Medical Informatics Can Improve Mexico's Public Health System

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Citation

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Abstract

The health system for any country is one of the top priorities to guarantee the proper development for their citizens. For the specific case of Mexico, management of medical records is still being done using physical files whether patient attends a public or private physician or hospital. This poses a potential problem for the health structure and the patient because physical files tend to deteriorate, damage, could be stolen or mishandled. One possibility is to evolve from the use of physical files and create electronic medical records. Mexico already has an official standard for medical records; this standard could serve as the foundation to devise an electronic universal record. The idea for the electronic universal record is to serve as the base to implement an electronic public health scheme. This article will provide several key aspects to take into account in order to provide an efficient, secure and cost efficient electronic medical record. Aspects to be considered include: standardized medical nomenclature, clinical procedures, data transmission standards, legal aspects, electronic security, and data storage schemes. The impact of this proposal for Mexico will be discussed in detail.

INTRODUCTION

The information and communication technologies (ICT) have impacted in all areas of society, penetrating the culture is such a way that youth have turned much of their social and leisure activities to the electronic media. Nevertheless, ICT's have also caused notorious impact in the productive and educational sectors. In the health area, the use of information technology and other sciences is known as medical informatics or medical computing; it exists since the origins of computers in the 50's. Health informatics includes computers, clinical guidelines, formal medical terminology, information and communication systems, and medical information standards among other aspects [1-7]. Electronic medical record is a key aspect for medical informatics, because around it there are areas like: consulting room [8,9,10], nursery [11,12,13,14,15], mental health [16,17], intensive care [18], clinical laboratory, clinical imaging [19,20,21], cardiology, blood bank, among others. However, in the United States only 5% [2] of providers of general medical services (family doctors) use electronic systems for medical records and just 19% of hospitals have integrated systems of medical software [3]. This fact is alarming if, only in that country, 98 million people annually dies due by direct medical malpractice [2]. Mexico does not escape of such problems; even the government agencynamedNational Commission for Medical Arbitration (CONAMED [22]) was created to resolve controversies caused by medical malpractices. Nevertheless, this action is corrective, while preventive action would be the developing of an integral software platform to improve the medical services in general. Besides, it has been estimated that United States could save 77.8 billion dollars [2] if an integral, and universal, software system is deployed [23], allowing to infer, even with the economy scale, that implementing a Mexican integral health electronic system would help to achieve big savings, derived of the bureaucracy decrease, optimization of resources, disease prevention, standardization, among most important. Penetration of medical informatics in health sector has been so gradual that despite humankind has been able to take men to the moon 4 decades ago; still is not possible for most developed countries, that a general doctor access an electronic medical record "comprehensible" for his patients from anywhere, because there is not even a standard version or "universal" of such file.

Nowadays, the market for hospital and clinic management systems is segmented in medium and small companies, that on one side, develop particular solutions for specific areas in health services, leaving in the background aspects like interconnectivity between different areas and, on the other hand, do not comply with standards that allows import and export results between programs created by different companies. Thus, the health system works as a granulated entity, such that even within the hospital, data exchange between different departments is made through paper, although electronic and informatics systems are deployed in the respective departments.

ELECTRONIC MEDICAL RECORD

In Mexico there is an official standard related to the medical record (NOM-168-SSA1-1998), which was issued in 1998 and subsequently amended in 2003 to include and validate the potential for an electronic medical record. Hence, this standard for the Mexican medical record, should serve as base for the creation of a standard electronic file for all the country. Besides, such standard is complemented with other standards like:

1. NOM-003-SSA2-1993.Provision for human blood and its components with therapeutic purposes.
2. NOM-005-SSA2-1993.Provisions for family planning.
3. NOM-006-SSA2-1993.Prevention and control of tuberculosis as primary attention to health.
4. NOM-007-SSA2-1993.Attention to women during pregnancy, birth and puerperium, and newborn.
5. NOM-008-SSA2-1993.Nutrition control, growth and development for kids and adolescents.
6. NOM-013-SSA2-1994.Prevent and check oral diseases.
7. NOM-014-SSA2-1994.Prevention, treatment, and control womb and mammary cancer in primary attention.
8. NOM-015-SSA2-1994.Prevention, treatment, and control of diabetes Mellitus as primary attention.
9. NOM-017-SSA2-1994.Epidemiological surveillance.
10. NOM-024-SSA2-1994.Prevent and control acute respiratory infections.
11. NOM-025-SSA2-1994.Provision of health services in integral attention units for Medical-Psychiatric Hospitals.

