

Patient Data Integration: A Panacea for Effective Healthcare

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Abstract: A huge challenge in the healthcare domain has remained the spread and proliferation of fragmented information systems and multiplicity of data that accumulate from growing quantities of heterogeneous data of patient. This challenge must be addressed as the whole domain gradually transforms into models of delivery of healthcare that is electronic and patient-centered. The presence of inadequate data integration at various levels incapacitates medical personnel from building a wholesome and total understanding of patient condition. In this paper, an integration platform called Integrated Patient Management System (IPMIS) for managing clinical and historical information for patients is incorporated. Previous systems could not undertake the problems like; delay in treatment of patients in cases of emergencies, wrong prescription of drugs due to wrong diagnosis as a result of unavailability of patients' history, lack of health data interoperability and loss of life. Seeking solution to the above problems led to the development of an Integrated Patient Management Information System (IPMIS) that enables patient clinical data sharing, provides streamlined operations, enhances administration and control, permits superior patient care and continuity of treatment, and improved decision making for healthcare institution. This paper enhances patient's referral, with a messaging system that alerts the hospital which the patient has been referred to and also the patient that is referred. The development of the system helps to collate patient's data that are disparately located to a centralized data base for efficient interoperability of care. It also helps for the interoperability of multiple hospitals for effective patient management. The new system enables and provides timely patient health record information sharing where it is need and when it is needed in cases of emergencies, referrals or continuity of treatment and it is presently being used in a federal teaching hospital in Nigeria.

Keywords: Integration, Security, Data Interoperability, Information Technology, Healthcare

Introduction

Background to the Study

Today's operational environment is dynamic and undergoes rapid changes as a result of technological innovation, increased awareness and demands from users. The healthcare industry of the 21st century is not left out as it operates in a competitive environment characterized by changing conditions and highly

unpredictable socio-economic forces. Information technology has remained at the centre of this global change curve. Hassey (2015) contended that managers of industries cannot ignore information technology because of its critical role in the contemporary organization especially in healthcare.

Ouma and Herselman (2018) defined healthcare as a set of activities geared towards providing medical related services which is aimed at maintaining health especially through prevention and treatment of diseases. Healthcare

therefore acts as a contributor and an indicator for the sustainability and development of a nation. Most ill-health conditions have weighty impacts on the economic growth and development of a nation.

Most human beings value being healthy, which implies a total state of mental, physical, social well-being and as well as absence of any illnesses. It is absolutely necessary that we understand the factors affecting the health of a nation and how such can lead to national development. In terms of sustainable development of a nation, human beings are always at the center and are as such entitled to a healthy and functioning healthcare system. Aniekwu (2006) agreed that public health and human rights help to promote and protect human dignity and wellbeing. Due to functional healthcare system in Nigeria over the decades, average life expectancy has increased. This also led to decline of infant and child mortality rates (Onwujekwe *et al.*, 2010).

Health has become a major concern in national development. Goldman and McGlynn (2005) asserted that good healthcare system plays a substantial role in national development. Poor healthcare system affects national development and growth through labour productivity and economic burden.

Despite undoubted health improvements and advancement in many areas, poor health has continued to be a setback on development efforts. In some cases the process of development itself is creating conditions where, as a result of economic, political and social upheaval, environmental degradation, and uneven development or increasing inequities, human health suffers. Nnamuchi (2007) found that Several Nigerian healthcare crashes have been experienced. The nation is significantly underserved in the healthcare sphere despite its strategic place in Africa. In this nation, particularly in rural regions, health services (health centers, staff and medical equipment) are insufficient. Although the Nigerian government has put forward numerous reforms to tackle the wide-ranging problems in the healthcare system, they still need to be implemented at the level of the state and local government. The healthcare system continues weak as demonstrated by absence of coordination, fragmentation of facilities, scarcity of resources, including drugs and supplies, insufficient and declining infrastructure, inequity in the allocation of funds and access to care and highly deplorable quality of care. It also discovered that the absence of clarity of positions and duties between the various levels of government compounded the scenario (Regli *et al.*, 2010).

Healthcare In Nigeria, as in many other nations, the demand for conventional treatment and services is on the increase. Shortell *et al.* (2000) contended that Nigeria's health care system performance is not under the spotlight as it deserves. The country's healthcare reform would not accomplish what it sets out for if the efficiency evaluation and governance of the healthcare system were

not on the government's policy agenda. This is because, health workforce is central to achieving health of a nation. A well performing workforce is one that responds to the needs and expectations of the people, is fair and efficient to achieve the best outcomes possible given available resources and circumstances. Countries are at different stages of development of their health workforce but common concerns include improving recruitment, education, training and distribution, enhancing productivity and performance; and improving retention with integration of datasets (Naveh and Stern, 2005).

In general, professionals and other actors in the healthcare industry face data overload and information shortages quite often. Heeks (2006) argued that Critical data needed for surgery or medical care on brief notice can lead to problem when it cannot be accessed instantly in order to save life. This has called for dynamism in the management of information in order to provide fast and reliable information storage and retrieval. When a patient visits the local doctor, the starting point of the doctor is to look for the medical history of the patient so that he can make correct and decisive decision. This often requires manually locating the patient's folder using the patient's hospital admit card. This can really be an ugly experience in cases of emergency where saving life depends on decisions made within split of seconds. Many Nigerians have lost their lives in emergency situations like road accidents, natural disasters, fire outbreak etc. This is because at such critical time, the patient may not have his or her hospital admit card, and as such his or her medical history may not be ascertained and any decision taken by the doctor at such time might be a guess work which may lead to the patient's death.

In this system, patients' records can be centralized in a database and access to it can be from any hospital within the country. Patients can be identified by only a unique location code which is unique to that patient alone. With such a method, any doctor might be able to continue with the treatment of the patient anywhere the patient may be. With this kind of centralized dataset, patients can be treated in any hospital in cases of emergencies and doctors can still have access to the patient's medical history which will lead to improved healthcare delivery in our country Nigeria.

In order for the healthcare industry to become efficient and effective organizations in meeting demand, it is suited that they adopt data management principles. Through the development of information technology (IT), current and future medical data and information can be leveraged to develop knowledge-based solutions that facilitate collaboration amongst institutions and address the demand for healthcare by improving record management, and the development of more efficient methodologies to diagnose and treat patients in a timely manner.

Draw Backs to the Existing System

The absence of a well secured operational information system to serve patients has led to inconveniences. There are problems which the existing system faces. In most hospitals today, especially the public ones, information flow is not guaranteed due to their methods of operation. Some hospitals however, still need some business process improvement. The present system being understudy has some limitations and problems which have necessitated for improvement. This Integrated System solves the following problems:

- i. Lack of patient's data integration.
- ii. Lack of real-time update and report generating system.
- iii. Inability of multiple hospitals to share patient clinical data.
- iv. Lack of security of patient data.
- v. Lack of information flow in cases of referrals

Efficacies of the System

This system is very important and beneficial in that it will help to share the same data within and across healthcare institutions. It is a system that will support effective and efficient healthcare delivery in that it will help for efficient continuity of care giving. It offers streamlined activities, improved administration and control, superior patient care, thorough control of costs and improved effectiveness. For example, A hospital surgeon records an operated patient's diagnosis and therapy in an operation report. Any other hospital that the patient may visit may refer to such report. This is because for statistics on patient care and quality management, diagnosis and treatment are essential.

