VOL. 12, NO. 22, NOVEMBER 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

INFORMATION SYSTEM FOR REGISTRATION AND CONSULTATION OF THYROID PROFILE TESTS IN THE HOSPITALS OF THE DEPARTMENT OF HUILA

Albeiro Cortés Cabezas and Yamil Armando Cerquera Rojas
Department of Electronic Engineering, Surcolombiana University Grupo de Tratamiento de Señales y Telecomunicaciones - GTST
Street 1, Pastrana Av. Neiva Colombia
E-Mail: albecor@usco.edu.co

ABSTRACT
In this project an information system was implemented to optimize the process of conducting the thyroid profile tests in Huila hospitals in order to improve the organization of the results, making access to the results much more comfortable and efficient. The HL7 standard set was used as a guide for good interoperability and to make the system scalable. Access can be made through any web browser or any device due to a responsive web design was used. The information system allows access to the data of a specific patient and it is possible to export information from the database to obtain different statistics.

Keywords: information system, thyroid profile, web services, HL7-FHIR.

1. INTRODUCTION

The Thyroid Profile is a group of laboratory tests that are used to evaluate the functioning of the thyroid gland, which is responsible for regulating innumerable functions of great importance in the body. Therefore, a small change in their performance leads to alterations in the results of these tests and distortions in the health status of the individual [1].

The Thyroid Profile consists of determining the blood levels of the following tests or laboratory tests [2]:

- TSH (Thyroid Stimulating Hormone) or Thyrotropin.
- T4 or T4 Total (Thyroxine).
- T3 or T3 Total (Triiodothyronine).
- T4L Free thyroxine.
- T3L Triiodothyronine Free.
- ATPO (Anti-Thyroid Antibody Peroxidase).
- ATG (Anti-Thyroglobulin Antibodies).
- Thyroglobulin,
- Others (TRH, Anti-TSH Receptor Antibody, Calcitonin and TU).

TSH (thyroid stimulating hormone) or thyrotropin:

It is the hormone of hypophyseal origin (coming from the pituitary gland) responsible for the stimulation of the thyroid gland to increase the production of thyroid hormones (hormones T3 and T4) [3]. TSH values (normal values) increase in blood when thyroid hormones are low and decrease when there is no need for increased production of T3 and T4 because they are in high values.
TSH secretion is regulated by a hypothalamic hormone called TRH (thyrotropin-releasing hormone), so the hypothalamus, by means of HRT, regulates the secretion of TSH in the pituitary and TSH regulates the production of T3 and T4 in The thyroid. In this way the regulatory system for the secretion of thyroid hormones is carried out.

In hypothyroidism are thyroid hormones T3 and T4 with decreased blood levels and high levels of TSH that seek to stimulate the thyroid to increase its production.

Hyperthyroidism shows lab results that reflect elevated T3 and T4 values and low, almost negligible TSH that try not to stimulate the thyroid gland to not further increases the production of thyroid hormones.

T4 or total T4 (Thyroxine):

It is a hormone of thyroid origin that represents 90% of the production of the gland, versus the T3 that only represents 10%. T4 is the inactive form of thyroid hormones. Therefore, it is considered a pre-hormone, since it needs to be transformed into T3 to be useful and able to enter the interior of the cells and perform their functions.

T4 is the thyroid hormone available in blood in case of a decrease or consumption of T3, can quickly convert this T4 into T3 and be used by various organs to meet their goals. It is found in two states:

- T4 bound to a carrier protein.
- T4 free carrier protein (T4L).

Then, the laboratory result of T4 is the sum of both states. This is why it is also called T4 Total.

T3 or T3 TOTAL (Triiodothyronine):

It is one of the two hormones produced by the thyroid. This is the thyroid hormone that has a function in the body. It is found in two states:

- T3 bound to a carrier protein.
- T3-free carrier protein (T3L).

Therefore, the measurement of T3 is the sum of the set of both states. Both that is bound to transport proteins, such as the one traveling in its free form (T3L) or non-bound to carrier proteins. This is why it is also known as T3 Total. The T3 that travels together to a carrier protein and to perform its functions requires release and

thus to be able to enter the interior of the cells (becoming T3 Free).