These standards support the standard for the medical record, so they have to be included in the design of the electronic version of the medical record. Currently there is not a standard way to design an electronic medical record [24, 25, 26]; in Mexico the starting point is the official standard for the medical record. Nevertheless, the standard just dictates the information to request, but not the way to organize it electronically, and in this aspect, organization, there is still more work and research to perform. There are several aspects to consider when the electronic medical record is implemented, like:

1. Access speed and storage capacity. When it comes to health, access speed to clinical information of a patient could, literally, save his life [20]. The volume of medical information produced by a registry of patients of about 500 thousand people may be in the order of 1.8 terabytes monthly [27], so search for information fast is a complex task. At present, there is a system with 8 millions of patients which performs 300 thousand queries in day at a cost of 200 million dollars [3]. Figures mentioned before should be escalated if the population of Mexico is considered since it is over 100 million inhabitants, this is when can be inferred that data base technologies commercially employed nowadays could not be able to handle efficiently such information load. Nevertheless, there is a data base named Big Table [28], which is a high performance data base, designed in a structured way under a distributed storage data scheme, capable to store data in the order of petabytes based on a distributed network with thousand of servers; such data base represents, philosophically, the way to follow in order to store such amount of information that an electronic universal medical record could generate, taking into account the huge number of health professionals (medics, chemistries, radiologists, nurses, social services, administrative, among others) that would access the system for various purposes.

2. Robust. The system must be functional no matter what happens, 24 hours a day, all year long. Besides, must be guaranteed the integrity of the information when the system fails or sabotage attempts. This implies the use of data redundancy schemes and servers that allows keeping the responsiveness and the reliability even under extreme load conditions.

3. Flexible. There are no patients alike; each person is an individual with his own life story and, therefore, diseases. So, the electronic medical record should be adapted to the particularities of each patient. Following, a scheme of information hierarchy is proposed and extended [4]:

4. Information unit.The medical record is divided in sub-blocks of information until the minimum expression is achieved, keeping the "meaning" within the health context of the patient, it is named information unit. For example, the glucose level in blood is an information unit, which has properties as values and units. Each information unit must have an identification code. The origin of an information unit could be by capture (manual) or directly of electronic equipment (automated).

5. Class. It is the group of information units that recreate a particular aspect of the health for an individual. Could be a disease, laboratory study, clinical history, among others. For example, a complete blood test is made of glucose, urea, creatinine, cholesterol, and uric acid, which are considered as information units.

6. Object. It is a specific case (in terms of time) for one or more classes. For example, blood test class is one that turns into an object when is the blood test for a patient, performed at a specific date and time.

7. Section. A section groups in logical way different objects. For example, surgical procedures could be a section that includes the following objects: acute appendicitis, caesarean, etc. An important aspect of a section is that, while maintains logic, may include objects from different sections. For example, a laboratory test could be in the section "surgical procedures" and the section "clinical analyses".

8. E-Views. The way that information is displayed to the user (units, objects or sections) using Web technologies; this content should be dynamic in order to adapt to user needs, which is the one that interprets the data. There should always be possible to create different views for new users or when scientific advances are achieved.

9. E-Forms. It is the user interface where information for units or objects is captured. A form based in Web technologies [29, 30, 31] would be a viable option, because the experience of the people using the Internet would be taken into account to use in a more efficient way the electronic medical record and, simultaneously, opens to adopt a scheme of hospital management and public health on line.

10. Secure. The information of every patient must be protected with different security schemes like passwords, electronic health cards and digital signatures.

11. The desirable characteristics mentioned above about the electronic medical record (EMR), provides a glimpse of the complex correlation and dependence between several hospital areas when the medical record is filled for each individual or patient.