This system will be so significant in that its two-layered secured node will guarantee privacy, secrecy and confidentiality of patient data. It's needful to integrate these subsystems to boost care-giving to patients. This will create a rich database for decision making to the government. With this security feature of two layered security structure, patients will be confident that their clinical data will be well secured.

Another significance of this system will be that of improve efficiency for inter hospitals communication. This system will provide much relief to patients and to health workers because it will help to facilitate referrals and inter-hospitals exchange of care within seconds. The system messaging aspect will alert another hospital where a patient is referred to that such a particular patient with such problem has been referred to them. This system will enable the hospital to be at alert in preparation of the patient's arrival so that there will not be delay in saving the life. The patient that is referred

will also get an alert that he or she has been referred to a particular hospital.

The system will support continuity in patient's treatment even across hospitals. It will help a healthcare organization not to face adversities such as missing records, delay, or duplicated records of patient. This is possible because of the patient unique location identification code.

Policy makers will find this system very important as it will guide them in the right decision making for the good of the citizens towards their healthcare.

Review of Related Literature

Health is a significant factor in the growth of human resources, which will play a crucial part in the improvement of human characteristics as the active agents of economic development. Many health challenges are currently facing developing countries. Issues such as waterborne disease and nutritional deficiency have an impact on many low-income people worldwide. So the task of healthcare improvement in Nigeria is likely to stay unsure just as income and living standards are gradually deteriorating. However, the need to find ways of strengthening healthcare systems is urgent in the face of these challenges. Whereas stronger health systems may come as a result of increased resources, there is need to maximize every available resources so as to operate an efficient healthcare systems in Nigeria. The perspective for effective application of healthcare information systems (HIS) is really good. Accessibility is anticipated to be increased, medical errors reduced, expenses reduced and healthcare quality improved. Blumenthal and Tavenner (2010) asserted that Implementers and promoters of Healthcare Information Technology (HIT) continue to support these advantages as possibilities for healthcare industry conversion. Yamamoto (2006) stressed that optimizing the documentation of patients, improving communication of information to physicians, improving access to patient medical information, reduction of errors, optimizing billing and improving reimbursement for services and forming a data repository for research and quality improvement are gains for integrated healthcare systems. Nevertheless, the journey to this ideal is fraught with challenges. These challenges range from issues arising from the very nature of healthcare information, to the issues pertaining to healthcare information technology and its users.

Health Management Information Systems

Health Management Information Systems are systems that allow the recording, storage and processing of health information for effective policy making, planning, execution and assessment of health programs (Evans and Stansfield, 2003). This systems help for

accurate decision-making right from the institutional levels to national level. When there is evidenced based decision-making in healthcare institutions, scarce resources in the country will be appropriately maximized. We conducted a cross sectional descriptive research and analysis in many healthcare institutions. During our researching, we found that Health Management Information Systems need a review due to the present health data management in hospitals and trans-institutional organization. There is a lack of precise and explicit decision-making owing to absence of understanding, inadequate analytical abilities among health employees and absence of training in the use of information systems that led to poor reporting.

Haux (2006) discussed major evolutionary developments from the primitive hospital information systems to the health information systems as we know them today. There is still an existing huge gap in the knowledge of Health Management Information Systems (HMIS). Our findings buttress that existing HMIS has not been institutionalized in the sense of being integrated in the daily activities of healthcare institutions, which is an essential factor for healthcare sustainability and reliability in the country Angelo (2010). The research work will aim at strengthening the capacity of HMIS timely and high-quality data in a helpful form for both the public and private healthcare institutions at all levels. It also seeks to promote innovations in health status surveillance and assessment. We posited that reformed and robust health management information systems will be able to harness the gathering danger of poor data management and lack of integration among healthcare institutions to achieve accelerated achievements in shared care.

In the present HMIS, the key issues of health management information systems which encompasses transmission of data to potential users, movement of secured data throughout the system, accessibility and analyzability and continuity of care due to the availability of data, integration of data and multiple healthcare institution data exchange have not been addressed efficiently. These key issues will ensure quality health data exchange, thereby strengthening the ability to analyze data that will invariably lead to informed decision-making. There is deficiency of information infrastructure in the current HMIS. The network in place now is very vulnerable to external interferences. Also, there is a significant underutilization of data and lack of timely reporting and feedback mechanism (Bozeman *et al.*, 2017).

However in this model, patient data are captured from different clinical application nodes and are integrated in a clinical data repository. Patient care data are aggregated for analysis in analytical database. This can be used to generate insight into patient care processes and to monitor performance. This system has a

key feature to permit information exchange across institutional boundaries. This would provide more complete patient information and better care coordination and continuum enablement. This is unlike the traditional model where most data exchange has mainly occurred within boundaries of large healthcare institution. This system will improve data linkages with and among smaller healthcare institutions. The system would be able to use data exchange standards as that of Health Information Portability and Accountability Act (HIPAA) to send and receive important patient data (Hassey, 2015).

In many countries, the driving force for healthcare and for ICT in healthcare has recently been the trend toward a better coordination of care, combined with rising cost pressure. One of the consequences is the shift toward better integrated and shared care. This means that the focus changes from isolated procedures in one healthcare institution (e.g. one hospital or one general practice) to the patient-oriented care process, encompassing diagnosis and therapy, spreading over institutional boundaries.

Hospital Management

A hospital is an organization that mobilizes the skills and efforts of a widely divergent group of professionals, semi-professionals and other personnel to provide highly personalized personal services to patients Malhotra (2009). World Health Organization (WHO), defined hospital as an integral part of social and medical organization that provides complete curative and preventive health care and treatment to people. Hospitals are the focal points of education for the health professionals and clinical research necessary for advancement of medicine. Thus, hospital is one of the complexes of all administrative organizations. It is a place where individuals are provided with appropriate care and treatment (Groene *et al.*, 2012). Hospitals are healthcare organizations with organized medical and other skilled employees, with 24-hour services (WHO, 2010). While Management in the other hand is the method of developing and sustaining an atmosphere in which people effectively achieve chosen objectives by working together in organizations. Therefore, Hospital management system is a system that streamlines business practices of hospitals towards acquisition, analysis and protection of digital and traditional medical data essential for the provision of quality patient care. It ensures the optimum use of medical records of patients through its electronic patient information system. High scalability guarantees a rapid upgrade when changes are made to the hospitals business practices making patient care regains its top priority with physicians and hospital personnel. It offers the advantages of streamlined activities, improved administration and control, superior

patient care, comprehensive price control and improved profitability. Health sector using information systems effectively achieves the goals, efficiency, effectiveness, and quality of services as well as patient satisfaction, which are a fundamental necessity (Nasiripour *et al.*, 2014). There is a positive relationship between accuracy, quality of information content; information and access to information have improved the response and positively related and significant. The lack of relationship between users' satisfaction and quality improvement system meets the expressed need for administrators to upgrade the system software and hardware to better satisfy its users to increase the efficient use of hospital accountability level hospital information system Fakhraddin (2016). Hospital management system not only provides improved decision making in healthcare but also helps in developing the organization which is an important and effective role in nation's development Gholamhossein and Sadeghi (2012).

