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ELECTROLYTE PANEL TESTS: AN INFORMATION SYSTEM FOR REGISTRATION AND CONSULTATION

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ABSTRACT

This article presents an implementation of an information system to optimize the process of performing electrolyte panel tests for the hospitals in Huila, Colombia, in order to improve the organization of the results and access to them. In the implementation, the HL7 standards set were used as a guide to achieve good interoperability and to make the system scalable. Access to test results can be done through any web browser and any device due to a responsive web design was used. The information system allows access to the data of patients and it is possible to export information from the database to obtain different statistics. Spring Framework was used to design the information system, which provides a complete programming and configuration model for modern, Java-based enterprise applications on any type of deployment platform.

Keywords: information system, electrolyte panel profile, web services, HL7-FHIR, spring framework.

1. INTRODUCTION

Electrolytes are minerals in the blood and other body fluids that carry an electric charge. These are found in the tissues and in the blood in the form of dissolved salts. They help to get nutrients into the cells and eliminate waste, maintain a healthy hydric balance and help stabilize the body's ph. Electrolyte panel tests determine the state of the body's principal electrolytes: sodium (Na +), potassium (K +), chloride (Cl-) and bicarbonate (HCO3 - sometimes expressed as total CO2).

Most of the sodium is outside the cells, in the plasma, where it helps regulate the amount of water in the body. Potassium is found primarily within cells, although it is also found in plasma in small amounts. Potassium monitoring is important. Small changes in K + can affect heart rate and contraction capacity of the heart. Chloride moves in and out of cells to keep the electrical charge neutral, and its concentration usually reflects that of sodium. The main role of bicarbonate (or total CO2, an estimate of bicarbonate) that is excreted and reabsorbed in the kidneys is to maintain a stable ph (acid-base balance) and, in a secondary way, also maintain the neutral charge. [1]

Electrolytes affect how the body works in many ways, including:

- The amount of water in the body
- The acidity of blood (ph)
- Muscle activity
- Other important processes

You lose electrolytes when you sweat and should replenish them by drinking liquids containing them. Water contains no electrolytes.

Common electrolytes include:

- Calcium
- Chloride
- Magnesium
- Match
- Potassium
- Sodium

Electrolytes can be acids, bases or salts. They can be measured by different blood tests. Each electrolyte can be measured separately, as [2]:

- Ionized calcium
- Serum Calcium
- Serum Chloride
- Serum magnesium
- Serum phosphorus
- Serum potassium
- Serum sodium

Sodium, potassium, and chloride levels can also be measured as part of a group of basic metabolic tests. A more complete examination, called the complete metabolic panel, can examine several of these electrolytes.

Sodium, potassium and chloride come from the diet. They are excreted through the kidneys. Through the lungs, body acquires oxygen and eliminates CO2, which maintains the balance with the bicarbonate. The balance between these substances is an indicator of the proper functioning of various processes that take place in the body, such as renal or cardiac function.

The electrolyte panel is based on the isolated determination of each of them: sodium, potassium, chloride and bicarbonate (or total CO2). The test that relates them is known as anion gap. It is a value calculated using the result of the electrolytic panel. It reflects the difference between positively charged ions (known as cations) and negatively charged ions (anions). An abnormal gap anion result reflects the unusual presence of some charged particle in the blood. It can be affected by metabolism products generated in some circumstances such as starvation, diabetes or the presence of toxic substances, such as oxalate, glycolate or aspirin. [3].

This article presents the design and implementation of an information system for the

registration, organization and analysis of the results of electrolyte panel 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 test of electrolyte panel. 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 [5-6]. 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 platform

For development of the Information System the model described in Figure-1 is proposed, 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 smartphones.

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 [7].

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 [8].

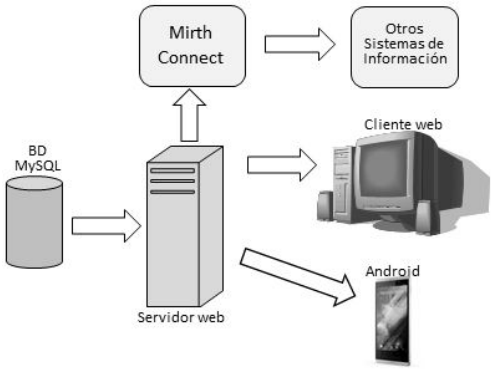

Figure-1. Information system architecture.