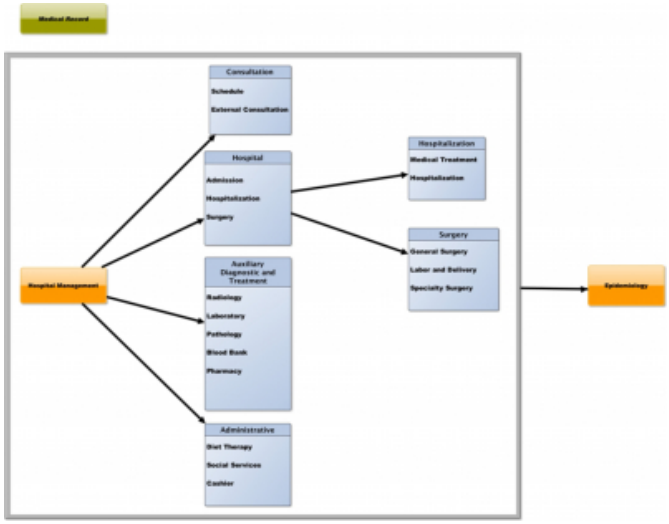
Official standards establish that all medical records must include: clinical history, medical notes in case of emergency, medical notes in case of hospitalization, notes after surgery, improvement notes, nursery notes, notes for auxiliary services of diagnose and treatment, letters of knowledge about information, voluntary discharge notes, notification notes for public prosecutor, and notes in case of death or foetal death. This standard details all the required information whether it is medical as for identification (including name of patient, date, place name of the doctor or assistant that created the note) that the note must include. Therefore, this information can be subdivided, classified and stored according to the already mentioned criteria.

HOSPITAL MANAGEMENT SYSTEMS FACING THE UNIVERSAL EMRCHALLENGE

The importance of a medical record lays in that it is an important piece that rules and provides coherence to the different processes and departments within a hospital. Figure 1 shows a general scheme on how a basic hospital management system is divided.

Figure 1

Figure 1.General structure of a hospital.



There are four basic departments: consultation, hospital, auxiliary diagnostic and treatment, and administration. Sections also form these departments; these departments have a complex relationship between sections within the same department and/or other departments. For example, the social services section, the information gathered is employed in the cashier section in order to assign costs of the services provided to the patient.

To maximize the utility of the universal EMR, each hospital will broadcast, via Internet, the files to a central system [29, 30, 31, 32], which keeps the official version of the EMR; this version will be consulted and increased by doctors in other hospitals when the patient has to.

STANDARDS AND PROTOCOLS

The existence and efficiency of the universal EMR demands, in consequence, the adoption of a standard language [33]: medical, clinical and communications. Next, some standards relevant to be considered are described:

1. ICD (International Classification of Diseases) [34]. The World Health Organization (WHO) constantly updates this classification. By much, the most standardized version of this classification is version 9; nevertheless, this version of ICD is now obsolete since it dates back to the 70's. In Mexico and countries like USA this version is still used in the hospital management systems, in many cases because the cost involved migrating to a newer version of this classification. In Mexico, migration to a newer version of the ICD classification implies lower costs than developed countries because hospital management systems are not fully implemented.
2. SNOMEDCT (Systematized Nomenclature of Medicine-Clinical Terms) [35, 36]. This nomenclature of medical and clinical terms was developed in USA in order to establish it as a universal medical language. It has higher reach in themes and dimensions than ICD, since it only covers diseases, also covers procedures and other medical and clinical aspects. In fact, even though SNOMED CT was developed independently to ICD, it has been possible to create crossing tables between both classifications. In Mexico dominates the use of ICD, but, the geography and close relationship with the United States of America could motivate, in the future, the use of the SNOMED CT classification [34].
3. HL7 (Health Level Seven International) [34, 36, 37]. It is information standard between different health information systems or hospital management. Standards like ICD classification or SNOMED CT nomenclature establish the medical and clinical language, but HL7 establish the mechanisms of transportation for the gathered medical information in the shape of medical records, statistics, among others. Besides, HL7 allows the interoperability between different hospital management systems, whether they are public or private. For example, when Health Secretary demands to the public or private hospitals statistical information about the spread of certain diseases, one way to standardize transmissions is by the HL7 protocol.
4. DICOM (Digital Imaging and Communication in Medicine)[19, 20, 21]. This standard is designed to handle, storage, impress and transmission of medical images, which have to be included into the electronic medical record. Radiology is an important area to diagnose, prevent and disease monitoring, so its inclusion in the electronic medical record is relevant.
5. CRYPTOGRAPHY. Cryptography is the science that deals on the data encryption for security and confidentiality purposes. This area is so dynamic that would be difficult to mention a standard that

tomorrow would not be replaced or lacks vulnerabilities. Nevertheless, in a comparative context, an electronic hospital management on-line requires a level of informatics security similar to the one employed in electronic banking. Currently, the most employed security protocol in electronic banking is SHTTP [38] (Secure Text Transfer Protocol), which in combination with other security measures (electronic keys, firewalls, etc.), allows providing the user "some degree of certainty" that personal data and money are safe. This security level is also desirable in massive hospital management systems since both population and health professionals keep reasonable doubts with respect to the security of their information. In general terms, to make the electronic medical record robust to informatics attacks, it should contain the following cryptographic schemes:

