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The Experience of Mexico's Social Security Institute

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Abstract[*]

Electronic medical record (EMR) systems are increasingly used in developing countries to improve quality of care while increasing efficiency. There is little systematic evidence, however, regarding EMRs' benefits and costs. This case study documents the implementation and use of an EMR system at the Mexican Social Security Institute (IMSS). Three EMR systems are now in operation for primary care, outpatient and inpatient hospital care. The evidence suggests that the primary care system has improved efficiency of care delivery and human resources management, and may have decreased incidence of fraud. The hospital systems, however, have lower coverage and are less popular among staff. The greater success of the primary care system may be due to greater investment, a participatory development process, an open workplace culture, and software appropriately tailored to the workflow. Moving forward, efforts should be made to exploit data housed in EMRs for medical and policy research.

JEL classifications: I18, L86
Keywords: Electronic medical records, Health care, Mexico

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Acronyms

Acronym	Name (English)	Name (Spanish)
CINVESTAV	Advanced Studies Research Center (National Polytechnic Institute)	Centro de Investigación y de Estudios Avanzados (Instituto Nacional Politécnico)
DICOM	Digital Imaging and Communications in Medicine	Imaginología y Comunicaciones Digitales en Medicina
EMR	Electronic Medical Record	Expediente Clínico Electrónico
HL7	Health Level 7	--
ICD9CM	International Classification of Diseases, Clinical Modification	Clasificación estadística internacional de enfermedades y otros problemas de salud, modificación clínica (CIE9MC)
ICD10	International Statistical Classification of Diseases and Related Health Problems, 10th Revision	Clasificación Estadística Internacional de Enfermedades y otros Problemas de Salud (CIE10)
IMSS	Mexican Social Security Institute	Instituto Mexicano del Seguro Social
IMSS VistA	Hospital administration information system	Administración Hospitalaria
ISSSTE	State Workers Social Security and Services Institute	Instituto de Seguridad y Servicios Sociales de los Trabajadores del Estado
LOINC	Logical Observation Identifiers Names and Codes	Nombres y códigos lógicos de los identificadores de observación
PAHO	Panamerican Health Organizaion	Organización Panamericana de Salud
SICEH	Outpatient Hospital Information System	Sistema de Información para Consulta Externa Hospitalaria
SIMF	Family Medicine Information System	Sistema de Información de Medicina Familiar
SNTSS	National Union of Social Security Workers	Sindicato Nacional de Trabajadores del Seguro Social
UNAM	National Autonomous University of Mexico	Universidad Nacional Autónoma de México
VPN	Virtual Private Network	Red Privada Virtual
WHO	World Health Organization	Organización Mundial de Salud

1. Introduction

Health indicators throughout Latin America and the Caribbean (LAC) have improved dramatically in recent decades. Since the 1980s, average life expectancy has risen by nearly six years, as both infant mortality and death by communicable disease have declined by close to one half (PAHO, 2009a). Meanwhile, changing diets and more sedentary lifestyles have given way to an increasing prevalence of chronic disease, such as cardiovascular disease, obesity and diabetes. The number of cases of diabetes in LAC is expected to double between 2000 and 2030 (WHO, 2009). At the same time, the decline of both fertility rates and mortality rates has contributed to the aging of the population. This demographic transition contributes to the increasing prevalence of chronic disease.

Despite great advances, the battle with communicable disease is not over. As populations migrate and travel across borders, no country will remain unaffected by others' health risks. The rapid international spread of the H1N1 flu pandemic in 2009 and 2010 is one example of this. In the longer term, climate change may bring diseases to new locations. Health ministries must be able to respond by identifying new diseases quickly; tracking their spread in real time will be important.

These changes in countries' health profiles have important consequences for public policy; in the coming years, health care institutions will need to respond to these evolving needs. Throughout LAC, challenging budget scenarios are aggravated by inefficiencies and fraud; addressing these challenges is made more difficult when systems are fragmented or poorly coordinated (PAHO, 2009a). To face these challenges, governments caring for aging populations with declining revenue streams must seek innovative ways to cut costs while improving care. With effective systems in place, health care administrators will be able to track spending to identify how costs can be cut, address wasteful spending and fraud, and track service demands and delivery. Information systems have a clear role in this process.