Requirement Analysis of the Proposed System

The proposed system will undertake a two-layered security approach towards securing patients clinical data. This system will alert any patient that has been referred to a particular hospital of such referral. In addition, the hospital where the patient is referred to, will be notified about the coming of a referred patient. This will help the hospital to prepare aforetime before the arrival of such patient. As this is done, it will eliminate the cases of loss of life especially during emergency. This system will work effectively for continuity in treatment across boundaries. This is because; every registered patient will have a unique patient identification code which can be used to reference his appointment or to continue in treatment. It will help for referential identity in the system. The issue of loss of data due to some uncertainty is critically taken care of in this system because the central data bank collates all patients across the country through the different platform where they are registered.

With the aforementioned problems that are associated with the current system, the proposed system has a better leverage against the odds. The proposed system has a good decision support system that assists users in making decisions on care options. The system gives health care institutions full patient demographics, progress note, medication, past medical history, laboratory data across hospitals. The proposed system has two-layered quantum cryptographic methods for data security. With integration of patient data, we believe that lives cannot be lost easily in cases of emergencies and referrals. The system allows for data sharing across hospitals for continuity of patient treatment and care. Due to increasing mobility of patients, this system helps to treat patient anywhere in the country because medical practitioners will easily access the medical history of such patient. This system will help policy

makers in the health sectors because Information is regarded a vital asset and an essential component in the pursuit of decision-making efficiency and effectiveness. This new system is designed to keep track of patient data not just within a hospital but across hospitals to improve efficiency in management of care.

Integrated Patient Management Information System (IPMIS) goes beyond the data collected in the provider's office and includes a more comprehensive patient history. The Security Rule extends to health plans, health care clearing houses and any health care provider that relays medical information electronically in conjunction with a transaction for which the health ministry has established requirements under HIPAA (the "covered entities") and its enterprise affiliates. For example, IPMIS is designed to contain and share information from all providers involved in a patient's care. IPMIS data can be created, managed, and consulted by authorized providers and staff from across more than one health care organization (Wootton *et al.*, 2006).

Far more so than EMRs, IPMIS also enables the medical history of a patient to switch with them to other health care providers, professionals, hospitals, nursing homes, and even across states. It has the ability to quickly provide care in a crisis. It provides instant access to information about a patient's medical history, allergies, and medications. This can enable providers to make decisions sooner, instead of waiting for information from test results.

The Fig. 1 shows a graphical representation of distributed database which holds the data for every hospital, the process of accessing the data from the database/data bank requires double authentication process to validate the information from the database in respect to the request sent by the user/hospital. In this two layered security measures, the user can create account on the general database which serves as a platform but such user cannot access any record from any hospital unless the hospital verifies and validate his entries.

Functional Requirement of the Envisaged System

The following is the desired functionality of the proposed system:

- The system should authenticate the users of the system.
- The system should generate reports on request.
- The system should only allow the administrator to delete records in the database
- The system should be able to refer patients to other hospitals
- The system should be able to keep the medical history of patients
- The system should be able to accept new users
- The system must have a two level layer of security
- The system must be platform independent

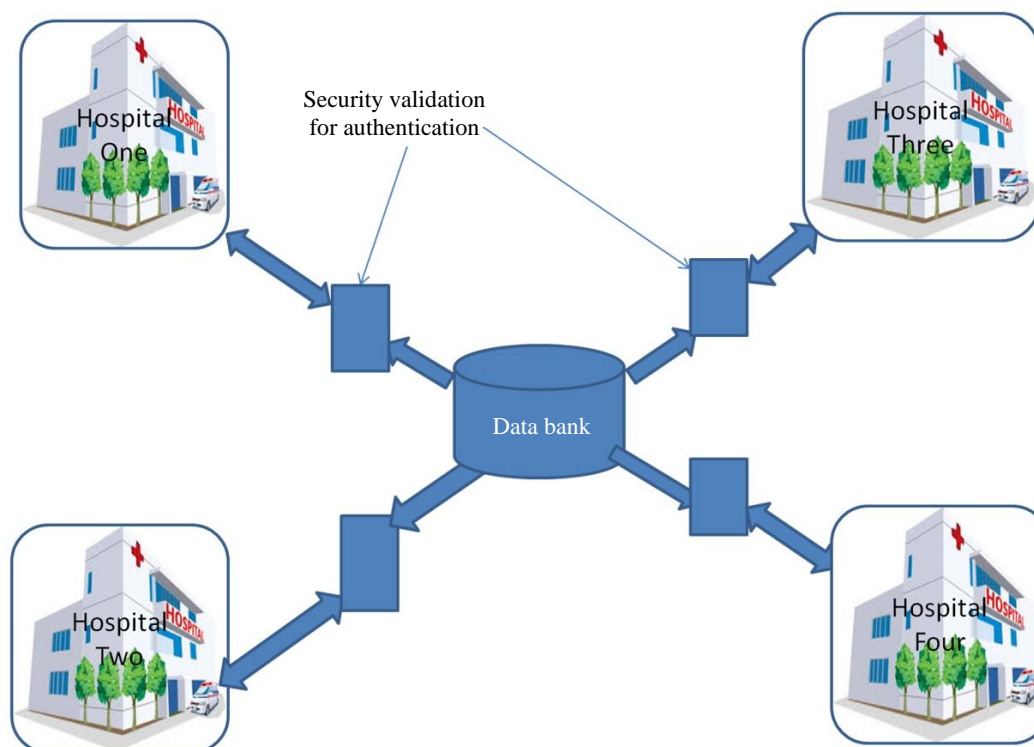


Fig. 1: A two-layered secured architecture of the envisaged system

Integrated Patient Management Information System (IPMIS)

This is a system that collates and integrates patient's data from different sources (wards, out-patients, pharmacy, inpatients, appointments, doctors etc), so that reports can be produced for clinicians, managers and administrators to enable them manage the patient and the services they need, and to allocate resources appropriately. The Integrated Patient Management Information System is conceptually a data warehouse that integrates data from multiple sources, and also reflects and supports the various practices around the registration, processing, analysis and use of data for decision making.