T4L (Free thyroxine):

This value represents the whole amount of thyroxine hormone that is circulating freely in the blood. That is, without being bound to carrier proteins. This is the fraction of thyroid hormone that is available to be transformed into T3 in the organs. Therefore, it is the active form of Thyroxine. T4L helps to assess thyroid function and allows, together with TSH, to provide a medical diagnosis.

T3L (Triiodothyronine free):

It is the least abundant form of thyroid hormones. However, it is the structure that actually performs function in the organism, since this is the fraction of T3 that circulates freely through the bloodstream without being attached to proteins. The correct functioning of all organs and tissues depends on this hormone in its free form.

Its main role is to induce the increase of metabolism, favoring the burning of fat to obtain vital energy to perform all the functions of the organism. Therefore, it helps to lower cholesterol levels, accelerates protein synthesis, increases cell reproduction, regulates temperature and promotes the growth of bone, muscle and brain tissues.

ATPO (anti thyroid peroxidase antibodies):

They are antibodies (proteins) that make the organism under abnormal conditions, these attack the own cells and thyroid tissues. Their determination in blood is useful for the diagnosis of autoimmune thyroiditis; they are also positive in 95% of cases of a type of hypothyroidism called Hashimoto's thyroiditis and in 85% of cases diagnosed with severe disease, one of the causes of hyperthyroidism.

ATG (antithyroglobulin antibodies):

These antibodies are proteins which under abnormal conditions the body creates against its own thyroid. These antibodies are found in cases of hyperthyroidism and in some cases of thyroiditis.

TG (thyroglobulin):

It is a protein generated in the thyroid that acts as a structure for thyroid hormones T3 and T4. On the thyroglobulin the molecules that make up these hormones adhere. When the thyroid is inflamed and enlarged it is able to produce more thyroglobulin than usual, which is evidenced in blood tests.

This article presents the design and implementation of an information system for the registration, organization and analysis of the results of thyroid profile tests in Huila hospitals. The main objective of the work is to create a healthcare information system - HIS, which allows register the laboratories' staff, physicians and patients and allows also register, consult and authorize the exams of thyroid profile. The data can be entered through the Hospital's local area network, as well as from any remote computer or device (Smart phone or Tablet) connected to the Internet. The designed HIS follows the guidelines of the HL7-FHIR standard, the most widely worldwide distributed, ensuring easy interoperability with almost any other hospital information system. According to the World Health Organization - WHO, if better information is available, better decisions will be made and the population will be able to have better health; this is what justifies the need for more robust HISs for hospitals in Huila. As information systems evolved, information systems were available that could present reports related to the health of each patient, statistics on the data obtained in the examinations performed, as well as medicines and treatments formulated by physicians. Examples of these systems are the Care2x (Open Source Hospital Information System), first published in 2002 by Elpidio Latorilla and the Mexican Government's Information System for Hospital Management (SIGHO), which began only in 2005 [6-7]. In the Department of Huila this technology is just beginning to be implemented; therefore, this work can be considered as an initial contribution in the area.

2. METODOLOGY

General design of the information system

For the development of the Information System its propose the system described in Figure 1, in which MySQL is used to store the data, a web server to control the platform and the web clients requesting a connection. Web clients can request the server to send pages from any device with internet connection; these devices can be desktop computers, laptops, tablets or smart phones.

In the stages of the project development process, the database was first designed taking into account the variables and records necessary for the correct functioning of the system. Then the control and the service of the web pages were defined through the server along with its visual design. The system follows the HL7-FHIR standard for sending medical information, so tools like MirthConnet can access the information using their standard-based connection protocols [8].

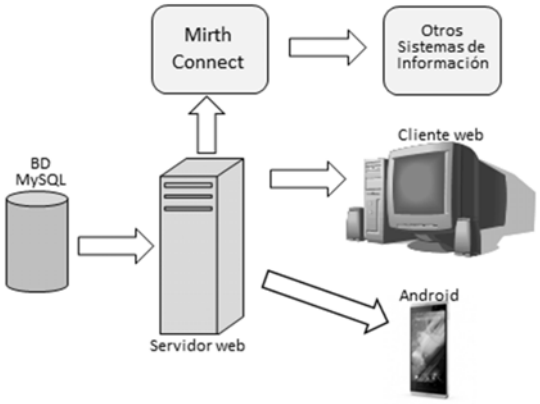

Figure-1. Information system architecture.

