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Development Of An Electronic Medical Record (EMR) System For A Typical Nigerian Hospital

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***Abstract*—An electronic Medical record (EMR) is a systematic collection of electronic health information about individual patients or populations. It is a record in digital format that is theoretically capable of being shared across different health care settings. At present, most hospitals in Nigeria still rely on the paper based way of keeping health records of patients. This comes with a lot of challenges like; inadequate physical space to keep the cards in case of high number of patients, inconsistency in handwriting of individuals as well as vulnerability to termite attack or other attacks. Hence, there is a need to migrate to an electronic method of keeping medical records.**

In this work, a simplified Electronic Medical Record system was developed to automate the activities of the following sections in a typical Nigerian hospital; the doctor's unit, the pharmacy, the nursing section, the accounts unit, Laboratory services and the radiology unit. The system was developed using the .NET framework (C Sharp programming language) as the front end, and MySQL Server as the database backend.

The developed system was deployed and tested to see its workability. This system – if adopted - would go a long way to solve the problems attached with the conventional paper-based records system that is being used in most Nigerian hospitals.

Keywords—EMR, Health records, Hospital, .NET.

I. INTRODUCTION

An electronic health record (EHR) is a systematic collection of electronic health information about individual patients or populations (Gunter and Nicholas, 2005). It is a record in digital format that is theoretically capable of being shared across different health care settings. In some cases this sharing can occur by way of network-connected, enterprise-wide information systems and other information networks or exchanges. EHRs may include a range of data, including demographics, medical history, medication and allergies, immunization status, laboratory test results, radiology images, vital signs, personal statistics like age and weight, and billing information.

The system is designed to re-present data that accurately captures the state of the patient at all times. It allows for an entire patient history to be viewed without the need to track down the patient's previous medical record volume and assists in ensuring data is accurate, appropriate and legible. It reduces the chances of data replication as there is only one modifiable file, which means the file is constantly up to date when viewed at a later date and eliminates the issue of lost forms or paperwork. Due to all the information being in a single file, it makes it much more effective when extracting medical data for the examination of possible trends and long term changes in the patient.

The issue of record keeping in healthcare service delivery is very important. This is evidenced in the evolvement of hospital record management as a core discipline in the area of hospital management in recent times. In fact, people now study hospital record keeping and management at tertiary level. However, conventional hospital records are mostly paper based. Most hospitals still rely on paper based hospital records for their day to day record keeping and health related activities. This however comes with a lot of challenges.

At present, most hospitals in Nigeria rely on paper based medical records. This traditional method of keeping the medical records of patients comes with a lot of challenges. With a huge number of registered patients, there arises the need for a lot of physical space to be able to keep and store the paper based medical records. Since these systems rely on the handwriting of individual professionals within the hospital (e.g. doctors, nurses, laboratory scientists e.t.c), there can arise the problem of illegibility of writing which can make it difficult to access information at some other times.

In many cases also, the patients might have to physically carry these paper based records from one unit of the hospital to another (e.g. from the doctor to the laboratory). This might give them access to some information they should not be privy to. Since the records are also paper based, occurrences like termite attack, fire outbreak, flood e.t.c can destroy such records. In a situation where there are many registered patients, looking for individual records may also take a longer time compared to doing so electronically. In lieu of all these limitations connected

with paper based medical records, there arises a need to develop a simplified Electronic Medical Record (EMR) system to replace the paper based system putting a typical Nigerian hospital setting into consideration.

II. ELECTRONIC MEDICAL RECORD (EMR) TERMINOLOGIES

The terms EHR, EPR (electronic patient record) and EMR (electronic medical record) are often used interchangeably, although differences between them can be defined. The EMR can, for example, be defined as the patient record created in hospitals and ambulatory environments, and which can serve as a data source for the HER (Habib, 2010). It is important to note that an EHR is generated and maintained within an institution, such as a hospital, integrated delivery network, clinic, or physician office, to give patients, physicians and other health care providers, employers, and payers or insurers access to a patient's medical records across facilities (Kierkegaard, 2011). A personal health record (PHR) is, in modern parlance, generally defined as an EHR that the individual patient controls.

