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RENAL FUNCTION PANEL: AN INFORMATION SYSTEM FOR RESULTS TESTS MANAGEMENT AT THE HUILA DEPARTMENT

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ABSTRACT

Globally, kidney disease affects about 10% of the population, and in Colombia about four million potential kidney patients. At the present, the information available for prevention and follow-up of patient treatment is insufficient. Consequently, if there is not an adequate prevention, it increases that the renal problems progress to advanced states, which implies higher health costs of the treatments. Therefore, this paper presents the design and implementation of an information system to optimize the process of performing and managing the results of renal profile tests to patients in the hospitals of the Huila department, is based on the HL7-FHIR standard (Health Level 7 - Fast Healthcare Interoperability Resources). As a result, a system was designed and implemented using 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 metabolic panel examination by the team of medical assistants when a patient's results have been performed.

Keywords: health care, HL7-FHIR, information system, renal profile, web services.

INTRODUCTION

The kidney profile is a diagnostic test that measures the values of various substances in the blood that are related to kidney function in the human body; also known as a renal blood test. A renal profile test is performed when a problem in the kidney is suspected or as part of a general health check, because kidney function can affect the health of the entire body [1].

On the other hand, tests for assessing kidney function include, in addition to the kidney profile, urine tests (mainly proteinuria and creatinine), and may also include additional tests, such as creatinine clearance. Also, in people with chronic diseases, for example, gout, kidney dysfunction, or in cases of kidney transplantation and donation, these tests are performed as monitoring of the patient's progress rather than for diagnostic purposes.

How is a kidney profile exam performed?

The kidney profile is a very simple test; it only requires taking a small sample of the patient's blood. The doctor will then give instructions on whether the patient should fast or not, as well as other possible measures that the patient should follow to perform a test that is not corrupted. Finally, the blood sample is sent to the laboratory and in maximum 4 days the results will be given to the patient. [2].

What values does a kidney profile exam measure?

To determine the results of a kidney profile, initially the values obtained for each measured parameter are compared with average reference values, and the deviations, therefore, the values of each parameter that are above or below the reference values, will provide important information for the diagnosis and possible application of additional tests.

Additionally, the kidney profile measures the blood concentration of numerous substances that can be divided into three groups:

Creatinine

Creatinine is a substance of protein nature formed by three amino acids and is produced in the muscles by degradation of muscle fibers. The concentration of creatinine in the blood depends on a person's muscle mass and remains constant if the muscle mass does not change.

Normal blood creatinine values are between 0.3 - 1.4 mg/dl in women and 0.5 - 1.2 mg/dl in men. When a higher blood creatinine level is detected and you want to determine if it is due to a kidney problem, you usually use the Creatinine Clearance measurement, a test that measures the rate of creatinine filtration in the kidneys. This test requires the concentration of creatinine in the blood and analysis of the urine collected over 24 hours. The normal value is 100-130 ml/min; a lower value would indicate a problem in the glomerular filtration.

It is also common to measure the estimated glomerular filtration rate (eGFR). Although the blood creatinine concentration may serve as an indication of glomerular function, the eGFR is a much more accurate data and can be obtained as an estimate from the blood creatinine concentration and patient data such as age and sex. The reference range is 90 - 120 ml/min. A value below 60 is a sign of some kind of kidney damage.

Urea

It is produced by the degradation of proteins, and is represented in a small molecule, whose chemical formula is $(CO(NH_2)_{2,}$ and the reference range of the concentration of urea found in the blood of a fasting patient, 15 - 50 mg/dl.

On the other hand, it can be said that the concentration of urea in the blood gives a general idea about the functioning of the kidney, but it is not very specific. Increased blood urea concentration may indicate kidney malfunctioning, but it can also be affected by liver function, catabolic states (proteinolysis), excessive dietary protein intake, and, as noted above, many other causes.

Finally, it is important to note that blood urea as such often determines Blood Urea Nitrogen (BUN), whose reference values are 5 - 20 mg/dl.

Electrolytes

Electrolytes are ions dissolved in the body's watery medium. The most prominent ones in the renal profile are Na+(sodium), K+(potassium), Cl- (chlorine), Ca_2+ (calcium), phosphates ($PO_{4/3}$, PO_4H_2 and PO_4H_3) and bicarbonate (HCO_3-).

Similarly, the concentration of electrolytes in the body is essential, among other things, to maintain pH and osmorality. Its concentration in blood is measured in mmol/L and is quickly affected by any alteration in kidney function.