VOL. 12, NO. 22, NOVEMBER 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

HL7-FHIR standard

HL7-FHIR (Health Level 7 - Fast Healthcare Interoperability Resources) is a standard that describes "resources", data formats, and electronic health records exchange (EHR) elements. The standard was created by the international health standards organization HL7. One of HL7-FHIR's objectives is to facilitate interoperability between different health care systems, so that be easy to provide healthcare information to healthcare providers and individuals through a wide variety of devices, from computers to tablets and cell phones; enabling third-party application developers to develop medical applications that can be easily integrated with existing information systems. HL7-FHIR is relatively easy to deploy, because it uses a modern web-based technology suite, including RESTful, HTML and Cascading Style Sheets (CSS) for UI integration. For data representation JSON or XML can be used and for authorization OAuth can be used [5].

In this paper, JSON was chosen for data representation, which means interoperability with other information systems using the same technology for exchanging EHRs will be simple and guaranteed. However, interoperability with information systems that use a different technology to represent data, such as XML or others can be achieved through a management tool for integration of multiple health information systems, such as MirthConnect [8]. It should be noted that this paper is part of a more ambitious project for the Department of Huila, which seeks to systematize the entire health system, so that interoperability between different health information systems must be guaranteed.

Database server

MySQL is the most popular open source database in the world, making it a reliable and secure option [9]. In addition, it has features such as high scalability, easy operation, high performance among others, making it the ideal choice for the information system needs.

In the project some tables were defined to store information about the users, the status of each session and the information corresponding to the defined thyroid profile tests. In Figure-2 the described database diagram can be visualized. For the tables of patients, staff and exams, the fields are constructed using the JSON format as defined in the HL7 standard. The following is a description of each table:

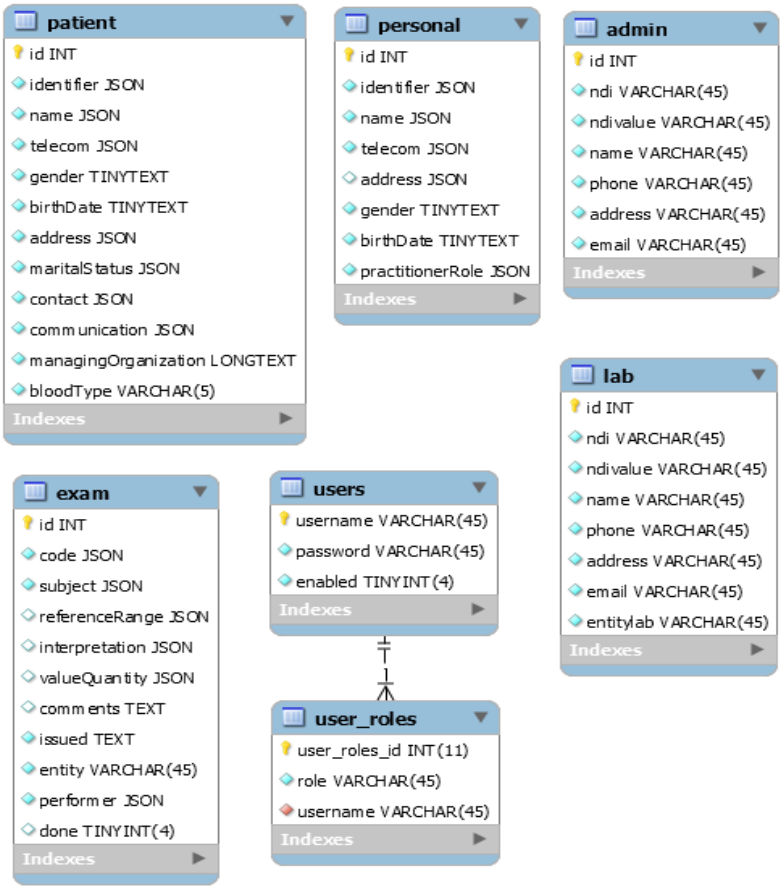

Figure-2. Database tables.

