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INFORMATION SYSTEM TO MANAGEMENT COMPREHENSIVE METABOLIC PANEL TESTS IN HOSPITALS OF HUILA - COLOMBIA DEPARTMENT

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ABSTRACT

Currently, hospitals in the Department of Huila in Colombia need hospital information systems that allow them to guarantee the integrity and readability of patient information; in addition, they need to do health information available at the point of care where it is located, regardless of the institution providing care where it is served. As a result, Huila's hospitals do not yet have these information systems; therefore, health care staff use outdated, complex and unstructured methods to store data on all types of results and examinations performed, so that they can later be examined and analyzed by a physician in charge and then make the appropriate decisions. Therefore, this project implements an information system to optimize the management process of Comprehensive Metabolic Panel (CMP) tests in Huila's hospitals in order to improve the organization of results; and thus make access more timely and efficient. The designed information system is based on the HL7-FHIR standard (Health Level 7 - Fast Healthcare Interoperability Resources). As a result, we designed and implemented a system that uses technologies such as Java, MySQL, Java, CSS3, HTML5, among others. Finally, we concluded that the proposed information system can minimize execution times, and facilitate the management of the comprehensive metabolic panel tests by the team of medical assistants when a patient's results have been elaborated.

Keywords: comprehensive metabolic panel, health care, HL7-FHIR, information system,, web services.

INTRODUCTION

The CMP test is a group of tests that measures different chemicals in the blood. These tests are usually done on the liquid (plasma) part of the blood. The tests provide information about your body's chemical balance and metabolism; and can give doctors information about your muscles (including the heart), bones, and organs, such as the kidneys and liver [1].

There are two types of the CMP test: Basic Metabolic Panel and Full Metabolic Panel. The first one checks your blood sugar, calcium, and electrolytes; additionally, it checks your creatinine to evaluate the work of your kidneys. The second, called the complete panel, includes all of the above tests, but includes cholesterol level, protein level, and liver function.

In addition, the complete metabolic panel may be ordered as part of a routine medical or physical exam, or to help diagnose other conditions, such as diabetes or kidney or liver disease. The complete metabolic panel may also be used to manage chronic conditions or when a patient is taking medications that may cause certain side effects.

On the other hand, the CMP helps to assess the following: [2]:

Glucose, is a type of sugar that the body uses for energy, and abnormal levels can indicate diabetes or hypoglycemia (low blood sugar).

Calcium plays an important role in the contraction of muscles, in the transmission of messages through the nerves and in the release of hormones.

Albumin and total protein, which are needed to build and maintain muscle, bone, blood, and organ tissue. The complete metabolic panel specifically measures albumin (the major blood protein produced by the liver), as well as the amount of other proteins in the blood.

Sodium, potassium, carbon dioxide, and chloride (electrolytes), which help regulate the body's fluid levels and acid-base balance. They also play a major role in regulating heart rate, muscle contraction, and brain activity.

Blood Urea Nitrogen (BUN) and creatinine are waste products of the blood that are filtered out by the kidneys.

Alkaline phosphatase, the enzymes alanine amino transferase, and aspartate amino transferase, and bilirubin; the first three components are liver enzymes, while bilirubin is produced in the liver.

Similarly, measuring electrolytes, such as potassium, sodium, chlorine, and carbon dioxide, can provide clues as to problems with heart disease, dehydration, or vomiting.

Other substances in the human body can detect systemic or organ-specific problems. For example, large amounts of bilirubin, AST, alkaline phosphatase, and ALT are indicative of problems with liver function. Likewise, elevated bilirubin levels may indicate hemolysis, jaundice, cirrhosis, bile duct obstruction, or acute hepatitis. Similarly, excess bilirubin, AST, and ALT one alkaline phosphatase indicate the possibility of a liver disorder or damage. Finally, the presence of diabetes is associated with high glucose levels; while very low glucose levels signal hypoglycemia.