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 electrolyte panel 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:

User: This table stores the information corresponding to the users of the platform. It defines the following fields:

- **Id:** INT field, which identifies the record.
- **password:** String field containing the encrypted user password.

- **Identifier**: JSON field that stores the user identifier according to the HL7 standard.
- **Name:** JSON field that stores the user name according to the HL7 standard.
- **Telecom:** JSON field that stores contact information.
- **Gender:** String field that stores the gender.
- **Birthdate:** String field that stores the date of birth.
- **Address:** JSON field storing address.
- **MaritalStatus:** JSON field that stores the marital status.
- **Contact:** JSON field that stores the information of a contact to go to.
- **Communication:** JSON field that defines the language of interpretation of information.

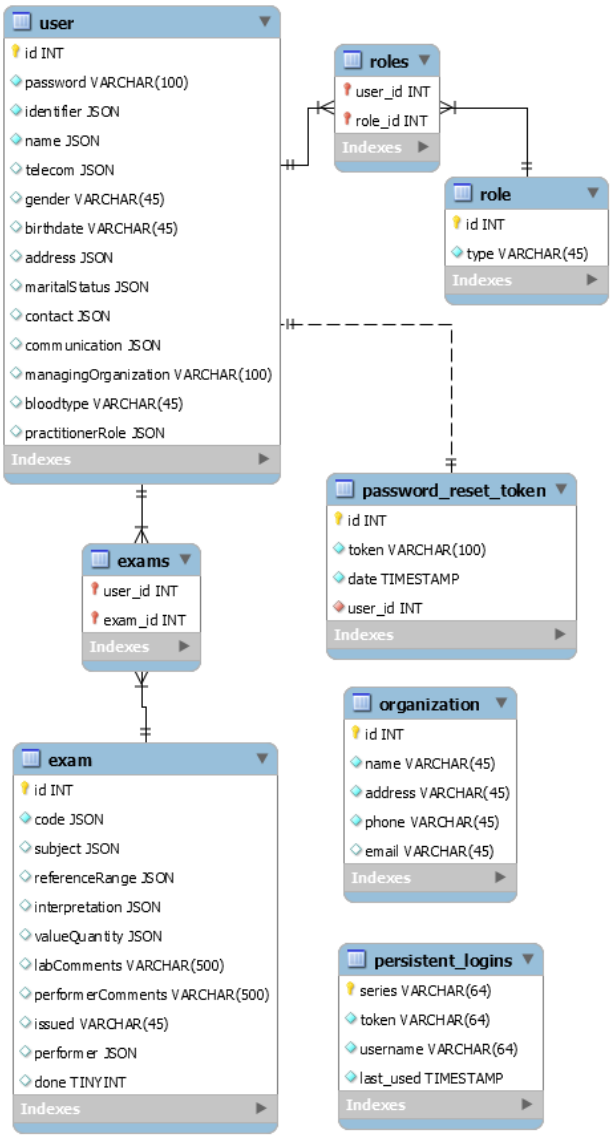

Figure-2. Database tables.

- **ManagingOrganization:** String field that stores health entity.
- **Bloodtype:** String field that stores blood type.
- **PractitionerRole:** JSON field that stores according to the standard HL7 the charge of a user of medical personnel.
- **Entitylab:** String field that stores the entity that provides the services for the laboratory.

roles: Table with many to many relationship between the user table and the role table, which stores user roles. In this the following fields are defined:

- **User_id:** INT field containing the id of the user table.
- **Role_id:** INT field containing the id of the role table.

role: This table contains the user roles of the platform. The user roles in the platform are shown below:

- ADMIN: role for the administrator.
- PATIENT: role for the patient.
- STAFF: role for staff.
- LAB: role for the laboratory.