A. Comparing EMR with Paper Based Medical Records

Paper-based records require a significant amount of storage space compared to digital records. In the United States, most states require physical records be held for a minimum of seven years. The costs of storage media, such as paper and film, per unit of information differ dramatically from that of electronic storage media. When paper records are stored in different locations, collating them to a single location for review by a health care provider is time consuming and complicated, whereas the process can be simplified with electronic records. This is particularly true in the case of person-centered records, which are impractical to maintain if not electronic (thus difficult to centralize or federate). When paper-based records are required in multiple locations, copying, faxing, and transporting costs are significant compared to duplication and transfer of digital records. Because of these many "after-entry" benefits, federal and state governments, insurance companies and other large medical institutions are heavily promoting the adoption of electronic medical records. The US Congress included a formula of both incentives (up to $44,000 per physician under Medicare or up to $65,000 over six years, under Medicaid) and penalties (i.e. decreased Medicare and Medicaid reimbursements for covered patients to doctors who fail to use EMRs by 2015) for EMR/EHR adoption versus continued use of paper records as part of the Health Information Technology for Economic and Clinical Health (HITECH) Act, enacted as part of the American Recovery and Reinvestment Act of 2009.

One study estimates electronic medical records improve overall efficiency by 6% per year, and the monthly cost of an EMR may (depending on the cost of the EMR) be offset by the cost of only a few "unnecessary" tests or admissions (Evans et al, 2006). Jerome Groopman disputed these results, publicly asking "how such dramatic claims of cost-saving and quality improvement could be true" (Groopman and Hartzband, 2009). However, the increased portability and accessibility of electronic medical records may also increase the ease with which they can be accessed and stolen by unauthorized persons or unscrupulous users versus paper medical records, as acknowledged by the increased security requirements for electronic medical records included in the Health Information and Accessibility Act and by large-scale breaches in confidential records reported by EMR users (Ramunni, 1999). Concerns about security contribute to the resistance shown to their widespread adoption.

Handwritten paper medical records can be associated with poor legibility, which can contribute to medical errors. Pre-printed forms, the standardization of abbreviations, and standards for penmanship were encouraged to improve reliability of paper medical records. Electronic records help with the standardization of forms, terminology and abbreviations, and data input. Digitization of forms facilitates the collection of data for epidemiology and clinical studies. In contrast, EMRs can be continuously updated (within certain legal limitations). The ability to exchange records between different EMR systems ("interoperability") would facilitate the co-ordination of health care delivery in non-affiliated health care facilities. In addition, data from an electronic system can be used anonymously for statistical reporting in matters such as quality improvement, resource management and public health communicable disease surveillance (Patel et al., 2005).

Ambulance services in Australia have introduced the use of EMR systems. The benefits of EMR in ambulances include the following: better training for paramedics, review of clinical standards, better research options for pre-hospital care and design of future treatment options. Automated handwriting recognition of ambulance medical forms has also been successful. These systems allow paper-based medical documents to be converted to digital text with substantially less cost overhead. Patient identifying information would not be converted to comply with government privacy regulations. The data can then be efficiently used for epidemiological analysis (Milewski et al, 2009).

Using an EMR to read and write a patient's record is not only possible through a workstation but, depending on the type of system and health care settings, may also be possible through mobile devices that are handwriting capable. Electronic Medical Records may include access to Personal Health Records (PHR) which makes individual notes from an EMR readily visible and accessible for consumers.

Some EMR systems automatically monitor clinical events, by analyzing patient data from an electronic health record to predict, detect and potentially prevent adverse events. This can include discharge/transfer orders, pharmacy orders, radiology results, laboratory

results and any other data from ancillary services or provider notes. This type of event monitoring has been implemented using the Louisiana Public health information exchange linking state wide public health with electronic medical records. This system alerted medical providers when a patient with HIV/AIDS had not received care in over twelve months. This system greatly reduced the number of missed critical opportunities (Herwehe et al, 2011).

