the supply of care: age at first initiation of replacement therapy, type of initial nephropathy, type of dialysis, comorbidities, handicaps, remoteness from dialysis unit, characteristics of the units of care and territorial distribution of the nephrologists. The MSIS initially tested in two adminitrative regions in 2002, is currently running in six regions : Limousin, Languedoc-Roussillon, Champagne-Ardenne, Provence Alpes Côte d'Azur, Ile de France, Centre. The control of exhaustiveness and quality of the data is performed regionally by clinical research assistants. At present the data set gathers more than 9000 records.

MSIS architecture

The architecture of MSIS-REIN is based on an n-tier architecture (figure 1). A universal client (1st tier) connects to a dynamic Web server (2nd tier) that is in relation with several databases (3rd tier). The information system tier may access three types of databases: the identification database, the production database and a data warehouse. Collected data supply the production database. After exhaustiveness and quality control is performed, consolidated data are integrated to the data warehouse. A secure connection and the use of an identification server warrant confidentiality and security of patient informations according to the French law.

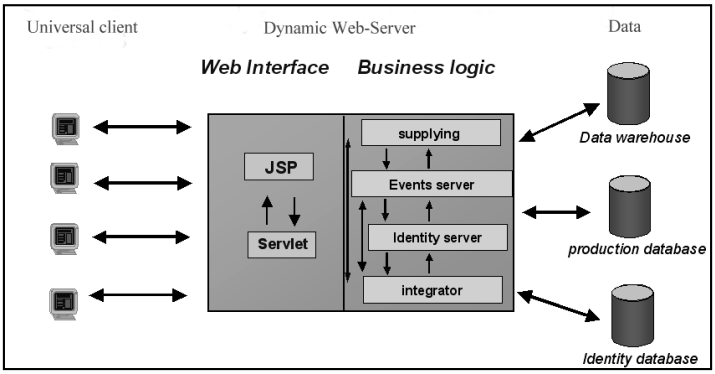

Figure 1 – MSIS-REIN n-tier architecture

Data Warehouse

A data warehouse [3] can be defined as a collection of data, which are subject-oriented, integrated, time variant, non-volatile and historicized. It allows reorganizing data imported from the production database in order to support analytical and decision processes. Data warehouse is often linked to data mining and On-Line Analytical Processing (OLAP) used in a decisional information system. This organization of ESRD data sets is helpful to create persistent views concerning different axes : temporal, age of patient, incidence, prevalence or other indexes.

SIGNe objectives and integration

Objectives

It is very useful and customary to divide the geography of health into two interrelated areas:

- the geography of disease, which covers the exploration, description and modelling of the spatio-temporal incidence and prevalence of disease, the detection and analysis of disease clusters and patterns;
- the geography of healthcare systems, which deals with the planning, management and delivery of suitable health services, after determining healthcare needs of the target community and service catchments zones.

The importance of Geographic Information System (GIS) for medical research and epidemiology has long been recognized [4,5,6,7]. Health geography plays an important role in public health surveillance, and can also help identifying interregional inequities in health service delivery, and in the efficiency of allocating and monitoring healthcare ressources. Thus geographical visualizations may be helpful for both studying spatial epidemiology and helping to assess the best distribution of healthcare units based on current needs.

SIGNe aims at answering distinct important questions: what is the temporal evolution of ESRD epidemiology? What is the spatial distribution of ESRD incidence and prevalence? What are the main chararcteristics of the ESRD population? What are the characteristics of the dialysis units? Are there any inequities in health care needs or accessibility to care?

In order to achieve these objectives, we developed a web-based interface aimed at ESRD professionals and decision-makers at a regional and national level. This interface includes tools that allow creating dynamically both maps and charts representing current data sets regarding epidemiological and care management aspects.

Web-GIS and OLAP

A GIS is a system composed of hardware and software used for storage, retrieval, mapping and analysis of spatially referenced (georeferenced) information. A GIS makes possible overlaying and integrating multi-source data. It helps discovering and visualizing new data patterns and relationships that otherwise would have remained invisible, by creating the link between spatial data and their related descriptive information. A Web-based GIS (Web-GIS) allow to reproduce on a Web-interface main functions of GIS: spatial analysis, navigation (zoom, pan), dynamic creation of map, layer overlaying, interactive querying. A Web-GIS is a new mean to dynamically share and represent spatial information, with a large access. A lot of Web-GIS have recently emerged (MapServer, ArcIMS, MapXtrem, Alov Map, GeoServer), using different displaying technologies : vector (SWF, SVG...), raster (PNG, JPEG...), server side or client side mapping. Regarding the interactivity, the database connection abilities and the costs of development, we chose to develop our interface with Flash MX™, Php™ and MySQL™.

Besides, we used tools to create dynamic charts in connection to the data warehouse. Different open-source programs allow to realize this on-line analytical processing (OLAP): JPGraph, PhP/SWF Chart, or owtchart. We used Php/SWF Chart, that create main chart types in a vector format (SWF) compatible with our Web-GIS system.

Integration to the MSIS

SIGNe interface was integrated as a new tool to the MSIS and to the data warehouse. The global architecture of the application is presented on figure 2. The MSIS supplies the data warehouse with consolidated data. Once the connection to the SIGNe established, the user send requests to the data warehouse that extracts current data.

SIGNe is being tested with three region data sets: Limousin, Languedoc-Roussillon and Champagne-Ardenne. Patients and dialysis units are georeferenced using their place of residence or their location, respectively.