Electronic medical record (EMR) systems are the core platform for a variety of applications that offer benefits for patients, doctors, and public health officials, as well as potential cost savings. A comprehensive EMR platform may include clinical and pharmaceutical administrative capabilities, decision support for doctors, and data aggregation. Administrative improvements have been associated with increased efficiency (Rotich et al., 2003; Chae et al., 1994), improved accuracy of medical records (Llido, 2006), prevention of duplicate procedures, and improved pharmacy inventory management (Fraser et al., 2006). Clinical decision support systems can provide reference information for doctors and automatic alerts may warn doctors when entering unusual values for a prescription or a prescription that may cause adverse reactions for the patient. Finally, an EMR platform that permits quick data aggregation may be an important policy tool. Accurate and timely information has clear potential for improving allocation of resources. Studies by the Rand Corporation and the Center for International Technology and Leadership have found that the generalized use of EMR systems can generate significant savings; both concluded that $80 billion of the $2 trillion in annual health care expenditures in the US could be saved if all providers used EMRs (Girosi, Meili and Scoville, 2005; Walker et al., 2005).

For these reasons, EMR systems have been adopted in developed countries like the United Kingdom, Sweden and Australia, and more recently in the United States. The UK is in the midst of implementing a large-scale national EMR system. With an expected cost of over US$20 billion, the system will allow health care providers in their National Health Service to access any patient’s record, medical imaging, or lab results at any NHS clinic or hospital, among other features. While EMR systems can carry a hefty price tag, studies have found that they may also yield significant savings. Today, EMRs are increasingly common in low- and middle-income countries as well. The open source OpenMRS platform is in use in at least nine African countries and several countries in South and Central America (Gerber, Brown and Pablos-Méndez, 2010). In each case, the decision to implement an EMR system involves balancing estimated costs against expected benefits. Personnel’s resistance to change and the probability of technical problems must also be considered.

Designing effective reforms of health care delivery requires information on what strategies have been effective at improving the cost effectiveness and quality of care. The goal of this case study is to identify the lessons that may be learned about EMR systems in LAC by studying the implementation of electronic medical records in the Mexican Social Security Institute (IMSS) clinics and hospitals, identifying what worked well, and in what circumstances the implementation was less successful. The IMSS experience may offer valuable lessons for other countries in the region that provide publicly funded health care on a large scale. Like many other countries in LAC, including most of the Central American countries, Bolivia and Venezuela, Mexico provides much of its public health care through its social security institute

The IMSS is the largest health care provider in Mexico, offering coverage to 44 million individuals, nearly half the population. The IMSS EMR system has been in operation on a large scale since 2003, giving the researcher the opportunity to see it in a mature stage. A medical staff of over 278,100 now has access to the system, which houses over 36 million individual records.

This paper addresses four main research questions:

1. Why did the IMSS decide to implement an EMR?
2. What were the benefits and limitations of the system? Were the benefits anticipated with an EMR system found in the IMSS?
3. What quantifiable evidence exists of the benefits and costs of the implementation and maintenance of the system?
4. What lessons have been learned from the IMSS experience that might be generalized to other countries?

The data used to answer these questions include existing reports, interviews with current and former IMSS employees and other experts on ICTs and health in Mexico, as well as direct observation of the use of the system in IMSS facilities. The reports include various presentations provided by IMSS employees and an evaluation of the IMSS EMR commissioned by the Secretary of Health, which includes analysis of the system, information on the system's coverage, and users' perceptions of the system's functionality (CINVESTAV, 2009).

A limitation of the single case study methodology stems from the fact that the conclusions drawn are based on just one case. Therefore, not all conclusions based on how an EMR worked in the IMSS may be generalized to other countries or institutions. However, presenting background information on the Mexican context provides information that may help others interpret lessons from the IMSS experience in another context. A further potential limitation of this study is the reliance on information provided by IMSS stakeholders. Their impressions of the IMSS EMR may not be unbiased. This concern is partially addressed by including the opinions not only of current employees, but also former employees and experts that are not associated with the IMSS. In the absence of quantitative data, conclusions may be drawn on assertions that various stakeholders and outside experts agree upon, and that are not inconsistent with direct observations.

This paper presents several important conclusions. First, the IMSS EMR made great advances in data storage in the IMSS and improved delivery of medical care. Second, the implementation of the system was especially effective in primary care. Patient data has been made more secure with automatic back-ups on local servers and a central server. Real-time personnel reports for clinic directors have facilitated supervision. Both prescriptions and orders for paid medical leave days are done much more quickly than before. Dramatic time savings in the production of aggregate data were found, though they did not translate into reductions in personnel.

Third, implementing an EMR system in a hospital is a more complicated endeavor. Hospitals have a larger and more varied staff than clinics and attend to a wider variety of complex conditions; in the IMSS, benefits to hospitals were less clear or consistent. Coverage in hospitals is much lower than in clinics, and infrastructure is at times insufficient to support the EMR system. Completing the installation in all hospitals has not been possible due to budgetary constraints. Some hospitals already had their own systems in place, leaving them with little incentive to learn and use a new system.