patient: this table stores all the information corresponding to the patients of the platform. For each user the following fields are defined:

- **id:** integer type field that identifies the record.
- **identifier:** JSON field, which stores, according to the HL7 standard, the patient identifier.
- **name:** JSON field, which stores, according to the HL7 standard, the name of the patient.
- **telecom:** JSON field that stores contact information.
- **gender**: String field that stores the gender.
- **birth date:** String field that stores the date of birth.
- **address:** JSON field storing address.
- **marital Status:** JSON field that stores the marital status.
- **contact:** JSON field that stores contact information.
- **communication:** JSON field that defines the language of interpretation of information.
- **Managing Organization:** String field that stores health entity information.
- **blood type:** String field that stores the blood type.

personnel: this table stores all the information corresponding to the medical personnel of the platform. For each member the following fields are defined:

- **Id**: Integer field that identifies the record.
- **Identifier**: JSON field wich stores, according to the HL7 standard, the patient identifier.
- **Name:** JSON field which stores, according to the HL7 standard, the name of the patient.
- **Telecom**: JSON field that stores contact information.
- **Address:** Field JSON storing address.
- **Gender:** String field that stores the gender.
- **Birth date:** String field that stores the date of birth.
- **Practitioner Role:** JSON field which stores, according to the HL7 standard, the charge of medical personnel.

admin: this table stores all information about the platform administrator. For this table the following columns are defined:

- **id:** Integer field, which identifies the record.
- **ndi:** String field, which stores the administrator identifier type.
- **ndivalue**: String field, which stores the identifier of the administrator.
- **name:** String field, which stores the name.
- **phone:** String field, which stores the phone. **address**: String field, which stores the address.
- **email:** String field, which stores mail.

lab: this table stores all information about the laboratory performing the thyroid profile examination. For this table the following columns are defined:

- **id**: Integer field that identifies the record.
- **ndi**: String field that stores the identifier type.
- **ndivalue**: String field that stores the identifier.
- **name**: String field that stores the name.
- **phone**: String field that stores the phone.
- **address**: String field that stores the address.
- **email:** String field that stores mail.
- **entitylab:** String field that stores additional information about the entity.

exam: this table stores the information corresponding to the medical exams of the thyroid profile. For this table the following columns are defined:

- **id:** Integer field that identifies the record.
- **code:** JSON field that stores the type of examination of the thyroid profile.
- **subject:** JSON field that stores patient information according to the HL7 standard.
- **Reference Range:** JSON field that stores the reference range of the variable to be measured according to the HL7 standard.
- **interpretation**: JSON field that stores according to the HL7 standard the interpretation of the results of the variables to be measured.
- **value Quantity**: JSON field that stores according to the HL7 standard the actual value of the variable to be measured.
- **comments**: String field that stores comments about the exam.
- **issued:** String field that stores the date and time of the exam.
- **entity:** String field that stores the entity providing health services.
- **performer:** JSON field that stores according to the HL7 standard the user of the medical personnel requesting the examination.
- **done:** Boolean field that stores 1 if the test was performed.

users: this table stores user session information. For this table the following columns are defined:

- **username:** field type String that identifies the user for login.
- **password:** String type field that stores the password for the login.
- **enabled:** Boolean field that is 1 if the user is enabled.

user_roles: this table stores the user roles. For this table the following columns are defined:

- **user_roles_id:** role identifier.
- **roles:** String field that stores the role of the user.
- **username (FK):** String field that identifies the user for the login that corresponds to the document number.

Web platform

The web platform allows users to perform operations to manage the information recorded in the system. There are four types of users, which are defined below:

- **Administrator:** Registered through the website. It is responsible for registering, modifying or eliminating the other users of the platform.
- **Staff:** This type of user can view your basic information and modify your data, also have access to

the patient's data, as well as authorize the thyroid profile tests and consult the test history.