In the role table the following fields are defined:

- **id:** INT field containing the role id.
- **type:** String field containing the user role.

exams: This table with many to many relationship between the user table and the exam table contains the user's exams. It defines the following fields:

- **user_id:** INT field containing the id of the user table.
- **exam_id:** INT field containing the id of the exam table.

exam: This table stores the information corresponding to the electrolyte paneltests. For each record in this table the following fields are defined:

- **id:** INT field that identifies the record.
- **code:** JSON field that stores the type of examination of the electrolyte panelprofile.
- **subject:** JSON field that stores patient information according to the HL7 standard.
- **referenceRange:** 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 value taken from the variable to be measured.
- **valueQuantity:** JSON field that stores according to the HL7 standard the value taken from the variable to be measured.
- **labComments:** String field that stores the lab's comments about the exam.
- **performerComments:** String field that stores the doctor's comments about the exam.
- **issued:** String field that stores the date and time of the exam.
- **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.

organization: This table stores information about the service provider. For this table the following fields are defined:

- **id:** INT field that identifies the record.
- **name:** String field that stores the name of the entity.
- **address:** String field that stores the physical location of the entity.
- **phone:** String field that stores the phone of the entity.
- **email:** String field that stores the email of the entity.

persisten_logins: This table stores the sessions that are remembered in the browser. For the records in this table the following fields are defined:

- **series:** Identifier of the record.
- **token:** String field that stores a token or session key.
- **username:** String field that identifies the user for the login.
- **last_used:** TIMESTAMP field that stores the date and time of the last recorded session.

Web platform

The web platform allows users to perform operations for the management of registered information and to record new information in the system. There are four types of users, which are defined below:

- **Administrator:** It is registered through the web page. Its function is registering, modifying or eliminating the other users of the platform.
- **Personal:** cans view his/her basic information and modify his/her data. In addition, has access to patient data, to authorize exams and to review exam history.
- **Patient:** cans view his/her personal information and modify his/her data. The platform allows consulting the history of exams that were practiced to him.
- **Lab-operator:** cans view his/her personal information; modify his/her data and those of the entity that provides the services of laboratories. The platform allows 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. The platform has support in English and Spanish. Figure-4 shows the view for the login in the platform.

Figure-3. Web platform home.

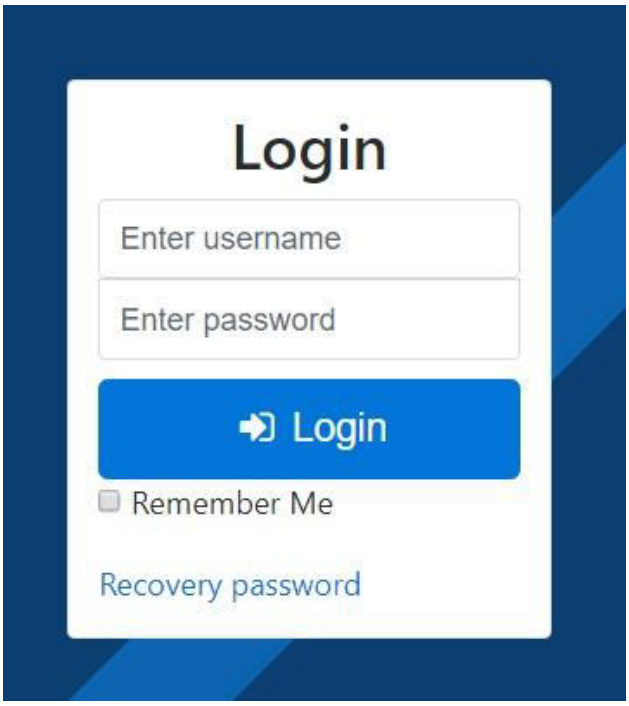

Figure-4. Web platform login.

Users can access with their personal identification number and password. The platform can remember the user session and recover the password if the user does not remember it. Figure-5 shows the start page when the user login,

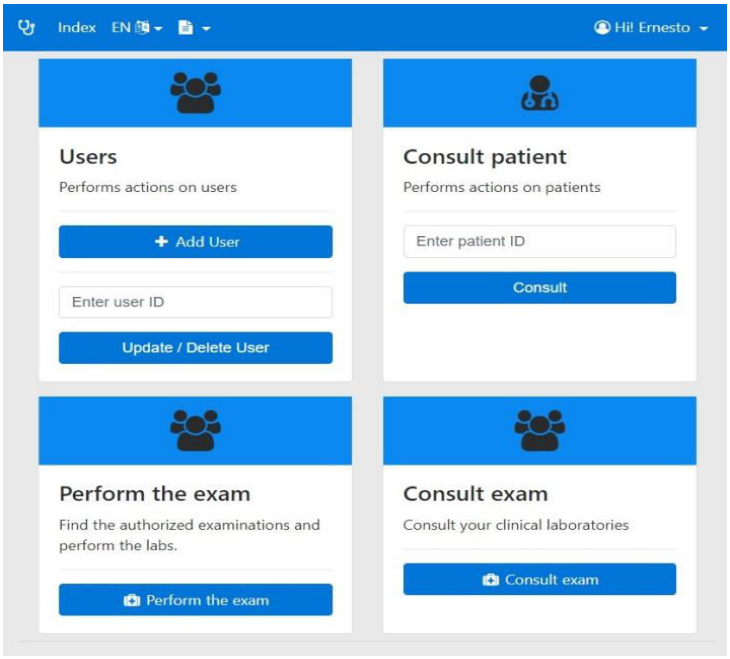

Figure-5. User's starting view.