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Normal values for a complete metabolic panel are listed below. Table-1 shows a brief description of the acronyms used:

- **Albumin:** 3.9 to 5.0 mg/dL
- **Alkaline Phosphatase:** 44 to 147 IU/L.
- **ALT (alanine transaminase):** 8 to 37 IU/L.
- **AST (aspartate aminotransferase):** 10 to 34 IU/L.
- **BUN (blood urea):** 7 to 20 mg/dL.
- **Calcium:** 8.5 to 10.9 mg/dL.
- **Chloride:** 101 to 111 mmol/L.
- **CO2 (carbon dioxide):** 20 to 29 mmol/L.
- **Creatinine:** 0.8 to 1.4 mg/dL .**
- **Direct bilirubin:** 0.0 to 0.3 mg/dL.
- **GT range (gamma-glutamyltranspeptidase):** 0 to 51 IU/L.
- **Glucose analysis:** 100 mg/dL.
- **Potassium analysis:** 3.7 to 5.2 mEq/L.
- **Sodium:** 136 to 144 mEq/L.
- **Total bilirubin:** 0.2 to 1.9 mg/dL.
- **Total protein:** 6.3 to 7.9 g/dL.

The values listed above are considered normal or "healthy"; however, for creatinine they may vary with age. This means that the normal value ranges for all tests may vary slightly among different laboratories.

Table-1. Units or acronyms description.

Unidad/Sigla	Descripción
IU	International unity
L	Liter
dL	deciliter = 0.1 liter
g/dL	grams per deciliter
mg	miligrams.
mmol	milimoles
mEq	milli-equivalents

On the other hand, as computer systems evolved, information systems appeared that were capable of presenting reports related to the health of each patient, statistics on the data obtained from the examinations carried out, as well as the medicines and treatments formulated by the doctors. Examples of these systems are Care2x (Open Source Hospital Information System), first published in 2002 by Elpidio Latorilla, and the Mexican Government's Hospital Management Information System (SIGHO), which began only in 2005 [4-5]. The technology mentioned above is currently being implemented in the Department of Huila, so this work can be considered an initial contribution to innovation in the area.

In view of the above, this article presents the design and implementation of an information system for recording, organizing and analyzing the results of CMP tests in hospitals of the Department of Huila. Likewise, the main objective of the work is to create a (Hospital Information System) that allows to store the data of patients, medical personnel, and laboratory personnel so that they can register, consult, or authorize the results of the CMP tests. Therefore, the data can be fed into the Hospital's local area network as well as from any remote computer or device (Smart phone or Tablet) connected through the Internet. It is also important to note that the design of the HIS follows the guidelines of the HL7-FHIR standard, which is the most widely used worldwide, ensuring easy interoperability (compatibility and data migration) with other hospital information systems using the same standard.

METHODOLOGY

In order to develop the SIH, different stages were made, such as Design, implementation and start-up which was done through tests to the platform.

General Design of the Platform

To begin with, Figure-1 presents the design of the general scheme of the described system that is proposed. This design has a MySQL database where the data is stored, the Web Server that delivers the pages carrying out the control of the platform, and the Clients that request the connection; the Web Clients can request the server to send pages from any device with a Web browser and Internet connection such as desktop computers, laptops, tablets or smart phones.

In the stages of the project development process, first the database is designed taking the variables and records necessary for the proper functioning of the system; then the control and service of the web pages through the server is defined along with the visual design of the pages that are delivered. The system takes into account the HL7-FHIR standard for sending medical information, so that tools like MirthConnet can access the information using their connection protocols based on the standard.

The HL7-FHIR Standard

HL7-FHIR (Health Level 7 - Fast Healthcare Interoperability Resources) is a standard that describes the "resources", data formats and elements for the exchange of electronic health records (EHR). The standard was created by the international health standards organization HL7. One of the goals of HL7-FHIR is to facilitate interoperability between different health care systems, to make it easy to provide health care information to health care providers and individuals on a wide variety of devices, from computers to tablets to cell phones, and to allow third-party application developers to develop medical applications that can be easily integrated with existing information systems. HL7-FHIR is relatively easy to implement because it uses a modern web-based technology suite, including RESTful, HTML and cascading style sheets (CSS) for user interface integration, a choice of JSON or XML for data representation and OAuth for authorization [3 de Renal].

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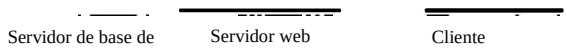

Figure-1. Interoperability diagram.

However, interoperability with information systems that use different technology to represent data, such as XML or others, can be achieved through a management tool for integrating multiple health information systems, such as MirthConnect [6]. It is important to emphasize that this work is part of a more ambitious project for the Department of Huila, which aims to systematize the entire health area, so that interoperability between different health information systems must be guaranteed.