- **Patient:** This user is able to view your personal information and modify your information. Through the platform can this user consult the history of exams that were carried out.
- **Lab_operator:** This user is able to view your personal information, modify your information and those of the service provider. The platform allows you to record test results when authorized.

Figure 3 shows the start page, in which the user manual it can be consulted and log on to the system.

Figure-3. Web platform home.

Pressing the login button (*Iniciarsesión*) will display a form as in Figure-4, where the user id and password registered in the platform can be entered. To recover the password press the link recover password (*recuperarcontraseña*).

Figure-4. Web platform login.

To authorize a test, the physician must select one of 6 options for the thyroid profile and add the authorization. The physician may remove the test after being authorized until it has been done. Figure-5 shows the screen which allows selecting the type o test.

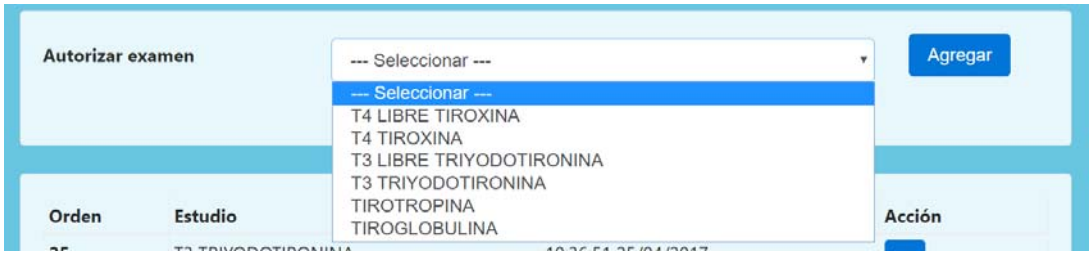

Figure-5. Type of thyroid profile test.

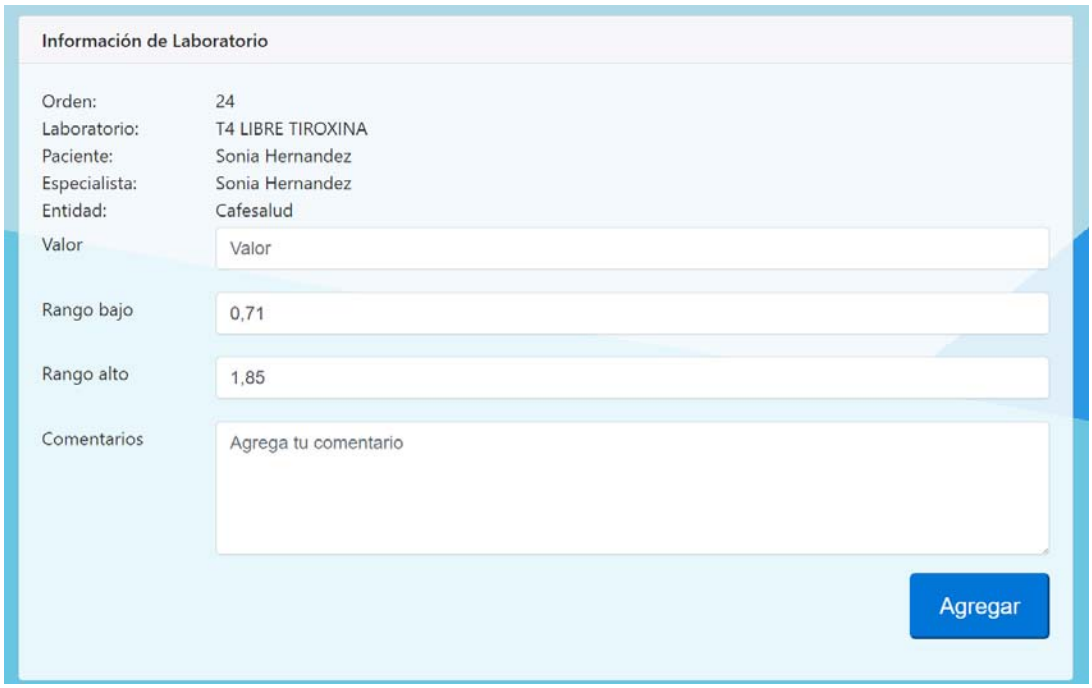

Figure-6. Thyroid profile test form.