B. Technical Issues in EMR

There are a number of technical issues surrounding the creation and use of electronic records. A few of those issues are briefly discussed below;

- Standards

The following are some common standards that are used in Electronic Medical records;

- ANSI X12 (EDI) - transaction protocols used for transmitting patient data. Popular in the United States for transmission of billing data.
- CEN's TC/251 provides EHR standards in Europe including: EN 13606, communication standards for EHR information
- CONTSYS (EN 13940), supports continuity of care record standardization.
- HISA (EN 12967), a services standard for inter-system communication in a clinical information environment.
- Continuity of Care Record - ASTM International Continuity of Care Record standard
- DICOM - an international communications protocol standard for representing and transmitting radiology (and other) image-based data, sponsored by NEMA (National Electrical Manufacturers Association)
- HL7 - a standardized messaging and text communications protocol between hospital and physician record systems, and between practice management systems
- ISO - ISO TC 215 provides international technical specifications for EHRs. ISO 18308 describes EHR architectures
- xDT - a family of data exchange formats for medical purposes that is used in the German public health system.
- openEHR: an open community developed specification for a shared health record with web-based content developed online by experts. Strong multilingual capability.
- Virtual Medical Record: HL7's proposed model for interfacing with clinical decision support systems.
- SMART (Substitutable Medical Apps, reusable technologies): an open platform specification to provide a standard base for healthcare applications.

- Customization

Each healthcare environment functions differently, often in significant ways. It is difficult to create a "one-size-fits-all" EHR system. An ideal EHR system will have record standardization but interfaces that can be customized to each provider environment. Modularity in an EHR system facilitates this. Many EHR companies employ vendors to provide customization. This customization can often be done so that a physician's input interface closely mimics previously utilized paper forms.

At the same time they reported negative effects in communication, increased overtime, and missing records when a non-customized EMR system was utilized. Customizing the software when it is released yields the highest benefits because it is adapted for the users and tailored to workflows specific to the institution. Customization can have its disadvantages. There is, of course, a higher cost involved to implementation of a customized system initially. More time must be spent by both the implementation team and the healthcare provider to understand the workflow needs. Development and maintenance of these interfaces and customizations can also lead to higher software implementation and maintenance costs.

- Long-term preservation and storage of records

An important consideration in the process of developing electronic health records is to plan for the long-term preservation and storage of these records. The field will need to come to consensus on the length of time to store EHRs, methods to ensure the future accessibility and compatibility of archived data with yet-to-be developed retrieval systems, and how to ensure the physical and virtual security of the archives.

Additionally, considerations about long-term storage of electronic health records are complicated by the possibility that the records might one day be used longitudinally and integrated across sites of care. Records have the potential to be created, used, edited, and viewed by multiple independent entities. These entities include, but are not limited to, primary care physicians, hospitals, insurance companies, and patients. Mandl et al. have noted that "choices about the structure and ownership of these records will have profound impact on the accessibility and privacy of patient information."

The required length of storage of an individual electronic health record will depend on national and state regulations, which are subject to change over time. Ruotsalainen and Manning have found that the typical preservation time of patient data varies between 20 and 100 years. In one example of how an EHR archive might function, their research "describes a co-operative trusted notary archive (TNA) which receives health data from different EHR-systems, stores data together with associated meta-information for long periods and distributes EHR-data objects. TNA can store objects in XML-format and prove the integrity of stored data with the help of event records, timestamps and archive e-signatures."

In addition to the TNA archive described by Ruotsalainen and Manning, other combinations of EHR systems and archive systems are possible. Again, overall requirements for the design and

security of the system and its archive will vary and must function under ethical and legal principles specific to the time and place. While it is currently unknown precisely how long EHRs will be preserved, it is certain that length of time will exceed the average shelf-life of paper records.