Additionally, the JSON standard was used for data representation; allowing interoperability and portability with other information systems using this same technology for the exchange of EHRs will be simple and guaranteed. However, interoperability with information systems that use a different technology to represent the data, such as XML or others, can be achieved through a management tool for integrating multiple health information systems, such as MirthConnect [6]. It is important to emphasize that this work is part of a more ambitious project for the Department of Huila, which aims to systematize the entire health area, so that interoperability between different health information systems must be guaranteed.

Development Technologies

Severals free software tools of the OpenSource type were used for the development of the SIH, which are described below:

- **Development environment:**

Spring Tool Suite
Version: 3.8.4.RELEASE
Build Id: 201703310825
Platform: Eclipse Neon.3 (4.6.3)
JavaSE-1.8 (jre1.8.0_121)

- **Database:**

MySQL Workbench 6.3.8 build 1228 CE (64 bits) Community
TCP port for database is MySQL:3306

- **Application server:**:

Apache Tomcat 8.5.14

Programming languages

To implement the information system, software development tools such as:

- HTML5 organizes the parameters for tagging the structure of the HTML page, CSS3 builds the appearance of the page 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 open source application development framework and control inversion container for the Java platform. It is used to control pages and develop application services.

In addition, other tools were used such as:

- **Bootstrap v4.0.0-alpha.6:** framework that facilitates web design adaptable to different devices using responsive design.
- **Font Awesome:** this library contains a compilation of icons to give more visual style to the pages.
- **javax.mail version 1.4.7:** allows the sending of mail messages from the server to users. It is used to send an email to the user when requesting a password recovery.
- **Mysql conector version 5.1.39:** library for controlling connections to the MySQL database from java.

Implementation

Database Server

MySQL is the most popular open source database over the world, making it a reliable and secure option [7]. In addition, it has features such as high scalability, ease of use, high performance among others, making it the ideal choice for information system needs.

Initially, the table that stores information about users is defined. Also, then a session table, and finally another one that stores the information corresponding to the CMP tests. Therefore, in Figure-2, the database diagram described above can be presented. Consequently, for the User and Exam tables, the fields are constructed in JSON format using the HL7 standard. Below is a description of the fields of each implemented table:

- User: stores the information corresponding to the users of the platform, and contains the following fields:
- **id:** INT type field that identifies the record.
- **password:** string-type field containing the user's encrypted password.
- **identifier:** JSON-type field that stores the user ID according to the HL7 standard.
- **name:** JSON type field that stores according to the HL7 standard the name of the user.
- **telecom:** JSON-type field that stores contact information
- **gender:** string field that stores the gender.
- **birthdate:** string type field that stores the date of birth.
- **Address:** JSON type field that stores the address.
- **maritalStatus:** JSON type field that stores the marital status.

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- **contact:** JSON type field that stores the information of a contact to go to.
- **communication:** JSON type field that defines the information interpretation language.
- **managingOrganization:** String type field that stores the health entity.
- **bloodtype:** String type field that stores the blood type.
- **practitionerRole:** JSON type field that stores according to the HL7 standard the position of a medical staff user.
- **entitylab:** string type field that stores the entity that provides services for the laboratory.

▪ **Roles:** table of many to many relationships between the user table and the role table that contains the user roles. This table contains the following fields:

- **user_id:** INT type field that contains the user table id.
- **role_id:** INT type field that contains the role table id.

▪ **role:** Table containing the platform's user roles, the fields in this table are:

- **ADMIN:** role for the administrator.
- **PATIENT:** role for the patient
- **PERSONAL:** role for staff.
- **LAB:** role for lab technician

The following fields are defined in the role table:

- **id:** INT type field that contains the role table id.
- **type:** string type field containing the user role.

▪ **exams:** multi-to-many relationship table between the user table and the exam table containing the user's exams. This table contains the following fields:

- **user_id:** Field type INT that contains the id of the user table.
- **exam_id:** Field type INT containing the id of the exam table.