After a test is authorized, the lab operator can access the order information and perform the test. A form like the one in Figure-6 must be filled in to take the exam.

Developments technologies

Tools with free software license were used for the development of the web project.

- *Project developed using*:
  Spring Framework
  Spring Tool Suite - version 3.8.4
  Build Id: 201703310825
  Java: 1.8.0_121

- *Data base*:
  MySQL Workbench 6.3.8 build 1228 CE (64-bit) Community
  Database port for MySQL: 3306

- *Application server*:
  Apache Tomcat 8.5.14

Programming languages

HTML, CSS and JS: For view handling and script functions on the client side. HTML5 organizes parameters for HTML page structure tagging, CSS3 builds the page appearance for an interesting visual style and JS allows the construction of page functions on the client to avoid loading on the server.

Java spring: Spring is an enterprise open source framework for application development for the Java platform. With this, it is done the control of pages and development of the services of the application.

In addition, the following tools were used:

a) Bootstrap v4.0.0-alpha.6: This framework facilitates the web design adapatable to different devices through a responsive design.

b) Font-awesome: This library contains a compiled icon to give a better visual style to the pages.

c) javax.mail version 1.4.7: allows you to send mail messages from the server to the users. It is used to send an email to the user when requesting a password recovery.

d) Gson version 2.6.2: class library for handling JSON messages using java language.

e) Mysql connector version 5.1.39: library for controlling connections to the MySQL database from java.

3. RESULTS

The system allows patients, physicians, auxiliary staff and laboratory operators to enter information for platform interoperability. Each user role has different functions according to their profile. First, medical personnel must authorize patient examinations; these authorized examinations are awaited by laboratory operators. While the examination has not been performed, medical personnel may cancel the issued order. When the laboratory performs the examination enters the results and the information is available to be consulted by the staff or patients and thus the process is completed.

The platform allows authorizing 6 different exams of the thyroid profile as shown below.

- T4 or T4Total (Thyroxine).
- T3 or T3Total (Triiodothyronine).
- T4L Free thyroxine.
- T3L Triiodothyronine Free.
- Thyrotropin.
- Thyroglobulin.

Data query

Patients and medical staff will be able to see the test results by accessing the patient profile, which will show a table at the bottom of the page with the laboratories performed, as shown in the Figure-7. To see the detailed order, just click on the View button, which will show descriptive data of the test performed. The test information contains in detail the type of laboratory, measurement range, measured value, unit of measurement and comments about the laboratory.

Connection with other information systems

The information system is enabled to communicate with any other health information system that supports the HL7-FHIR standard and package the data using the JSON standard. This can be easily achieved by establishing channels between this system and any other that meets the above requirement and using Mirth Connect or a similar tool. Systems that pack their data using XML or other technologies can also be supported by making small adaptations.

Project file

The project can be consulted at: https://github.com/albecor/PerfilTiroideo; where you can find the following files:

- Database / EERDatabase.mwb: Databasemodel.
- Database / ScriptDatabase.sql: Script file of the database.
- Javadoc /: Contains the project API documentation
- User Manual /: Contains the user manual of the web application.
- Web Application / MedicalThyroid /: Application project file.
- Web Application / medicalThyroid.war: Application deployment file for the Tomcat server.

4. CONCLUSIONS

With the information system implemented, it is possible to optimize the communication between the agents involved in the authorization, realization and publication of the examinations for a patient in the Hospitals of Huila. This allows shorter test times and facilitates the work of medical staff to choose treatments that are appropriate to the specific condition of each patient. The use of information technologies should be intensified through the development of projects that solve many of the problems that afflict the Colombian health system. As has been shown, the Surcolombiana University's electronic engineering program can contribute to the development of the city, the department and in general the country.