Prasser *et al.* (2018), it is worthy to note here, that the proper application of management Information system, (MIS) to healthcare system will help monitor its information flow and processing. The key to efficient Integrated Patient Management Information System administration and management is the accessibility of accurate, valid, and qualitative data. The application of Information Technology (IT) to support and improve the delivery of healthcare has rapidly evolved in the last decades and now considered an essential component of an effective business model. The ability of Information Technology to support tracking of patient information and coordination of human and capital resources to speed up

response time and guide patient remain invaluable to administrators and care providers Swartz (2015).

Longest *et al.* (2000) defined management as a method consisting of social and technical tasks and operations that take place within organizations in order to achieve predefined goals via human capital and several other resources. Healthcare quality and patient safety are the common mantra of all primary and secondary healthcare providers.

Okemiri *et al.* (2016) asserted Management Information System as a system using structured processes to report on management, supervision and tracking of organizational tasks, resources or other functions using computer systems.

Hospital Management System Provides the advantages of streamlined activities, improved administration and control, superior patient care thorough control of costs and improved profitability. This is possible using the information technology tools. It is also expected that the use of IT in diagnostic and treatment processes will add to the development of networks of clinical, hospital and healthcare processes.

In a related study Mursaleen *et al.* (2017) noted that it is hard to achieve precise diagnoses without the use of IT systems. He also argued that IT helps with diagnosis and offers plans to support decision making that reduces costs. Using IT systems, more or different patient and treatment data can be obtained for better care dispensary.

Furthermore, a system can alert doctors or medical personnel to any adverse effect relating to the drugs offered to a patient. If people are a country's principal asset, then their health status defines the course of development. Nigeria needs investment in health research and innovations.

Health Information Systems

Health Information Systems are computer systems that capture, store, process, retrieve, display and transmit data in education, administration and research on a timely basis. It is also a mechanism that integrates information collection, processing and reporting to improve the effectiveness and efficiency of health services at all levels. The future of medicine still lies on Information Technology as the latest research is now geared toward developing expert systems that has adequate human intelligence to represent doctors in some specialized areas like neurosurgery Malliarou (2006). Using information systems has many advantages. Not only do they decrease errors and boost the pace of care and precision, they can also decrease health costs by orchestrating services and enhancing care quality.

Healthcare quality and patient safety are the common mantra of all primary and secondary health care providers. In hospitals, over the years, a variety of models and schemes for hospital interventions and development have been deployed. The healthcare Information system management is in three tiers; tertiary healthcare- provided by the Federal Government of Nigeria (FGN), mostly coordinated through the university teaching hospitals and federal medical centers. The secondary healthcare provision is by the state governments which manage the General Hospitals. The third tier is the Local Government (774 LGAs) focuses on primary health care services administered in the dispensaries. It is the primary health care that suffers the most neglect. The health sector suffers from the dearth of qualified healthcare personnel and regulations, as Nigeria's promising doctors, pharmacists, nurses and other health professionals continue to leave Nigeria to apply their services more profitably in other countries. Nigerians are being denied quality healthcare services, especially those in the rural areas (HDR, 2013).

It is still of importance that elimination of diseases and improvement of individual health will enhance income earning capacity WHO (2010). Nigeria's health reform agenda is well articulated in the National Economic Empowerment and Development Strategy (NEEDS), engineered by the National Planning Commission NPC (2004). The goal of this health reform is to improve the health status of Nigerians in order to attain a globally acceptable level of poverty reduction. Aranda (2010) maintained that the major reason for

health expenditure is the expectation of improved health status, and that health status is governed by health investment. The demand for health care is derived from the demand for health itself. Both healthcare expenditure and improved health status are means to an increased productivity and national development.

The deployment of Information Systems have improved the accuracy, speed and reliability of many of the administrative and technical tasks traditionally involved in patient care beside improving the services offered to the patients. This has change the workload of healthcare professionals, allowing them to spend more time on the human aspects of patients care. Management Information Systems help to input data, process data into information, storage of data and information and the production of output such as management reports Poissant *et al.* (2015).

Health Level Seven Development Framework

Health level seven (HL7) is a Set of specifications globally recognized for the transfer of clinical and administrative information by most hospitals and medical centres. Health Level 7 is the highest level of the Open Systems Interconnection (OSI) communications system for the application layer of the International Standards Organization (ISO). as can be seen in Fig. 3. It is the American National Standard Institute (ANSI) that operates in the healthcare arena. It is a protocol for data exchange between computer systems in healthcare environment. It describes texts as they are shared as well as how they are exchanged. Health Level seven focuses on clinical and administrative data domain. There are two versions of HL7 messaging standards. These are the HL7 v2.x which is syntactic in operation and the HL7 v3.0 which has semantic capability added to it. Mauro (2005) posited that HL7 will establish an infrastructure for healthcare interoperability. The exchange of patient's information requires suitable mechanisms to secure.

Figure 2 illustrates some of the standards developers would be utilized by a Healthcare Information System. These standards are the most efficient ways in which cost-effective interoperable systems can be developed.

From the chart we found that Clinical System, Immunization Database, Agency Reporting, Adverse Event Reporting Provider Repository, Waveforms use Health Level seven (HL7) standards to communicate with Health Information System. Retail Pharmacy Order and Reimbursement uses National Council for Prescription Drug Programs (NCPDP), Images, Pictures use Digital Imaging and Communications in Medicine (DICOM), Bedside Instruments use Institute of Electrical and Electronics Engineers (IEEE), American Society for Testing and Materials (ASTM).