The evolution of technology is such that the programs and systems used to input information will likely not be available to a user who desires to examine archived data. One proposed solution to the challenge of long-term accessibility and usability of data by future systems is to standardize information fields in a time-invariant way, such as with XML language. Olhede and Peterson report that the basic XML format has undergone preliminary testing in Europe by a Spri project and been found suitable for EU purposes. Spri has advised the Swedish National Board of Health and Welfare and the Swedish National Archive to issue directives concerning the use of XML as the archive-format for EHCR (Electronic Health Care Record) information.

- Synchronization of records

When care is provided at two different facilities, it may be difficult to update records at both locations in a co-ordinated fashion. Two models have been used to satisfy this problem: a centralized data server solution and a peer-to-peer file synchronization program (as has been developed for other peer-to-peer networks). Synchronization programs for distributed storage models, however, are only useful once record standardization has occurred. Merging of already existing public healthcare databases is a common software challenge. The ability of electronic health record systems to provide this function is a key benefit and can improve healthcare delivery.

C. The Future of EHR – Personally Controlled EHR

A Personally Controlled Electronic Health Record (PCEHR) is a system that proposes to store admission or event summaries in an electronic format over a large network accessible by doctors, nurses, GPs and chemists without the need for written scripts or requesting medical files from another hospital. The system proposes to record and store any health information provided by a health care professional that has agreed to be a part of the system. This allows the storage and retrieval of a lifetimes worth of clinical and demographic information of a patient that can be viewed as event summaries and reports with the appropriate authorization.

III. METHODOLOGY

In this Electronic Medical Record software development process, the design phase involved decomposing the system into modules and defining the relationship among the constituent modules. Top down design approach was employed in doing this. This involved dividing the system into sub-systems or modules and each sub-system being further divided into even smaller subs. This process of division was repeated until each module was sufficiently small enough to be conveniently coded (implemented) as an independent entity that performs a clearly defined operation.

A typical Nigerian hospital setting was analyzed and modeled in a bid to implement the appropriate EMR System that would accurately automate the usual manual operations carried out on a day-to-day basis. The Admin (the hospital records unit) manages the registration side of the software. When patients visit a hospital for the first time, they are given cards and card numbers (in the conventional manual way of operation). In this case, the hospital record logs on as admin to the system, and registers each new patient electronically as well as generates a unique patient ID for them. This ID is what the patients would use to access healthcare services at all the other sections of the hospital like; Doctors Section, Nursing Section, Accounts, Pharmacy, Laboratory e.t.c. This ID could either be sent to Patients phone, e-mail or printed out on a Card with other minute details like Patients name and Sex plus any other detail. This card would help the patient access all their records within the hospital via any unit, using the ID as the primary key.

The hospital records unit would also keep a log of eligible users at every other unit of the hospital, managing all user names and passwords being used to log on to the system

from all the units for security reasons. Figure 1 below shows the Class diagram for the System.

IV. DEVELOPMENT TOOLS

The development phase of this work was carried out using the .NET Framework (C Sharp Programming Language). The database was designed using MySQL Server DBMS. Microsoft's .NET Framework is a new computing platform built with the internet in mind, but without sacrificing the traditional desktop application platform. .NET is a collection that works together in a framework to provide the solutions that are needed to easily build and deploy truly robust enterprise applications. These .NET applications are also able to easily communicate with one another and provide information and application logic, regardless of platforms and languages.

The framework sits on the Operating System. Examples of Operating Systems that are currently compatible with .NET are; Windows XP, Windows 2000, Windows NT, Windows Vista and Windows 7. At the base of the .NET Framework is the Common Language Runtime (CLR). The CLR is the engine that manages the execution of the code. The next layer up is the .NET Framework Base Classes. This layer contains classes, value types, and interfaces that are often used the development process.