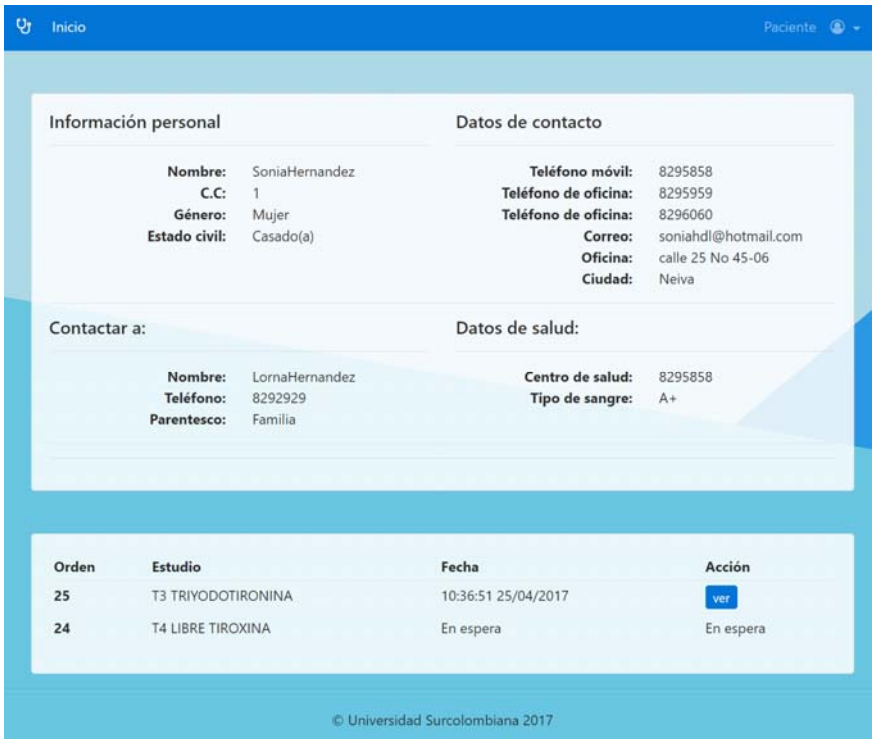

Figure-7. Patient profile.

The information system presented here ensures the integrity and readability of patient information and makes it possible for information to be available anywhere, regardless of the institution providing health services.

The execution of this project is expected to mark the way forward in the department and in the country in terms of the use of computer technologies as an immediate solution to many difficulties of the hospital centers. We hope to generate the basis for future projects that involve a full integration of the different areas of the hospital into robust, effective and reliable hospital information systems.

ACKNOWLEDGEMENTS

This work was funded in part by the Surcolombiana University in Colombia.

REFERENCES

[1] Harrison, Tinsley Randolph, Fauci, Anthony, *et al.* 2005. Harrison. Principios de Medicina Interna. 16ª Edición. España: Editorial McGraw-Hill.

[2] Salvatore D, Davies TF, Schlumberger MJ, Hay ID, Larsen PR. 2016. Thyroid physiology and diagnostic evaluation of patients with thyroid disorders. In: Melmed S, Polonsky KS, Larsen PR, Kronenberg HM, eds. Williams Textbook of Endocrinology. 13th ed. Philadelphia, PA: Elsevier Saunders: chap 11.

[3] Kids Health. The Nemours Foundation. Análisis de sangre: hormona estimulante de la tiroides (TSH). [Consulta: 21 de octubre del 2014]. Disponible en: http://kidshealth.org/parent/en_espanol/medicos/test_tsh_esp.html#.

[4] FHIR community. 2017. FHIR V3.0.1. HL7 FHIR. Extraído de: https://www.hl7.org/fhir/.

[5] Care2x. The open source hospital information system, 2013 Care2x Team. Extraído de: http://www.care2x.org/demo-page-online.

[6] e-Salud: El caso de México. Nancy Gertrudiz. Extraído de: http://cetes.medicina.ufmg.br/revista/index.php/rlat/article/viewFile/71/192.

[7] MirthConnect, Mozilla Licencia Pública (MPL) 1.1. Extraído de: https://www.mirth.com/.

[8] MySQL. 2017. Oracle Corporation and/or its affiliates. Extraído de: https://www.mysql.com/.