Uric acid

It is the final product of the purines, which are the product of protein catabolism. Consequently, the decrease in uric acid levels is not clinically important. However, an increase may reflect cell destruction or diseases such as leukemia, pneumonia or poisoning during pregnancy. Severe mammalian kidney disease may show elevated uric acid levels. In birds and reptiles, because of their primary uricotelic metabolism, its measurement is used as a test of renal function, making the differential diagnosis with gout hyperuricemia.

Albumin

Albumin is a protein synthesized in the liver. The urine albumin test detects and measures the amount of albumin in the urine. The presence of a small amount of albumin in the urine is an early indicator of kidney damage. Previously, when these small amounts of albumin were detected in urine, the term "microalbumin" was used, although this term is incorrect; some healthcare professionals may still use this inappropriate terminology. The measurement of urine albumin is useful in screening for some chronic diseases such as diabetes and hypertension, both of which favor the development of kidney damage or disease.

Others

The kidney profile is often accompanied by other tests and analyses, especially if there are already indications of another specific health problem. The most common are urine protein (proteinuria), blood and urine glucose, blood count, and urine sediment.

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 relation to the above, this article presents the design and implementation of an information system for the registration, organization and analysis of the results of the kidney profile tests in the 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 renal profile 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 smarphones.

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.

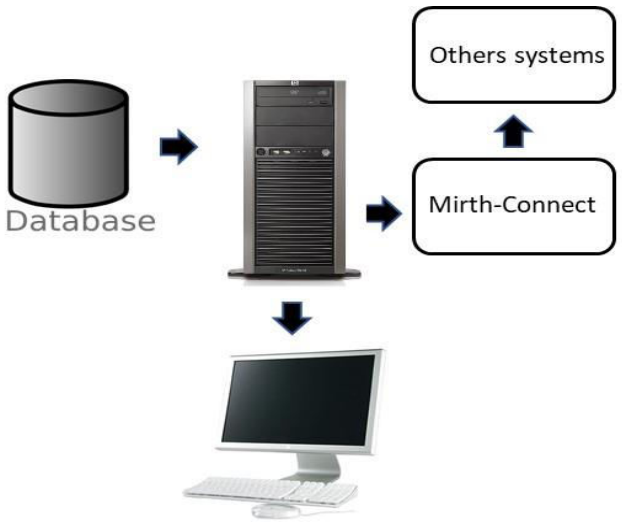

Figure-1. Interoperability diagram.

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].

In this work JSON was chosen for the data representation, this means that the interoperability 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 highlight, that this work is part of a more ambitious project for the Department of Huila, which aims to systematize the entire health area, so 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 tests of the renal profile. 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.
- ***contact*:** JSON type field that stores the information of a contact to go to.
- ***communication*:** JSON type field that defines the information interpretation language.
- ***managing Organization*:** String type field that stores the health entity.
- ***bloodtype*:** String type field that stores the blood type.
- ***practitioner Role*:** 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 tests of the liver profile. 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 liver profile exam.
- **subject:** JSON-type field that stores the patient's information according to the HL7 standard.
- **reference Range:** 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.
- **value Quantity:** JSON type field that stores, according to HL7 standard, the value taken from the variable to be measured.
- **lab Comments:** String type field that stores the comments of the lab technician about the exam.
- **performer Comments:** 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.

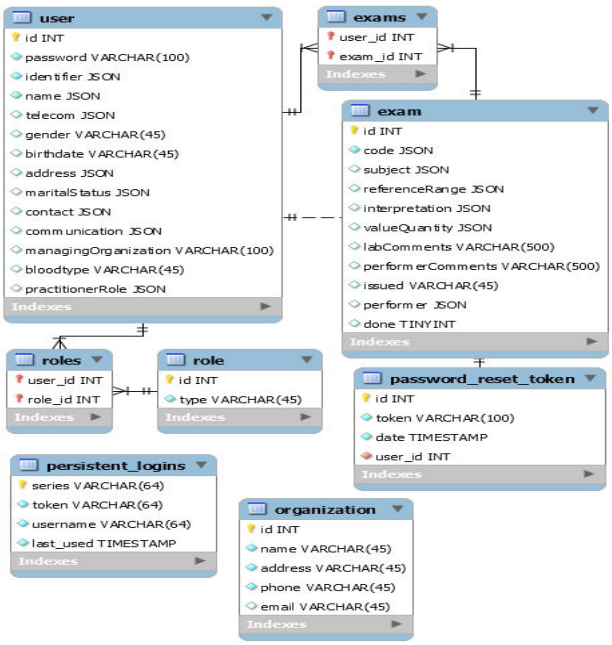

Figure-2. Database Diagram.

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 exams of the renal profile 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.