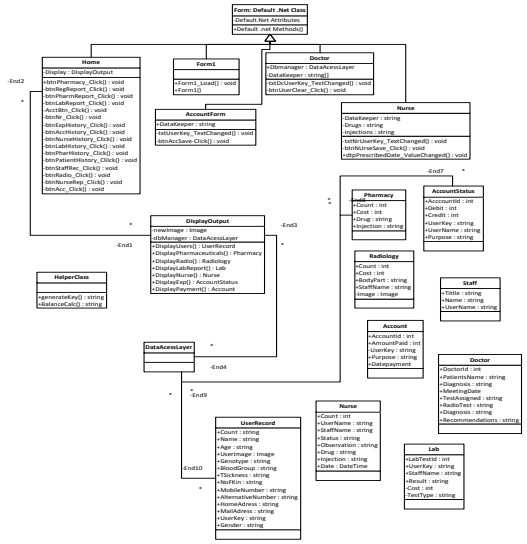

Figure 1 Class Diagram showing the design for the EMR System

V. RESULT AND DISCUSSION

The implementation of this work was done using Microsoft Visual Studio 2010 Integrated Development Environment (IDE). Visual Studio .NET is Microsoft's IDE for creating, documenting, running and debugging programs written in a variety of .NET programming languages. Visual Studio .NET also offers editing tools for manipulating several types of files .NET is the Microsoft Web services strategy to connect information, people, systems, and devices through software. Integrated across the Microsoft platform, .NET technology provides the ability to quickly build, deploy, manage, and use connected, security-enhanced solutions with Web services.

.NET-connected solutions enable heterogeneous systems to integrate more rapidly and in a more agile manner and help them to realize the promise of information anytime, anywhere, on any device. .NET is not just about easy-to implement components. .NET applications run under the control of a runtime called the common language runtime (CLR). CLR compiles all code at execution time, it implements strict type checking. Errors such as unsafe casting of one object type to another, addressing an array of bounds, or writing past the end of a buffer are just not possible. The common language runtime also manages security, allowing much finer control over the functions that a piece of code is allowed to perform and the resources it may access. The development and deployment of this work was carried out on a HP 630 Laptop Computer with the following specifications;

- 500 Gigabytes Hard disk
- 4 Gigabytes RAM (Random Access Memory)
- 4 Gigahertz Processor Speed (Intel Pentium Dual Core)
- A 64-bit Operating System (Windows 7)

The various components of the EMR System relate with each other dynamically and sequentially. After the developed system is successfully installed, the first operation is to get a new patient duly registered. Figure 2 shows the home page after the installed application is runned. The next thing is for any authorised user to log in so as to access the system in dispensing healthcare services. However, for any caregiver to have records to work on, patients must be first duly registered by the records unit, and be given patients ID. Figure 3 shows a successful patient registration.

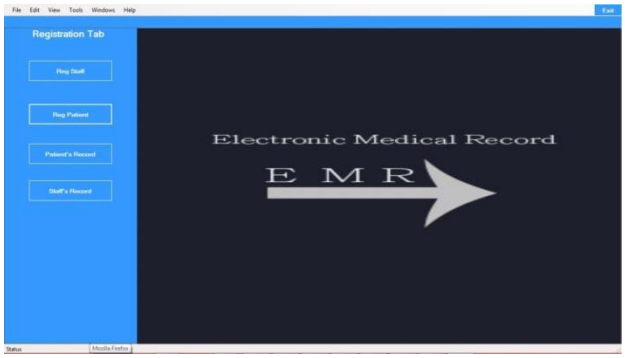

Figure 2: Home screen of the EMR System after running the installed application

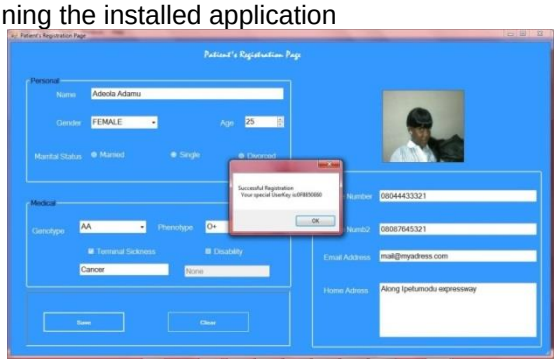

Figure 3: A successful patient registration

Once a Patient is registered and has a patient ID, this ID becomes his/her access code to be attended to at any unit of the hospital he/she needs to visit. Figure 4 shows a patient's record accessed by a doctor during consultation upon supply and entry of the ID. The doctor can then update the patient's record appropriately, and further refer the patient to other units of the hospital where the same would be done on the patients records. All these updates are done real time as such, it reflects immediately on the patient's record. Figures 5 and 6 show the doctor's log-in pages.