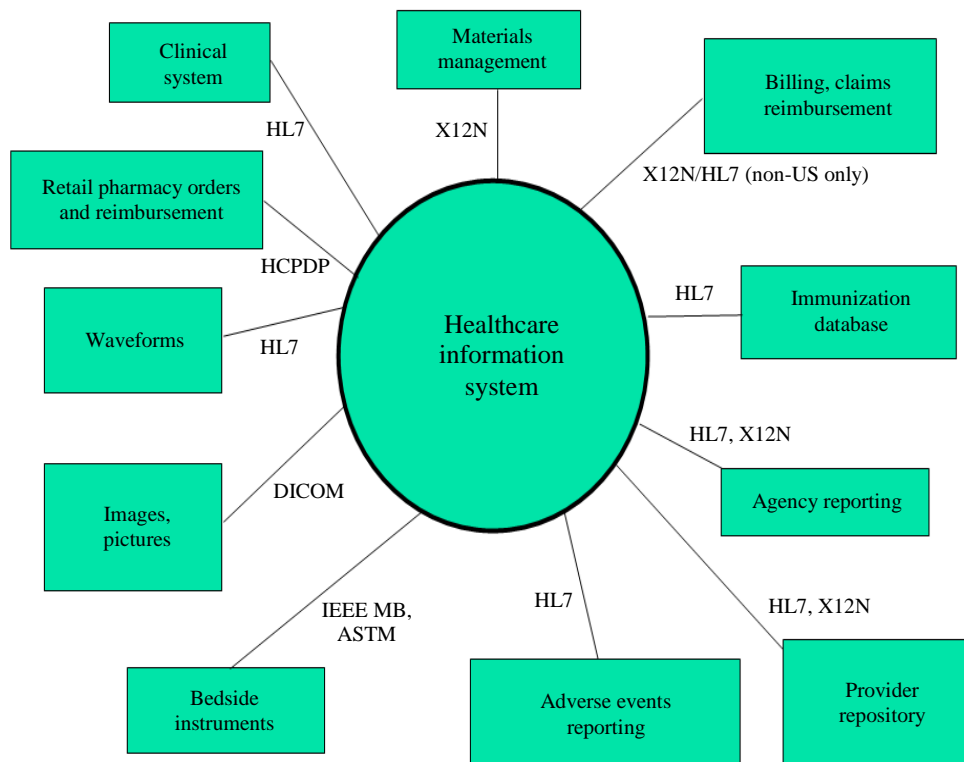


Fig. 2: Typical healthcare information system with standards. HL7, 2006

The 7 layers of OSI

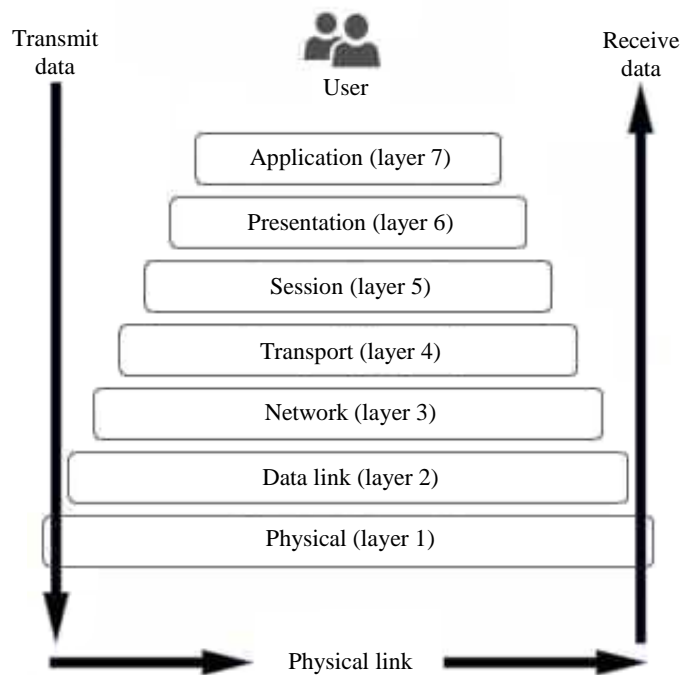


Fig. 3: The OSI model for ISO

Supachai Parchariyanon

The seven relates to the ISO communications model's seventh layer. This is the layer responsible for data formatting and framework. It describes and transfer file structure and maintains compatibility between distinct systems and provides standards for interoperability. The Fig. 3 shows the layers of the OSI model where the seventh layer is for the Health Level seven.

Application of Cryptography to Health

Cryptography is the art of hiding information in a string of bits meaningless to any unauthorized party. In the context of the Health Information Exchange (HIE), there are many shared and overlapping interests around privacy and safety problems. Best practices in privacy and safety related to protected health information (PHI) are the cornerstones of the relationships of confidence needed for the exchange

of health data throughout the care continuum. Many of these problems and solutions are not peculiar to healthcare and can be learned from other information-intensive sectors such as banking, payment cards, insurance and finance.

To achieve this goal, one uses encryption. This is the process whereby a message is combined according to an algorithm with some additional secret information, the key, to produce a cryptogram as shown in Fig. 4. In the traditional terminology, Alice is the party encrypting and transmitting the message, Bob the one receiving it, and Eve the malevolent eavesdropper. For a crypto-system to be considered secure, it should be impossible to unlock the cryptogram without Bob's key. In practice, this demand is often softened, and one requires only that the system is sufficiently difficult to crack. The idea is that the message should remain protected as long as the information it contains is valuable.