▪ **Exam:** stores the information corresponding to the medical CMP tests. The following fields were included for the exam table:

- **id:** INT type field that identifies the record.
- **code:** JSON-type field that stores the type of CMP test.
- **subject:**JSON-type field that stores the patient's information according to the HL7 standard.
- **referenceRange:** JSON type field that stores, according to HL7 standard, the reference range of the variable to be measured.
- **interpretation:** JSON type field that stores, in accordance with the HL7 standard, the interpretation of the value taken from the variable to be measured.
- **valueQuantity:** JSON type field that stores, according to HL7 standard, the value taken from the variable to be measured.
- **labComments:** String type field that stores the comments of the lab technician about the exam.
- **performerComments:** String type field that stores the doctor's comments about the exam.
- **issued:** String type field that stores the date and time of the exam.
- **performer:** JSON-type field that stores, according to the HL7 standard, the user of the medical staff that requests the exam.
- **done:** Boolean-type field that stores 1 if the test was performed.

▪ **organization:** table stored by the service provider; this table contains the following fields:

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

▪ **persisten_logins:** table that stores the sessions that are remembered in the browser. The following fields were established for this table:

- **series:** record identifier.
- **token:** string type field that stores a token or session key.
- **username:** string type field that identifies the user for the login that corresponds to the document number.
- **last_used:** field of type TIMESTAMP that stores the date and time of the last session remembered.

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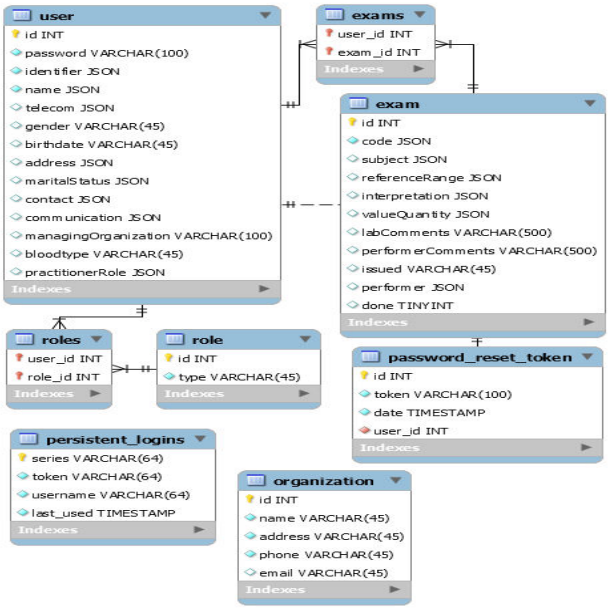

Figure-2. Database Diagram.

Web Platform

The web platform allows users to perform functions for handling the information registered in the system. the Figure-3 shown the home page screen. The SIH allows four types of users, and they are defined below:

Administrator: It is registered through the website. It has the function of registering, modifying or eliminating the other users of the platform.

Personal: He can see his basic information and modify his data, he also has access to the patient's data, which allows him to authorize the CMP exams and consult the history of exams.

Patient: You can see your personal information and modify your data. The platform allows you to consult the history of exams that were performed.

Lab technician: You can see your personal information, modify your data and the data of the entity that provides the laboratory services. The platform allows you to register the values given during the medical examination when it is authorized.

Figure-3. Home page.

On the other hand, the login system allows users to log in with their personal identification number and password; the platform can remember the user session and retrieve their password if they do not remember it, see Figure-4. Additionally, the platform supports English and Spanish language

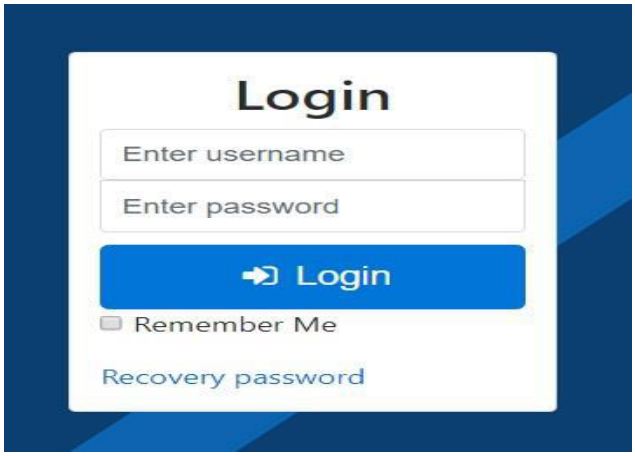

Figure-4. Login screen.