Figure-6 shows the presentation form for the general user information

A physician can authorize any tests to a patient only by entering the profile. Figure-7 the authorization form for tests.

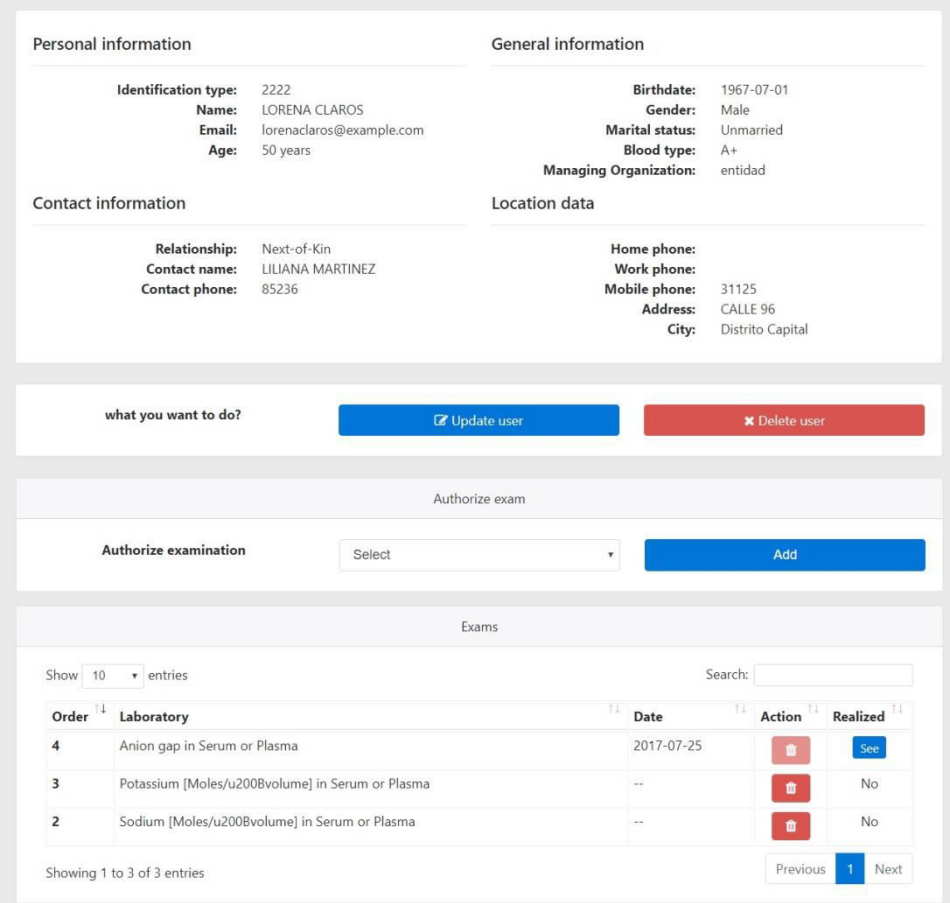

Figure-6. General user information form.