7. Private Keycipher. The function of a private key cipher is to encrypt the bulk of information in a fast and highly secure way. The most known and standardized block cypher is AES[39].

8. Public key cipher. This algorithm allows safe and automatic interchange of private keywords. Among the most known and secure are RSA [40] and Dieff-Hellman [41].

9. The HASH function aims to secure data integrity, eliminating the possibility that the cryptosystem be susceptible to the middleman cryptic attacks. The most known and secure hash functions are: MD5 [42] and SHA [43].

10. Digital signature. Has the function to serve as identification mechanism for both medical personnel and patients. This way modification on the system performed by authorized personnel would leave an identity indelible mark. In Mexico the digital signature is legal only for tax payments; nevertheless, there is still a long way for the digital signature to be accepted as a legal identification mechanism. DSA [44] is the digital signature most secure and recognized.

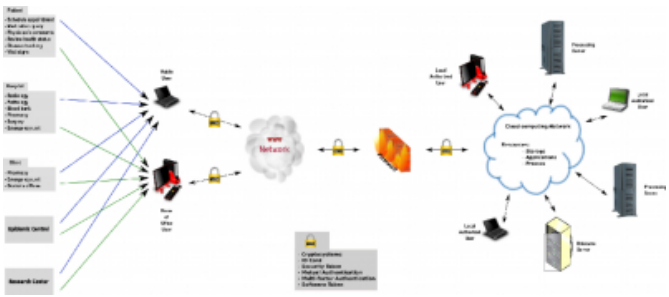
11. Random number generation scheme. Some non-critical cryptosystems use software generators (Blum-Blum-Shub [45]) for pseudo-random numbers, but there is hardware capable to generate truly random numbers using the advantage of the physical phenomenon known as thermal noise. Random numbers are essential for cryptosystems to generate private keywords and some other key aspects of the cryptic public key algorithms. Therefore, it is highly recommended that the central system for EMR use a number generator for truly random numbers that maximize the security of the cryptosystem.

12. Electronic health card (electronic key) [46]. This kind of cards help to increase the privacy of the patients, allowing them to choose which medic is able to access his/her medical record.

1. CLOUD COMPUTING [47, 48]. Cloud computing is an informatics scheme based on the Internet and remote data centres to manage information services and applications. This scheme would allow medics and patients manage the electronic file, and use medical support applications (without the need to install them) in any computer having Internet access. Such technology offers more efficient use of resources, like storage space, memory consumption, processing resources and bandwidth, all in a convenient approach since it would provide just the required resources on demand, that is, it depends on the number of users and their activities. Also, the required investment could be low if the government negotiates a contract with one of the companies that offer this kind of services.

Figure 2

Figure 2.Electronic public health structure.



In general terms, a public health system on-line, based in an electronic medical file (see Figure 2), would prompt the existence of an electronic public health network simplifying the flow of information between the different players involved: patients, doctors, medics, nutritionists, psychologists, technical staff and support management, epidemic control centre, research centres, among other.

Besides, this could only be possible using modern technology and informatics schemes like: cloud computing, distributed databases (Bigtable), cryptosystems, and electronic ID cards.

LEGAL ASPECTS

Despite that the standard for the medical record provides recording the file in electronic media there is still not a standard or law that regulates in a comprehensive manner the use of the electronic medical record. In fact, for Mexico, the legal framework for these aspects is still not developed adequately. Nevertheless, the state of Colima is the exception in Mexico because at present has the "LAW FOR PROTECTION OF PERSONAL DATA", which by its nature is applied to diverse fields. However, here are some articles that could affect the use of the electronic medical record:

1. Article 4th, fraction XI mentions that: "General public, professionals, and workers that for some reason of their activities have access to files or personal data, will be obligated to keep the confidentiality of them and are not allowed to provide them to third parties. This obligation will prevail event after finishing the liaisons that granted access to such data. Contravention to this provision will be sanctioned under the criminal law". One aspect left open to discussion is: who, exactly, can or may access the information in the medical record? Common sense says that only the doctor or doctors treating the patient should be granted the access and no one else, although there could be exceptions when data is retrieved for statistic reasons.