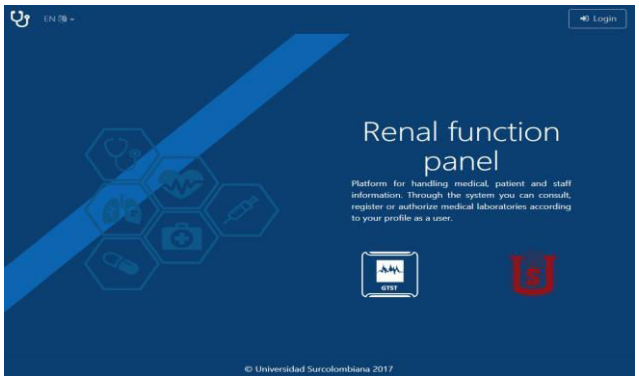

Figure-3. Home page.

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.

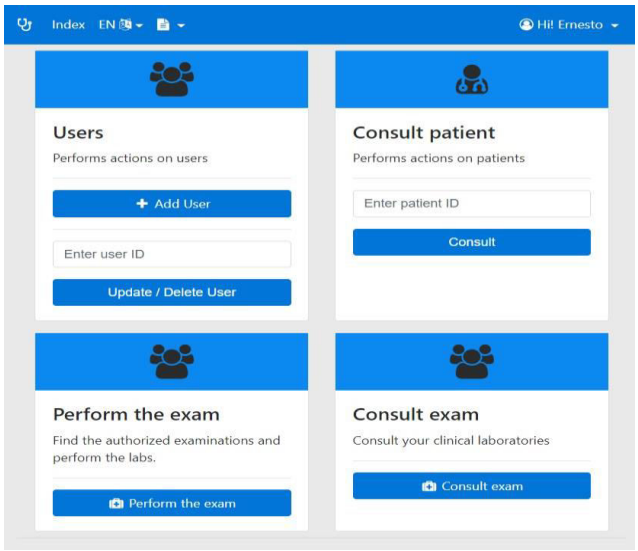

Figure-5. User profile home page.

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.

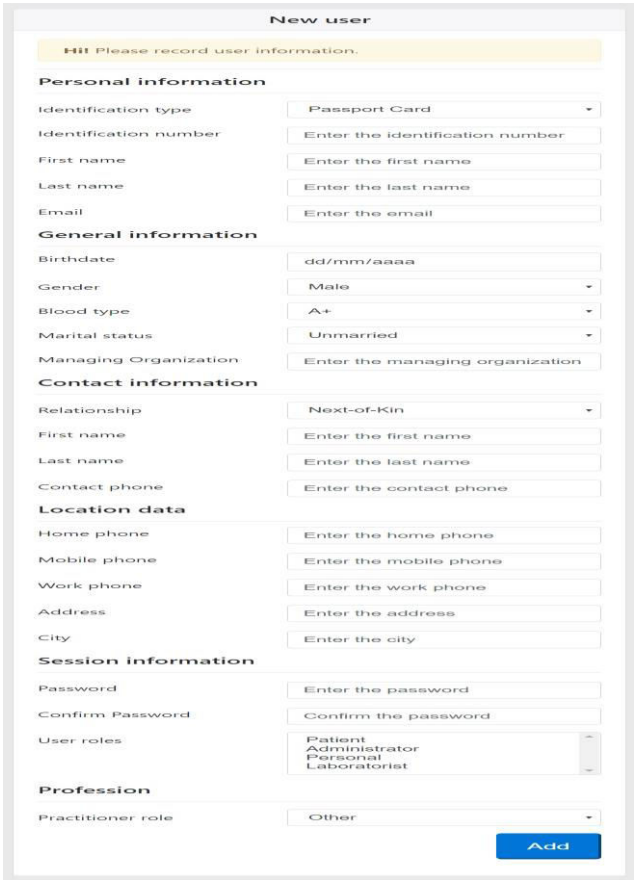

Figure-6. User form.

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.

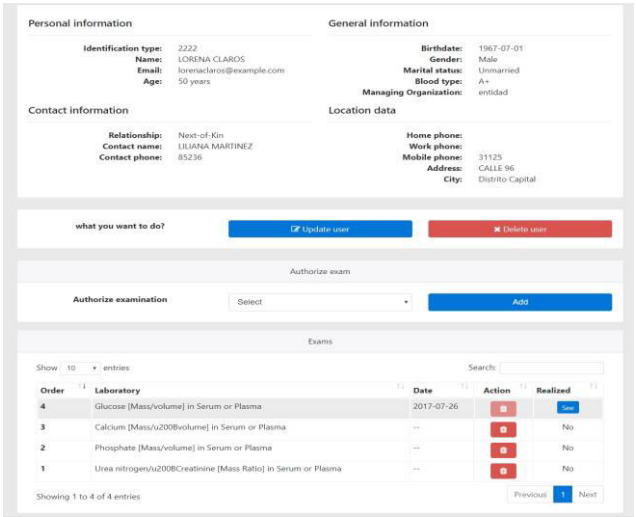

Figure-7. General user information.