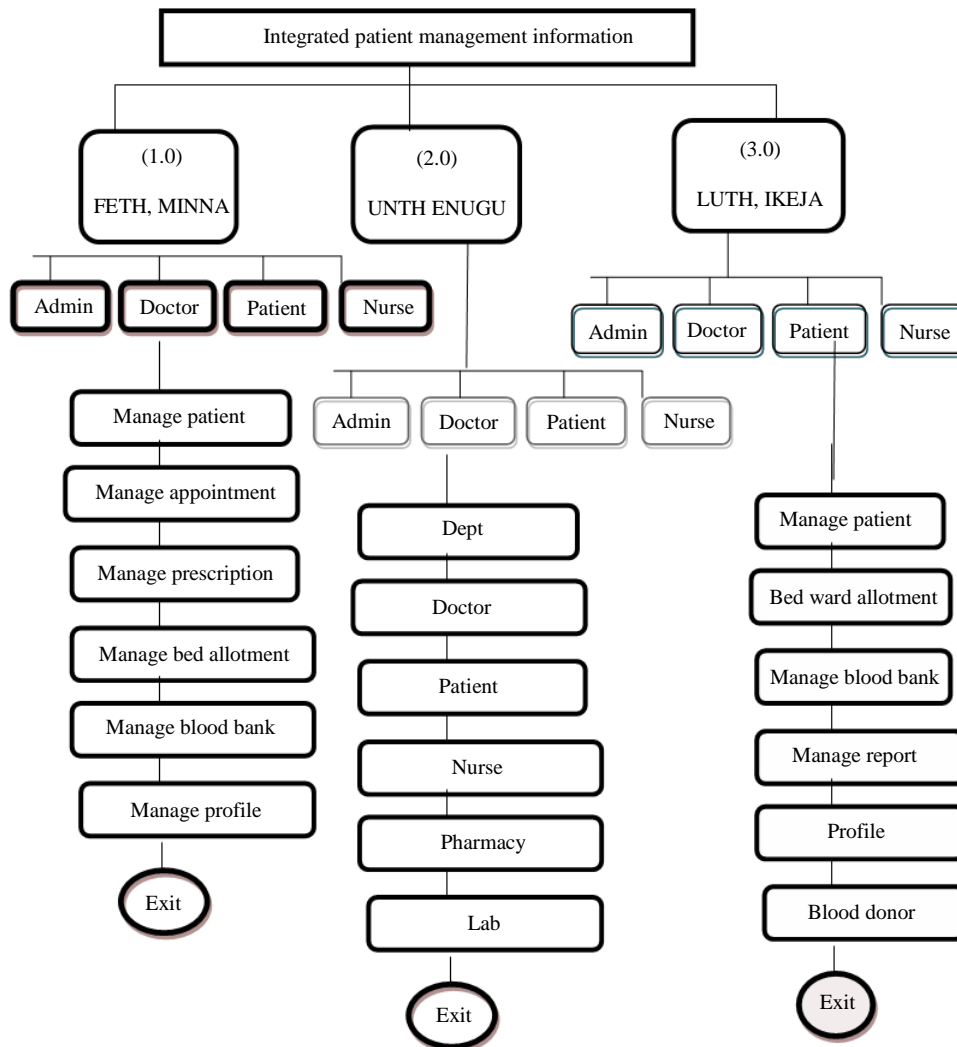


Fig. 4: Process diagram of the proposed system

Cryptography is an area that has developed suitable mechanisms for securing digital information. The use of cryptography for securing patient's data prevents attacks that can disclose personal information, thereby making the data authentic, confidential and also to have integrity as it passes down the networks from several nodes. There are two families of encryption algorithms that are based on symmetric and asymmetric approaches. In symmetric algorithms, a private key is used to encrypt and decrypt a message. In asymmetric algorithms, a pair of keys is used which are the private key and the public key. The private key is used to encrypt and public key to decrypt. Haque *et al.* (2014), asserted cryptographic system should be used to secure communication between mobile devices and the electronic medical recording scheme. Symmetric and asymmetric cryptography are used for secure data communication across networks.

However, in this research we employed quantum cryptography algorithm, which is suitable to protecting a patient's data when they are exchanged through the network even under the nose of eavesdropper.

Health Information Privacy Regulations

In the last four decades, the Nigeria healthcare industry has undergone revolutionary changes, driven by advances in information technology and legislation such as the 1973 Health Maintenance Organizations Act. As personal health information is digitized, transmitted and mined for effective care provision, new forms of threat to patients' privacy are becoming evident. In view of these emerging threats and the overarching goal of providing cost effective healthcare services to all citizens, several important federal regulations have been enacted including the Privacy and Security Rules under Health Insurance Portability and Accountability Act (HIPAA) 1996 and State Alliance for electronic health.

HIPAA was enacted to reform health insurance practices as a step towards moving to a nationwide electronic health records system and standardizing information transactions. The goal was to reduce costs by simplifying the administrative processes to provide continuity of care services. The Health Insurance Portability and Accountability Act (HIPAA) aligns with state requirements in defining and monitoring access to safeguard health information while allowing permitted consumers to access the minimum data needed for continuity of care. Policies, rules and arrangements should be created to guarantee that only those users (and roles) that have a particular need to access the data are given access to the data. The technology component involved in managing health information and necessity of disclosure to third parties has led to stipulations of privacy compliance and provision of security safeguards under HIPAA (Mursaleen *et al.*, 2017). The Privacy Rule of HIPAA addresses the use and disclosure of a patient's protected health information by healthcare plans, medical

providers, and clearinghouses, also referred as —covered entities. By virtue of their contact with patients, covered entities are the primary agents of capturing a patient's health information for a variety of purposes including treatment, payment, managing healthcare operations, medical research, and subcontracting. The Security Rule of HIPAA requires covered entities to ensure implementation of administrative safeguards in the form of policies and personnel, physical safeguards to information infrastructure, and technical safeguards to monitor and control intra and inter organizational information access.

Analysis of the Design Process

This is the first among the two login subsystems. Here in the first login, only authorized user with the appropriate login details will have access to the main home page of the system. When wrong user name and password is used the system rejects the access.

This is the first login subsystem menu which allows the user an access to the central database and also gives the user access to the subscribed hospitals. It grants users the privileges of viewing registered hospitals (Fig. 5).

System Main Menu

This is the second page where the system will take the user to if access were granted in the first login page. At the home page of the central system, there are multiple hospitals in different locations which communicate to share patient clinical information (Fig. 6).

This is the second layer of the main system. It shows the names and logos of the registered hospitals. For any user to access the information from any of the hospitals he/she must be a registered user in one of the hospitals and hence privileges such as viewing, updating, booking and confirmation of appointment and patient's referral can be granted depending on the type or level of user.

Patient Submenu Design

This subsystem permits the entering of a patient record to the database, generating a unique patient medical number for every patient and updating a patient record. This module is available to the nurse and doctor with some privilege access to the system. Here in the subsystem, the doctor manages the appointment he has with the patient. The doctor sees the medical history of every patient in the system.

Tools to Implement the System

The choice of various programming tools used in the implementation of this system is based on the nature of data to be handled, best technology to suite the implementation and many other factors. The following tools were deployed in the implementation of the system: Hypertext Markup Language (HTML), Cascaded Style Sheet (CSS), Javascript, PHP, and MYSQLi.