Users can perform functions that are specific to each profile, in the Figure-5 we shown a platform view:

- Administrators can add, update or remove any type of user.
- Medical staff users can view patient information and authorize tests.
- Patients can review their personal information and authorized tests.
- Labs are performed by labs that are authorized by medical staff.

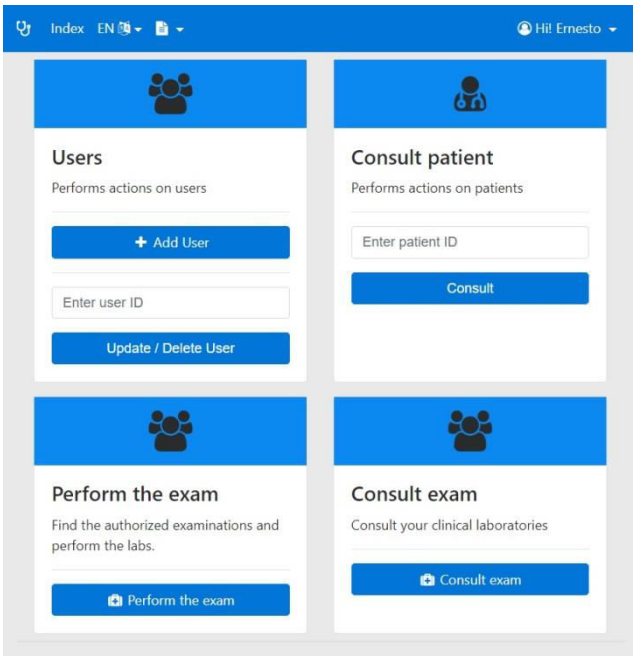

Figure-5. User profile home page.

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In the same way, each user can update their personal information from the platform, see Figure-6. Therefore, you must go to the administrator if you want to change the user's identity card number.

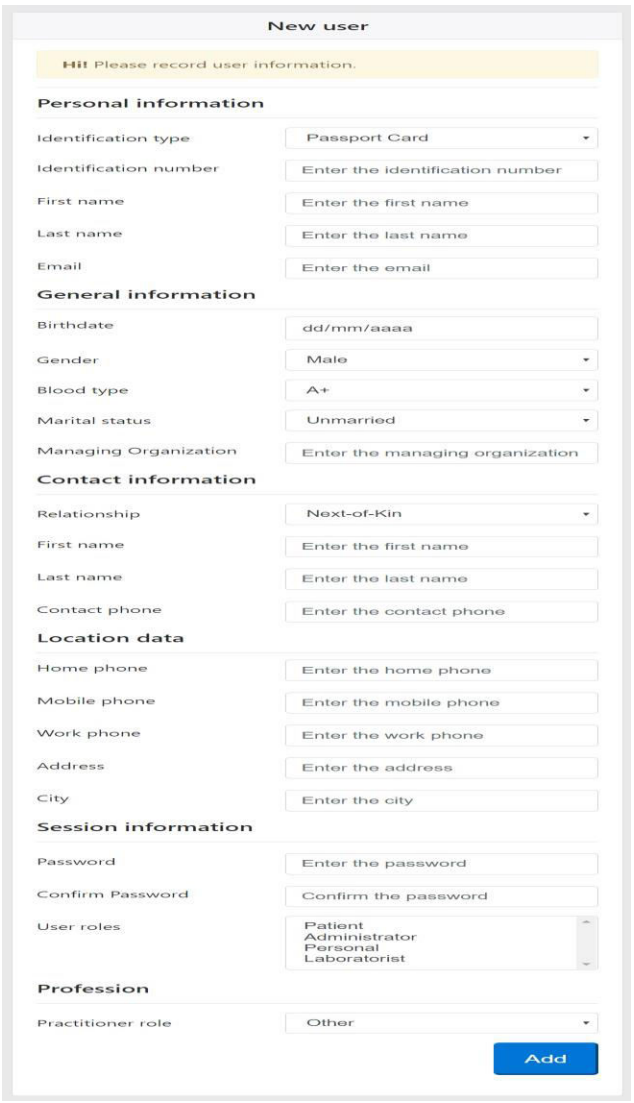

Figure-6. User form.