In the same vein, other units of the hospital can access and make necessary updates on the patient's record once their patient ID is supplied. The security of patient's information is a reason why that ID is only known and unique to individual patients, and also only authorized personnel are given access into the EMR System in each unit of the hospital. Figures 7 to 12 capture the activities carried out within the system from unit to unit.

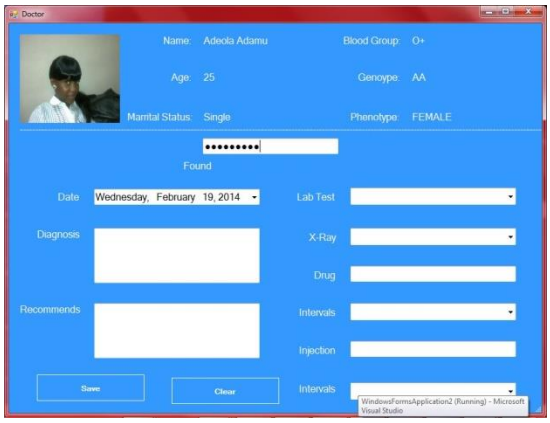

Figure 4: A patient's record updated by the doctor upon entering the patient's ID

Figure 5: The Doctor's log-in page

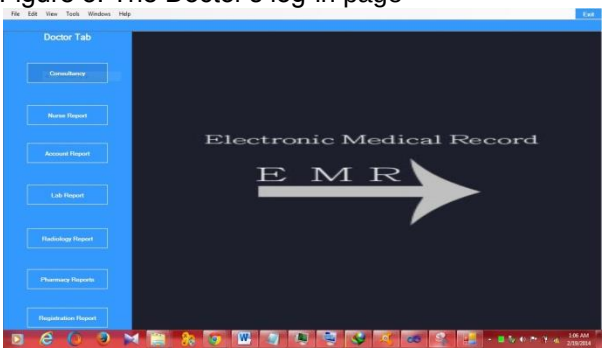

Figure 6: Full options in a doctor's login page

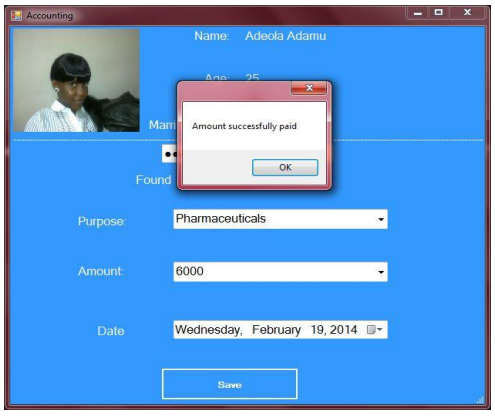

Figure 7: the account section carrying out a payment update on a patient's record