2. Article 4th, fraction XII mentions that: "Personal data related to health can be operated by professionals and institutions according to the health legislation while maintaining the confidentiality of such according to this law". This fraction provides the possibility that professionals and institutions use data in the electronic medical record. This is relevant because allows data from the electronic medical record not only be used not only in personalized treatment but also to generate statistics and health alerts, disease modelling, among other aspects.

3. Article 5th states that: "The person or institution liable of the file should establish the security mechanisms that guarantee the reliability and confidentiality of the data. The corresponding regulation will establish the minimum security characteristics for facilities that handle personal data". This article establishes a protection scheme for information and this will be enforced in regulations created, in this case, by the Health State Secretary.

4. Article 7th mentions that: "Persons working for enterprises and private business whose personal data have been integrated into a record, will have the following rights… request and obtain for free information of their personal data and the origin of such data". Article 7th establishes, essentially, that a patient will be able to receive a "free" copy, a year, of the electronic medical record for purposes it deems appropriate, which leads to the following question: who owns the electronic medical record? Does it belong to the doctor, the hospital, the State, or the patient? There is some philosophical tendency that states: "the patient is who owns the file". For example, it is allowed for the patient to perform annotations about his health status, non-controlled medicine consumption, allergies, substance exposition, habits, and other aspects that until now are normally an unknown and may be relevant for medical treatments.

The protection of personal data law for the State of Colima is the first step towards the legislation of the electronic medical record and can be used as based to create a national law that legislates and regulates the use of the electronic medical record in the benefit of the population. Besides, the Federal District (Mexico City) published in 2008 the "LAW FOR PERSONAL DATA PROTECTION" and in April2010 approved the same law for "PERSONAL DATA PROTECTION HELD BY INDIVIDUALS", which provides some aspects of health data in general.

ELECTRONIC MEDICAL RECORD FOR THE NEWBORN

The electronic medical record is a tool that allows doctors to visualize health of their patients in an integral way both in content and in time. Truth is that health problems, in particular the chronic, have usually an indelible mark evidenced when the medical record of the patient is observed through long time.

The standard (NOM-007-SSA2-1993) for Attending Women during Pregnancy, Birth and Puerperium, and Newborn at section "5.11 Registry and information" details all the information that about the mother and newbornshould be gathered for statistical reasons, touching aspects like: vaccination, maternal death, fetal death, gestational age births, abortions, among other aspects, birth or death certificate. Pregnancy, because of its importance and complexity, must be filed in a section of the electronic medical record for women. Considering all the critical aspects of monitoring pregnancy helps to decrease maternal deaths. In this sense, standard NOM-007-SSA2-1993 provides enough information to create a robust section about pregnancy and birth that allows the doctors, for instance, use the electronic medical record as the base to plan the labor and delivery surgeries.

While conducting statistics related to birth and newborn is important for health state policies, it is also equally important to establish what information should be stored in the medical record for the newborn, situation missed in such standard. This would have direct impact in the health of the infants, since many deaths happened during the first year of life would be preventable if information about the newborn is standardized and regulated. In this context this question should be asked: what medical information from the medical record should be transferred from the mother to the newborn? How much of the privacy of the medical record of the mother should be "invaded" in order to provide the newborn with more informed treatments and, therefore, more reliable? The mother "should," decide which information should or should not be transferred to the baby's medical record? Health and legal implications are broad [45, 46], so this process should be regulated by official standards. It is considered that all health data of a mother involving the evolution of pregnancy and birth of the product, are important aspects that cannot be left in limbo of ignorance, to baby's benefit. Although Human Rights indicate that privacy of the mother's EMR is violated [45, 46], this has to be transferred to the baby's EMR, especially everything that relates to the evolution and good health for the newborn and leave out unrelated clinical aspects. Setting aside the legal aspect, it is known that the relationship between baby and mother is so tight that the newborn health is intimately related to the health of the mother previous to the delivery and after it (when the newborn consume breast milk). Information proposed to extract from the mother's medical record is [4]: Mother's age, date of birth, maturity, mode of delivery, duration of membrane rupture, birth weight, diagnose and related procedures, among others.