Likewise, the identity card number and user roles can only be updated by the administrator, the other data can be updated from the platform by the user himself, see Figure-7.

In addition, a doctor can authorize the different tests by making a consultation with the user. Consequently, when the test is authorized, the doctor can withdraw the authorization as long as it has not been carried out by the laboratory, see Figure-8.

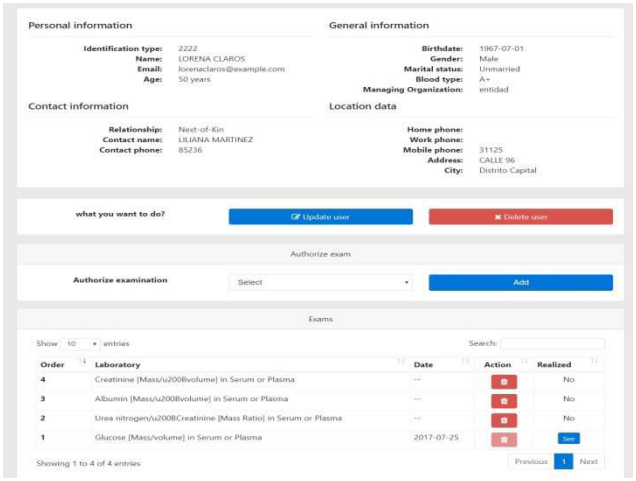

Figure-7. General user information.

Finally, the tests performed by the laboratory may be quantitative if a variable is measured or descriptive if only the presence of the compound in the sample needs to be determined, see Figure-9.

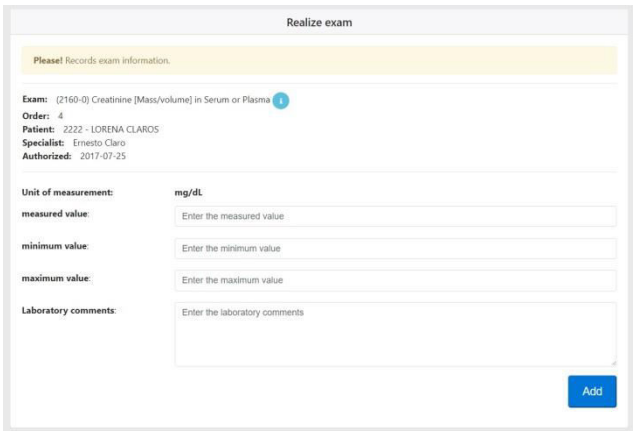

Figure-8. Quantitative test form.

RESULTS

In general, the SIH developed allows patients, doctors, auxiliary personnel, and laboratory staff to enter information for the platform's interoperability.

On the other hand, each user role has different functions according to its profile. First the medical staff must authorize the tests to the patient; these authorized tests are waiting to be performed by the laboratory users. Therefore, as long as the test has not been performed, the medical staff can cancel the order issued. Similarly, when the laboratory staff performs the exam, they enter the data and the information is available for consultation by the staff or the patients, thus completing the process.

In addition, the platform allows the management the highest number of exams respect to the CPM test (17 in total), and they are shown below:

1. Glucose [Mass/volume] in Serum or Plasma
2. Urea nitrogen [Mass/volume] in Serum or Plasma
3. Creatinine [Mass/volume] in Serum or Plasma

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4. Urea nitrogen/Creatinine [Mass Ratio] in Serum or Plasma
5. Glomerular filtration rate/1.73 sq M.predicted [Volume Rate/Area] in Serum or Plasma by Creatinine-based formula (MDRD)
6. Glomerular filtration rate/1.73 sq M predicted among females [Volume Rate/Area] in Serum or Plasma by Creatinine-based formula (MDRD)
7. Glomerular filtration rate/1.73 sq M predicted among non-blacks [Volume Rate/Area] in Serum or Plasma by Creatinine-based formula (MDRD)
8. Glomerular filtration rate/1.73 sq M predicted among blacks [Volume Rate/Area] in Serum or Plasma by Creatinine-based formula (MDRD)
9. Calcium [Mass/volume] in Serum or Plasma
10. Protein [Mass/volume] in Serum or Plasma
11. Albumin [Mass/volume] in Serum or Plasma
12. Globulin [Mass/volume] in Serum by calculation
13. Albumin/Globulin [Mass Ratio] in Serum or Plasma
14. Bilirubin.total [Mass/volume] in Serum or Plasma
15. Alkaline phosphatase [Enzymatic activity/volume] in Serum or Plasma
16. Alanine aminotransferase [Enzymatic activity/volume] in Serum or Plasma
    Aspartate aminotransferase [Enzymatic activity/volume] in Serum or Plasma

Another contribution of the implemented system, is the data query, because it facilitates patients and medical staff can see the results of the tests by accessing the profile of each patient, the user profile shows a table at the bottom of the page with the laboratories performed.