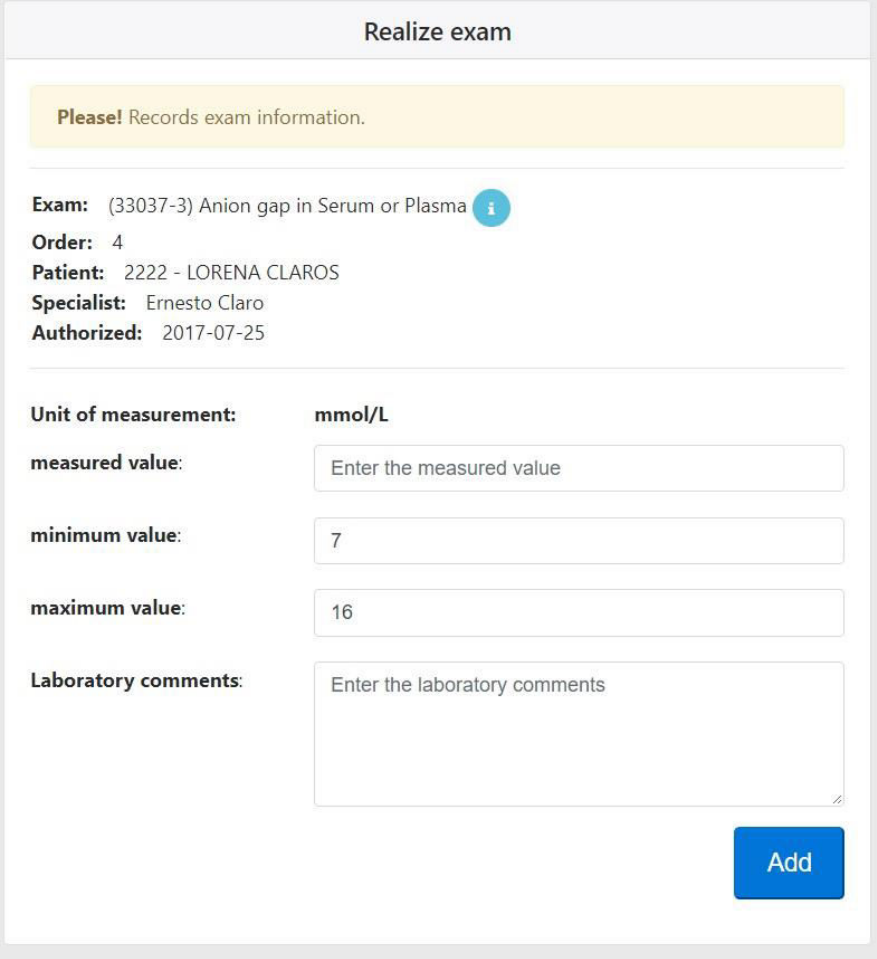

Figure-7. Authorization form.

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:

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

2.Font-Awesome: This library contains compiled icons to give a better visual style to the pages.

3.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.

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

5.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 lab-operators entering 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 5 different exams of the electrolyte panel tests as shown below:

a) Sodium [Moles/volume] in Serum or Plasma
b) Potassium [Moles/volume] in Serum or Plasma
c) Chloride [Moles/volume] in Serum or Plasma
d) Carbon dioxide, total [Moles/volume] in Serum or Plasma
e) Anion gap in Serum or Plasma

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-8.

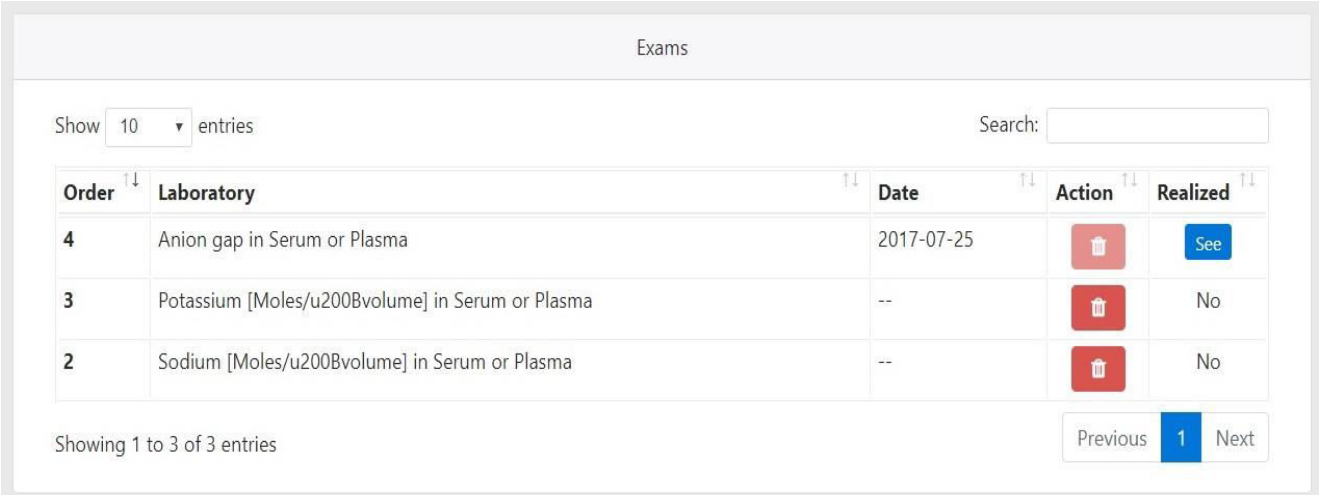

Figure-8. Form for accessing to the tests results.