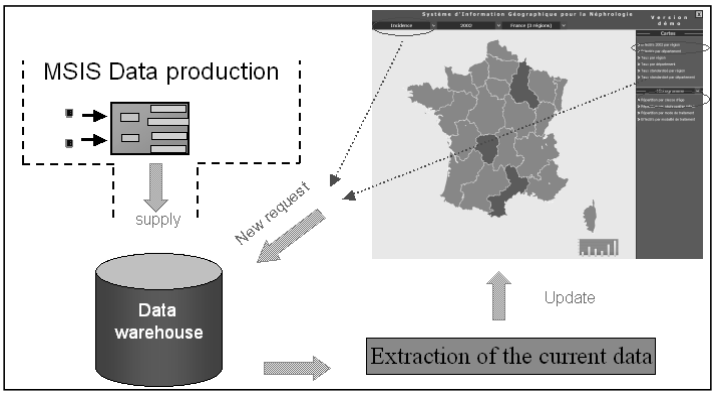

Figure 2 – SIGNe integration to MSIS

User interface

SIGNe offers representing on a single interface cartographical and statistical representations. The screen structure and the different functionalities are presented on figure 3. The user defines the theme (incidence, prevalence, survival....), the year and the region of interest (one region data set or the whole data set). A list of maps and charts is then updated, and eventually displayed on the representation area.

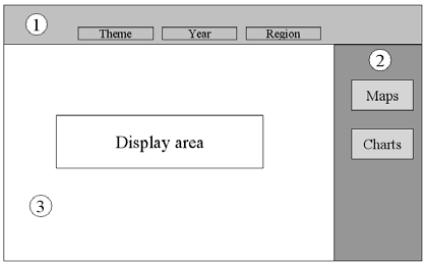

Figure 3 – Screen layout structure

3. Results

Epidemiological results

Examples of epidemiological results are presented on figure 4. The thematic map is a data visualization where the attributes of geographic features (here the incidence rates by region) are displayed on a map. It allows assessing the geographical distribution of new ESRD cases considering several French departments. Other thematic maps can be obtained for different themes (prevalence, mortality...), and also at a smaller scale. For instance, the user is able to map the disease distribution by district or even smaller administrative boundaries.

The bar chart aimed at defining more precisely the ESRD population. It represents the distribution of incidence cases by age group. Other similar representations can be created regarding the type of treatment, the co-morbidities or the handicaps

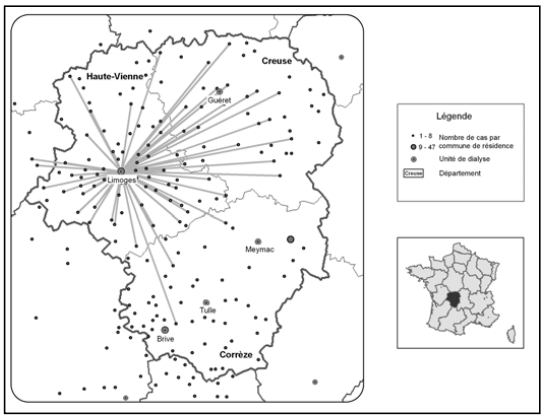

Figure 4 – Epidemiological representations.

Health care attractiveness

Figure 5 shows an example of both supply and demand of care representation. Patient's affiliations according to their district of residence (points) are linked to the location of their dialysis unit. It shows that Limoges hospital attracts patients beyond the limits of the Haute-Vienne department despite the presence of other dialysis units in the adjoining departments.

Such a map of several different types of data, provides medical professionals and administrators with information about the matching between the supply and demand of care for dialysis.

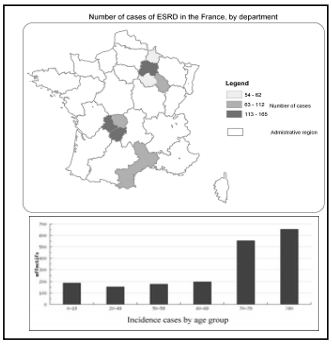

Figure 5 – Attractiveness of the Limoges Hospital dialysis unit.

4. Discussion

This study shows how Web-GIS and statistical tools can be useful to better respond to information needs concerning the demand and supply of care of ESRD. SIGNe offers an intuitive way of accessing and mining large health care informations. Besides the need of epidemiological knowledge regarding the demand of care, SIGNe helps describing the relationships between the location of care and the place of residence of ESRD patients. It may assist in better health care planning, aiming at more efficient and effective utilization of resources. The use of web-based interfaces including interactive mapping is growing in health geography. Such interfaces are usually developed in order to help public health surveillance and a better knowledge of disease geographical distribution, such as the application of the world health organization [8]. In the field of renal disease, the United

States Renal Data System has also developed an interactive atlas to share information about ESRD, the Renal Data Extraction and Referencing (RenDER) [9]. It is an online data querying application accessible through the USRDS website. Based upon user's query specification, it returns a table of data or an interactive map. SIGNe proposes a user-friendlier tool, including not only the demand of care but also the offer of care, at the interface of epidemiology and public health. The cost effectiveness of SIGNe has not been evaluated yet in this implementation and loading phase. It will be initiated considering macroscopic markers followed longitudinally: for instance, shortening patients' travel-time to their dialysis unit, or improvement of clinical performance measures (e.g. erythropoietin level according to European standards).

5. Conclusion

SIGNe is a GIS embedded in the Multi-Source Information System of the French Renal Information and Epidemiological Network. It was dedicated to representing the demand and the supply of care and their match at a regional level. Complementary tools are presently in preparation aiming at describing more precisely accessibility to health care units. For instance, works on model to determine the minimum travel time and distance to health care units are currently developed [10]. We'll adapt this approach and develop scenarios for renewed resource allocations. In effect, geographical access models have enormous potential for fruitful debate on how to achieve social equity of care access. These scenarios will be a useful information resource that can be used in health service delivery planning and assessment.

6. Acknowledgments

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7. Reference

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