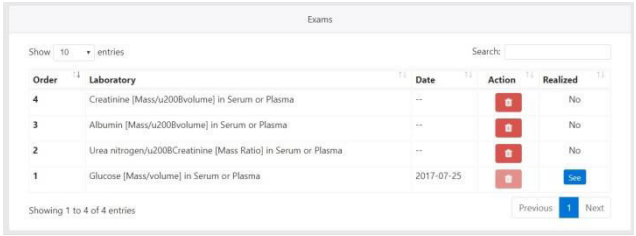

Figure-9. Results information for a patient.

Consequently, in Figure-10, you can see the laboratory order made, which details the descriptive data of the test performed; and also shows the type of laboratory, the range of measurement, the measured value, the unit of measurement, and the comments about the laboratory. Likewise, for non-quantitative examinations, the comments of the laboratory technician and the doctor about the presence of a chemical compound are shown.

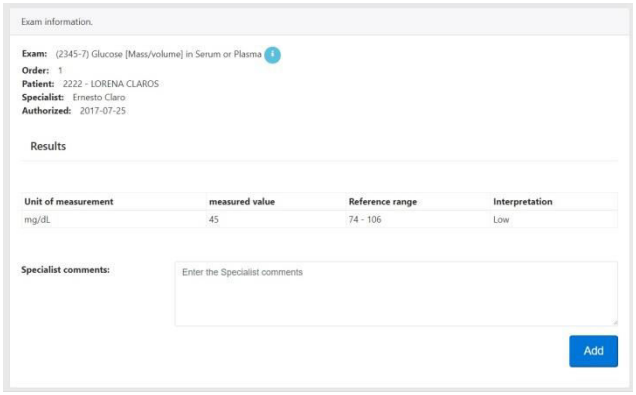

Figure-10. Information on the test performed.

Besides this, the interconnection of the HIS with other information systems is ruled out, once it has been implemented, the HIS goes into operation, is enabled to communicate with any other health information system that supports the HL7-FHIR standard and packages the data using the JSON standard. This can be easily achieved by establishing channels between this system and any other system that meets the above requirement and by using Mirth Connect or a similar tool. Systems that package their data using XML or other technologies can also be supported with minor adaptations.

Finally, to consult additional information about the SIH; and also the project code, you can consult the following address:: https://github.com/albecor/Medical_Metabolic, donde se pueden encontrar los siguientes archivos:

- ***Database/EERDatabase.mwb:*** Modelo de la base de datos.
- ***Database/ScriptDatabase.sql*:** Archivo script de la base de datos.
- ***Javadoc/:*** Contiene la documentación del API del proyecto
- ***Research Project/:*** Contiene el archivo de información de la investigación del proyecto.
- ***User Manual/:*** Contiene el manual del usuario de la aplicación web.
- ***Web Application/medical_metabolic/*:** Archivo de proyecto de la aplicación.
- ***Web Application/medical_metabolic.war*:** Archivo de despliegue de la aplicación para el servidor Tomcat.

CONCLUSIONS

The implemented information system allows optimizing the communication between the agents involved in the authorization, execution and publication of the tests for a patient in Huila's hospitals, reducing the execution time and facilitating the work of the medical staff when choosing treatments according to the specific condition of each patient. Consequently, the use of information technology must be intensified, through the development of projects that provide solutions to many of

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the problems or needs that afflict the Colombian health system.

It is important to emphasize that the information system presented in this work makes it possible to guarantee the integrity and readability of patient information, and makes it possible for the information to be available to any entity (Patient, Medical Nurses, among others), at the time it is needed, regardless of where it is located, and independent of the institution providing health services that needs it.

Finally, it should be noted that 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 HIS for Huila's hospitals.

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