BENEFFITS AND INNOVATION OPPORTUNITIES

Create a Mexican electronic file, under the framework of standards like: medical nomenclature, data transmission, image handling; would allow opening a new frontier in the health system to directly benefit patients. Among the direct benefits of such implementation are:

1. Medical diagnoses more accurate and appropriate. The immediate electronic access to laboratory results, radiological images, among others; would allow doctors to visualize comprehensively the amalgam of aspects that conforms the health of a patient, allowing generating medical diagnoses more reliable. Besides, dead times implicated in a hospital management system based in paper would be shorter because medical information is available electronically immediately after is generated in the different departments.

2. It will be possible to monitor with higher precision and accuracy the progress of epidemics in the population.

3. Would reduce the mortality rate due by wrong diagnostics.

4. Laboratory results and image would be transferred electronically to the hospital management system, substantially reducing human errors.

5. Emergency rooms would have immediate access to relevant data about the patients like allergies, diseases and treatments, increasing the survival probabilities for patients in critical condition.

6. Surgeons, anesthesiologists and nurses would be in a position to interact electronically from the planning of a surgery to the intervention itself. This is an interesting aspect because it would allow the medical staff to consult at all times before and during the surgery procedures, required materials, etc. For example, the system could guide a nurse to verify the required surgical supplies.

7. Radiology images. X-rays often are cause of problems for the doctor and patient, on one side the medical record in paper do not have enough space to store X-rays, on the other side doctors usually

do not have with adequate storage spaces to keep them organized. So the X-rays end up in hands of the patients, who throw them away, causing pollution, and decreasing the life of the plaque. Thus, traditional plaques are cause of pollution by the chemicals employed in its development. An electronic system may allow mitigating such problem.

8. Narrowing medical frauds [5]. Doctors, and some with collaboration of the patients, carry out some frauds; implementing electronic systems could reduce this risk. This could become evident by an abnormal request of clinical analysis, for instance.

9. Design of software tools for prevention and treatment of diseases. There are several guidelines for clinical practice, diagnose and treatment of diseases created by

10. development groups for Public Institutions from the National Health System, which regulate thoroughly the diagnose and treatment of more than 100 diseases considered relevant to the public health context in Mexico. Such standards are susceptible to be reproduced as software tools that guide the physician diagnosing and provide treatment for certain diseases.

11. It would be possible to notify the patient by SMS o e-mail, about aspects like: schedule for medication, appointments with the physician, and information about conditions, among the most important.

12. The patient could register (by himself or with telemedicine schemes) in the medical record health aspects like: diet, habits, and exposure to toxic substances, vital signs, among others.

13. The patient would face the possibility to change physician anytime without the risk to lose his medical record.

14. Medical treatments would enter into a new era, where mathematical models for diseases could be benefited of abundant data from the electronic medical record for certain individual. In the end, this could help to create personal health mathematical models, in order to prevent diseases in an unseen way.

CONCLUSIONS

Medical informatics has proven to be a fundamental tool in the process of modernization of the public health system. The openness of the society to such information systems, in particular the universal electronic medical record, is a slow process but one cannot be stopped, because the benefits to implement such modernization far outweigh the debatable aspects both moral and legal. The advent of a universal electronic medical recordaccessible from the internet would allow an immediate improvement on the medical attention increasing the quality, and avoid adverse events by having the background of the patient; thus the incidence of lawsuits against the medical staff, service provider be kept to a minimum, also being source of useful information to researches in the health field. The economical and cultural dynamics of countries like Mexico delay medical informatics applied to public health systems, making it scarce or almost null. This situation, curiously, can be seen as an advantage, considering that advanced countries like United States or England started the use of medical informatics applied to the health system even before the appearance of the internet and other advanced technologies, so to migrate their infrastructure to new technologies represents an astronomical cost even for their strong economies. Nevertheless, Mexico, practically, is virgin territory to implement an electronic health scheme nationwide, so it is urgent for the government, researchers, and general public to sit down to discuss and define the future of our public health system in the regard of medical informatics, at the present time, that high investment costs in the health sector overwhelm the national budget. Prevention is an alternative to reduce costs and, in this area, to have a "generational" electronic file would greatly help to incise on the patients and their actual health condition.

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