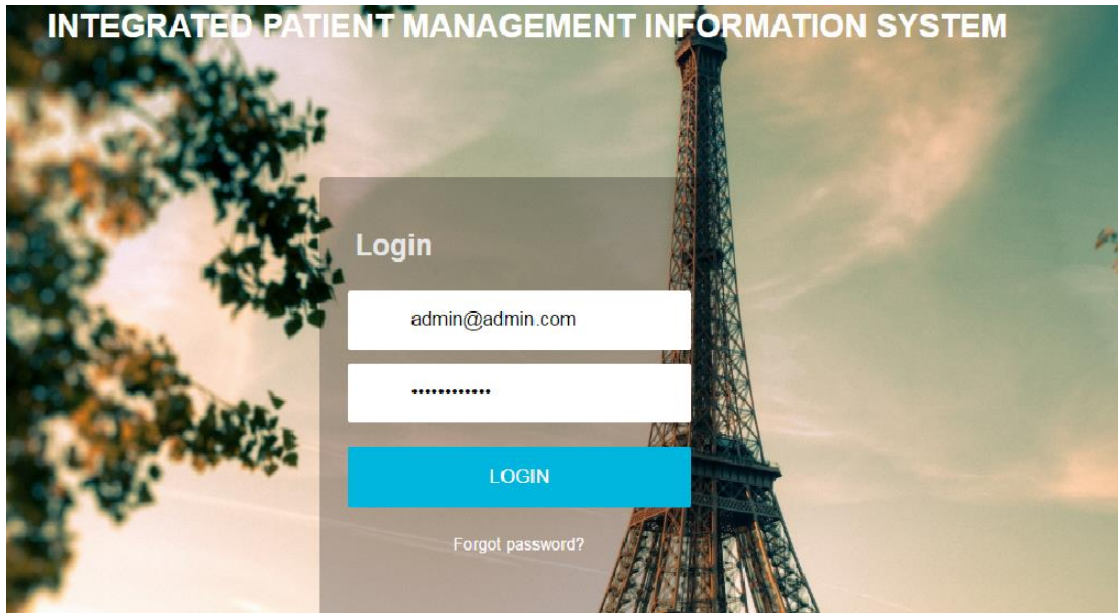


Fig. 5: First login subsystem menu

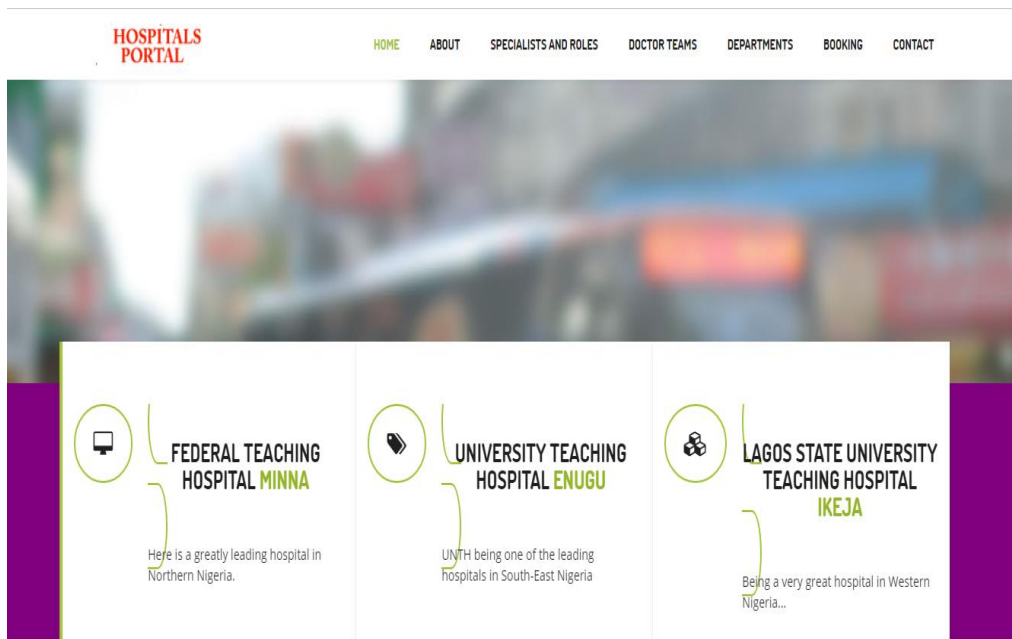


Fig. 6: System main menu

Factors That Influenced the Choice of Programming Tools

1. Portability: the program can be executed in different machines without any alteration to the source code when compiled.
2. Maintainability: The program is broken into modules. Each module is assigned a specific function for easy maintenance of the system.
3. Security: Quality control mechanism for all modules and unauthorized access to sensitive data is prohibited therefore the robustness, flexibility, scalability and extensibility of the system

The Need for Consistent Agreements and Standards for Data Sharing

Organizations involved in the exchange of clinical information for patients should enter into a mutual

franchise agreement for data sharing. Common standards of access to information must be included in these agreements. Through application of the National Data Use and Reciprocal Support Agreement (DURSA), data disclosers are anticipated to take choices on data sharing based on the policies of their own organization, in line with the minimum legal standards required. The exchange of data on clinical health across organizational borders requires national regulatory guidance and harmonization of privacy and regulations, knowing the sensitivity of clinical data. When considering connecting information systems and information-generating organisations, it is essential to have suitable agreements in place to regulate the sharing of data related to patients. Clear and unambiguous policies stating that irrespective of who created the record, any provider requested to exchange data must act as the steward for that combined record – which includes both protection and sharing in accordance with the policies of the entity where the combined record resides. Once the information is taken into the record of a supplier, that supplier must be prepared to use it and reveal it just as if the information were initially acquired within their own organization through their own attempts.

Testing Phases Involved in the System

During the course of developing this work, concrete steps were taken to ensure total functionality and efficiency of the system. Test plans, test data and the actual analysis of the test results obtained were to provide quality assurance during the actual development and deployment.

System Testing

System testing contains various activities carried out to find out possible bugs that might still be found in the designed system. It encompasses the activities undertaken to verify that the system meets its functional requirement specifications and also detect any inconsistencies among the integrated modules. It evaluates the system to ensure that user requirements were met. It also helps to determine if actual test result (output) corresponds to the expected test given some input test data. All the various modules were tested to ensure it processes correctly and efficiently. The MYSQL queries were tested to ensure that transactions and communication with the database were properly established.

Approaches for test case design are generally divided into two broad categories. These are: Black Box Testing and White Box Testing:

- **Black Box Testing:** The tester has limited knowledge of the inner workings of the item being tested. Test cases are based on the specification of the item's external behavior

- **White Box Testing:** The tester has knowledge of the inner workings of the item being tested. Test cases are based on the specification of the item's external behavior and knowledge of its internal implementation

Testing is unlike other software development activities because the goal is to break the software rather than to create it. Effective testing requires the assumption that you will find defects. Effective testing requires that you want to find defects. If you think you won't find defects, or you don't want to, you will have set up a self-fulfilling prophecy. Testing by both developers and an independent testing group are essential. They have different perspectives and motivations. They do different kinds of tests (developer does white box, test team does black box), which tend to discover different types of defects. Both tests were carried out on the system.

Test Plan

The experimental results showed that the system is robust and efficient in its performance. The duration for data acquisition and transfer rate is quick given the computer network capabilities of the hospital. The information storage, printing and reporting statistic modules of the software work appropriately. The test plan adopted was Top best, this is the scenario where the main menu followed by each sub system and then the modules are separately tested. After which the subsystems are integrated and test as a whole system.

Test Data

The test data employed in this work is categorized into two. They are:

- **Verification Testing:** This is also called alpha testing. It involves running the software in a simulated environment using simulated data. In this case we had to use imaginary data input values to carry out the test. The essence of this test is to look out for errors and omission regarding end users and designed specifications that were specified in the phase but not implemented during coding
- **Validation Testing:** This type of test data involves running the system in a life environment using real data. This form of testing is at times called beta testing. We used real data of patients to validate the test

Conclusion

The use of multi-agent technologies allowed the successful integration of a large amount of heterogeneous clinical data from across various platforms of healthcare. Patients' clinical data can now be accessed from any workstation in any hospital across the nation via the

Internet thus making the implementation of a (IPMIS) a useful reality. Also the system provides a user friendly and uniform view of clinical reports instead of the previous multiple interfaces and disjointed data from the various hospitals, which were likely to confuse the user. The system significantly eliminated data redundancy. It also handled the data security which was seen as lapses in the old system using quantum cryptography which was able to securely guard against eavesdroppers in the system. The system implementation also helped in integration of several hospitals and the Trans institutional referral processes well achieved. Nevertheless, the clinical and economical consequences of the utilization of this (IPMIS) need to be externally and formally assessed in the near future. A significant increase of health professional satisfaction may be expected. Finally, we hope to expand this system in order to include clinical information produced in regional and development health centers and, conversely, to provide hospital data to primary care health professionals thus achieving a fully integrated (IPMIS).

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Author's Contributions

Okemiri Henry Anayo: Wrote and coordinated the core of the manuscript.