Figure-9 shows a laboratory order performed, detailing descriptive data of the examination performed. It shows the type of laboratory, the measurement range, the measured value, the unit of measurement and the comments about the laboratory. For all examinations, the lab-operator and specialist comments on the presence of the compound are shown.

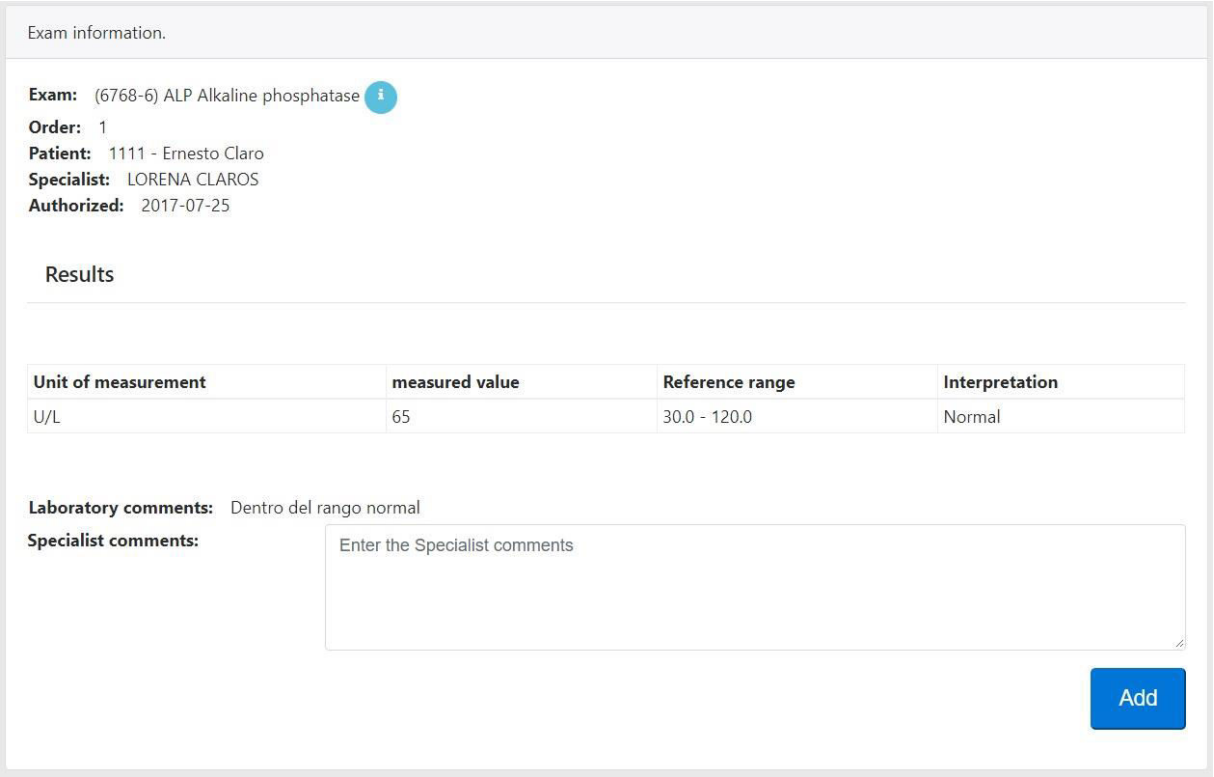

Figure-9. Results information form.

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/Medical_Electrolytes; where it can find the following files:

- Database/EERDatabase.mwb: Database model.
- Database/ScriptDatabase.sql: Script file of the database.
- Javadoc/: Contains the project API documentation
- User Manual /: Contains the user manual of the web application.
- WebApplication / Application/ medical_electrolyte /: Application project file.
- Web Application / medical_electrolytes.war: Application deployments file for the Tomcat server.

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.

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.

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