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.

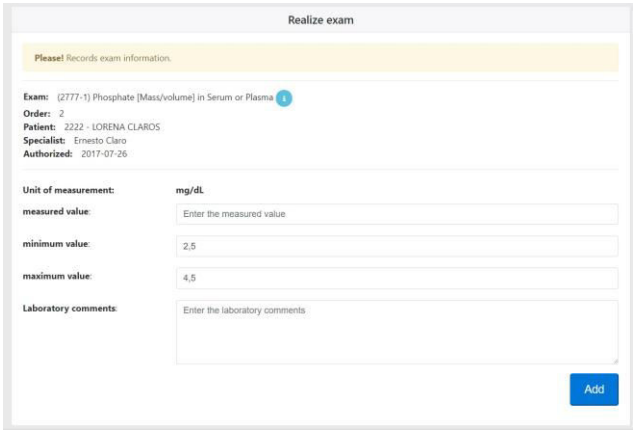

Figure-8. Quantitative test form.

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.

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, see Figure-9.

In addition, the platform allows the management the highest number of exams respect to the renal profile (11 in total), and they are shown below:

a) Glucose [Mass/volume] in Serum or Plasma.
b) Urea nitrogen [Mass/volume] in Serum or Plasma.
c) Creatinine [Mass/volume] in Serum or Plasma.
d) Urea nitrogen/Creatinine [Mass Ratio] in Serum or Plasma.
e) Glomerular filtration rate/1.73 sq M. predicted [Volume Rate/Area] in Serum or Plasma by Creatinine-based formula (MDRD).
f) Glomerular filtration rate/1.73 sq M predicted among females [Volume Rate/Area] in Serum or Plasma by Creatinine-based formula (MDRD)
g) Glomerular filtration rate/1.73 sq M predicted among non-blacks [Volume Rate/Area] in Serum or Plasma by Creatinine-based formula (MDRD).

h) Glomerular filtration rate/1.73 sq M predicted among blacks [Volume Rate/Area] in Serum or Plasma by Creatinine-based formula (MDRD).
i) Calcium [Mass/volume] in Serum or Plasma.
j) Phosphate [Mass/volume] in Serum or Plasma.
k) Albumin [Mass/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.

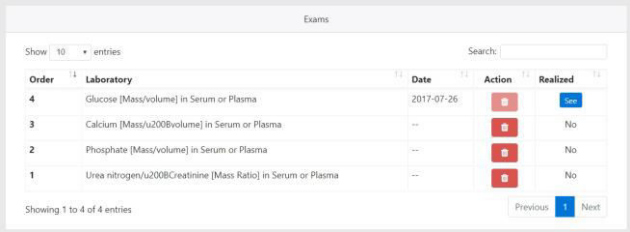

Figure-9. Results information for a patient.

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.

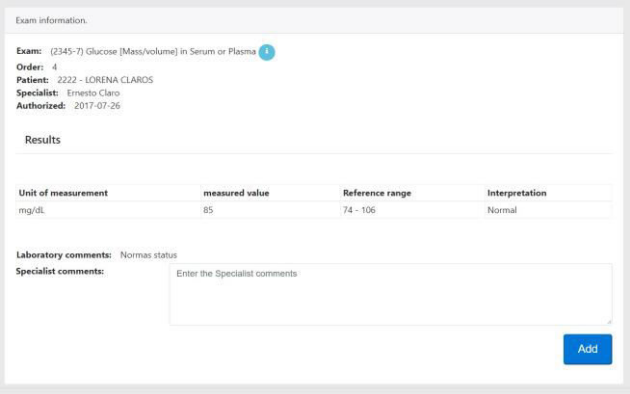

Figure-10. Information on the test performed.

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_Renal, where you can find the following files:

- **Database/EERDatabase.mwb:** database model.
- **Database/ScriptDatabase.sql:** database script file.
- **Javadoc/:** contains the project's API documentation
- **Research Project/:** contains the research project information file.
- **User Manual/:** contains the user's manual of the web application.
- **Web Application/medical_renal/:** application project file.
- **Web Application/ medical_renal.war:** application deployment file for the Tomcat server.

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 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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