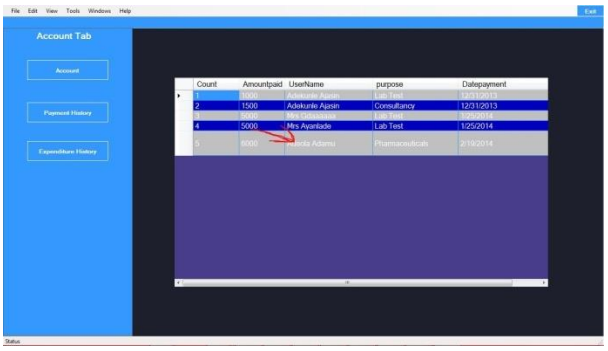

Figure 8: Payment histories of Patients

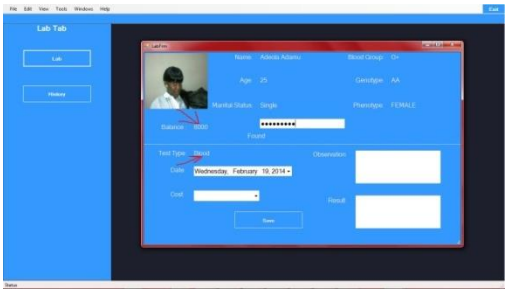

Figure 9: Patient's record being accessed at the Laboratory Unit

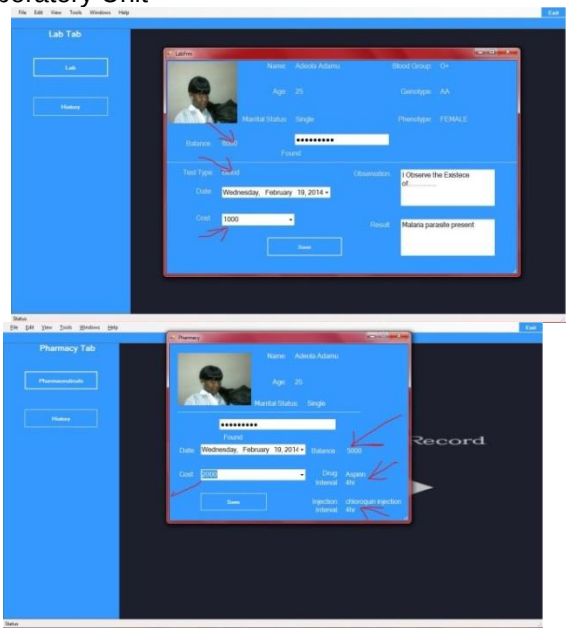

Figure 10: Deductions made on patient's account after a Laboratory test is carried out

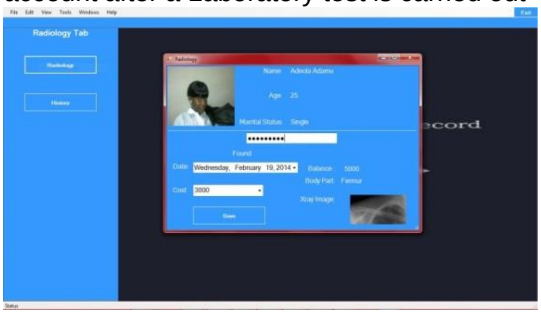

Figure 12: Changes made on the patient's record at the radiology unit.

VI. CONCLUSION AND RECOMMENDATIONS

This work presents the implementation of a simple Electronic Medical record system that tries to automate the manual day-to-day paper based record system of a typical Nigerian hospital. The EMR System designed in this work incorporates the duties of the; hospital records unit, doctor's unit, nursing section, laboratory services, accounting section and even the radiology unit of the hospital together. Through this system, each of these units can access individual patients record (upon getting their patients ID from them), and then make necessary updates. The coding was done from scratch using the .NET Framework (C Sharp Programming Language) as the frontend and MySQL Server as the database backend. The EMR software developed is secured and dynamic enough to provide exclusivity and integrity of patients data, and to circumvent every problem associated with the paper-based system of hospital records.

Given the constant increase in the development of Information and Communication Technology (ICT) in every sector of our economy, there arises a need to continue to harness both as tools for delivering qualitative and secured healthcare services. Hence the following recommendations are made:

- The government and the stake holders should make sure that all government and private hospitals and healthcare institutions are equipped with enough ICT equipment that will enable them to gradually swap from the old and stressful paper based patient record system to the fast, easy and secure Electronic Medical Records System.
- Health workers (e.g. Doctors, Nurses, Pharmacists, Radiologists, Laboratory Technicians e.t.c.) with little or no computer knowledge should be encouraged across board to embrace ICT related skills so that this technology can be more adaptable to their work.

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