Alo Uzoma Rita: Coordinated and developed the system architecture and design with other necessary corrections.

Achi Ifeanyi I: Acquisition of data, data analysis and interpretation.

Oketa Kelechi Christian: Critically reviewed the significant intellectual content of the work.

Nnamene Chizoba Christopher: Design and programming issues.

Chima, Chinazo I.: Data Gathering and analysis.

Ethics

This paper is original and includes content that is not published. The corresponding author confirms that the manuscript has been read and endorsed by all the other authors and that there are no ethical problems associated.

References

Angelo, S.M., 2010. Bridging the gaps in the Health Management Information System in the context of a changing health sector. *BMC Medical Informatics Decision Making USA*, 26: 851-883.

- Aranda, P., 2010. The determinants of health and the differences in healthcare expenditures among countries. *J. Health Economics*, 15: 103-118.
- Blumenthal, D. and M. Tavenner, 2010. The "meaningful use" regulation for electronic health records. *N Engl. J. Med.*, 363: 501-504.
- Bozeman, T.E., K. Harvey, I. Jarrell, W. Jones and K. Kock *et al.*, 2017. The development and implementation of a computer-based patient record in a rural integrated health system. Proceedings of the 3rd Annual Nicholas E. Davies CPR Recognition Symposium. Chicago: Health Information Management Systems Society, Casalino *et al.*, 2003. *J. Am. Med. Assoc.*, 289: 434-441.
- Evans, T. and S. Stansfield, 2003. Health information in the new millennium: A gathering storm? *Bull World Health Organisation*, 81: 856.
- Fakhraddin, M., 2016. Examining the relationship between hospital information systems and improving accountability of nurses. *Int. J. Asian Social Sci.*, 6: 272-279.
- Gholamhossein, L. and M. Sadeghi, 2012. Evaluating efficiency of Shafa Hospital information system in Imam Reza Hospital. *J. Islamic Republic Iran Armed Forces*, 10: 6-62.
- Goldman, D. and E.A. McGlynn, 2015. *U.S. Health Care: Facts About Cost, Access, and Quality*. Santa Monica: Rand and The Communications Institute.
- Groene, O., N. Klazinga, V. Kazandjian, P. Lombrail and P. Bartels, 2012. The World Health Organization Performance Assessment Tool for Quality Improvement in Hospitals (PATH): An analysis of the pilot implementation in 37 Hospitals.
- Haque, W., D. Horvat and L. Verhelst, 2014. A secure mobile platform integrated with electronic medical records. Prince George BC, Canada: University of Northern British Columbia.
- Hassey, A., 2015. Response of health and social care information centre to article on access to Patient Data. *Bmj Br. Med. J.*, 351: 5820.
- Haux, A., 2006. Health information systems: Past, present, future. *Int. J. Medical Informatics*, 75: 268-81.
- HDR, 2013. The rise of the South: Human progress in a diverse world. *Human Development Report*.
- Heeks, R.B., 2006. Health information systems: Failure, success and improvisation. *Int. J. Medical Informatics*, 75: 125-137.
- Knapp, K.J., 2006. Cyber security and global information assurance: Threat analysis and response solutions. U.S Air force Academy, Colorado, USA.
- Longest, B.B., J.S. Rakich and K. Darr, 2000. *Managing Health services organizations and systems*. Health Professions Press, Baltimore.
- Malhotra, 2009. *Hospital management system: An evaluation*. Global Indian Publication.

- Malliarou, 2006. Policy of safety and guarantee of medical secrecy in electronic health record of patients. Master Thesis National and Kapodistrian University of Athens, Nursing Department, Health Informatics, Athens.
- Mauro, R., 2005. Web services enablement for healthcare HL7 applications-Web Services Basic Profile Reference Implementation.
- Mursaleen, L.R., J.A. Stamford, D.A. Jones, R. Windle and T. Isaacs, 2017. Attitudes towards Data Collection, Ownership and Sharing among Parkinson's Disease Patients. *J. Parkinsons Disease*, 7: 1-9.
- Nasiripour, A.A., M. Mahboubi, S.H. Mousavi, A. Arash and M. Alireza *et al.*, 2014. Evaluating Hospital Information System (HIS) of Imam Reza Therapeutic Educational Center of Kermanshah. *Adv. Environ. Biol.*, 8: 748-753.
- Naveh, E. and Z. Stern, 2005. How quality improvement programs can affect general hospital performance. *Int. J. Health Care Quality Assurance Emerald Group Publishing Limited*, 18: 249-270.
- Nnamuchi, O., 2007. The right to health in Nigeria. 'Right to health in the Middle East' project, Law School. University of Aberdeen. Draft Report.
- Okemiri, H.A., E.N. Nweso and M.O. Eze, 2016. Critical review of petrol station management system with emphasis on the advantages if digitalized in Nigeria. *J. Multidisciplinary Engineering Science Technology*, 3: 3687-3693.
- Onwujekwe, O., C. Onoka, N. Uguru, T. Nnenna and B. Uzochukwu *et al.*, 2010. Preferences for benefit packages for community-based health insurance: An exploratory study in Nigeria. *BMC Health Services Res.*, 10: 162.
- Ouma, S. and M.E. Herselman, 2018. E-health in rural areas: Case of developing countries. *Int. J. Biological Life Sci.*, 4: 194-200.
- Poissant, L., J. Pereira and R. Tamblyn, 2015. The impact of electronic health records on time efficiency of physicians and nurses: A systematic review. *PubMed*, 12: 505-516.
- Prasser, F., O. Kohlbacher, U. Mansmann, B. Bauer and K.A. Kuhn, 2018. Data integration for future medicine (DIFUTURE)- An architectural and methodological overview. *Methods Inform. Med.*, 57: 57-65.
- Regli, S.H., P. Tremoulet, A. Samoylov, K. Sharma and K. Stibler *et al.*, 2010. Medical intelligence informatics. *Proceedings the SIGCHI First International Workshop of Interactive Systems in Healthcare (WISH'2010)*. Atlanta, GA, pp: 145-148.
- Shortell, S.M., R.R. Gillies and D.A. Anderson, 1996. *Remaking Health Care in America*, San Francisco: Jossey-Bass.
- Shortell, S.M., R.R. Gillies and D.A. Anderson, 2000. *Remaking Healthcare in America: The Evolution of Organized Delivery Systems*, 2nd Edn., San Francisco: Jossey-Bass.
- Swartz, N., 2015. Electronic medical records' risks feared. *Information Management J.*
- Wootton, R., J. Craig and V. Patterson, 2006. *Introduction to Telemedicine*, 2nd Edn., England, U.K. Royal Society of Medicine press.
- WHO, 2010. <http://www.who.int/gho/indicatorregistry>
- Yamamoto, T., 2006. Flagellate erythema. *J. Dermatol.*, 45: 25-26.