Fourth, the enormous amount of data stored in the IMSS EMR has had a limited use for policy analysis, medical research or patient tracking. The potential for research and policy analysis that digitally stored data offer may be one of the most important benefits of using an EMR system. Using these data to track patient compliance, ensure high coverage of inexpensive preventive measures and identify individuals at risk of having or developing particular diseases is very promising. However, the IMSS system has not been used for this type of analysis. At the clinic level, the system is not used to analyze patient data beyond at the time of a patient exam. There is potential to benefit much more from the IMSS EMR system by exploiting clinic and system-wide data for research. During the system's first years, maximizing coverage was prioritized over exploiting the system for these uses. Moving forward, however, the IMSS is exploring new ways to use the data.

This paper is organized as follows. In Section 2, the potential uses of EMR systems are reviewed. In Section 3, a description of the context of health care in Mexico, previous EMR initiatives in the IMSS, and the development of the current EMR system is provided. Section 4 describes how the system is used in primary care, while Section 5 describes the hospital care systems. In Section 6, main findings and lessons learned are reviewed. In the final section, conclusions and directions for future research are presented.

2. A Crash Course on EMR Systems

Electronic medical records are a flexible tool that is capable of improving efficiency in the delivery of health services as well as the quality of care. EMR systems range from local single-clinic systems to extensive system-wide networks that change how care is provided and how health policy is made. In addition to basic patient data and medical notes, additional features may be built into an EMR system that leverage doctors' connectivity to pharmacies or other points of care, and access to medical information online.

In the growing body of literature on EMR systems, a number of benefits appear to be common to many EMR systems. While not all EMR implementations are beneficial, evaluations that find a positive impact show the potential a well designed and implemented EMR can have. Reviews by Blaya, Fraser and Holt (2010), Williams and Boren (2008) and Fraser et al. (2005) cite legibility, improved patient tracking, reduced medical errors through clinical decision support, and improved data quality for policy-making. These and other key EMR benefits are described below.

- **Data quality and legibility.** Data in an EMR may be more accurate than data from paper records for three reasons. First, aggregate data may be more accurate if each observation is entered by the doctor himself rather than copied over during aggregation; doctors are more likely to notice a mistake since they are familiar with the data. Second, EMR systems are capable of generating alerts if a value is entered that falls outside an expected range. Third, data in an EMR is more legible than handwriting (Fraser et al., 2005; Douglas, 2003; Williams and Boren, 2008).
- **Reduced medical errors.** EMR systems are capable of responding to information entered with suggestions or alerts. These may be alerts to drug allergies, improper doses or interactions, suggested treatments for a given condition, or suggested preventive care, such as vaccines (Fraser et al., 2005; Hunt et al., 1998). In a randomized controlled trial at a hospital, Bates et al.

(1998) found that a computerized order entry system for prescriptions reduced medical errors by 55 percent.

- **Improved efficiency.** If an EMR makes patient information available to multiple doctors, and prevents the loss of lab or imaging results, this may prevent duplicate procedures or tests, saving both money and doctor and patient time. Garrido et al. (2005) conducted an evaluation of the introduction of an EMR system in Kaiser Permanente's clinics in the US, and found that visits to primary care doctors fell by 11 percent and to specialists fell by 5-6 percent. With a fast EMR system, further efficiency gains are found in simply saving time looking for patient records (Levesque, 2001).
- **Improved patient tracking.** EMRs may be a useful tool to track the care of patients with chronic conditions, as they help the doctor maintain records over time. They may also be used to increase coverage of preventive care, generating cost-savings down the line. This is made possible if doctors are able to search an EMR system for patients with specific profiles. EMRs may also be programmed to generate reminders when a patient is due for preventive care. Some may interact with mobile phones to give patients periodic reminders to follow a course of treatment (Fraser et al., 2005). A randomized controlled trial in Malaysia found that text messages to patients significantly increased patients' likelihood of returning for follow-up appointments (Leong et al., 2006).
- **Information for public health and policy analysis.** EMR platforms may be used to generate reports more quickly than with paper systems. Depending on the system's design, data may also be manipulated to conduct a variety of analyses. This improved access to data can provide important benefits for surveillance of disease trends and following preventive medicine efforts, as well as for analysis of health care delivery. In an implementation in Kenya, reports generated with an EMR system revealed an outbreak of a sexually transmitted disease in a village and a pocket of children that had not been vaccinated (Rotich et al., 2003). This shows how data may be used at a local

level; clearly, policymakers at a national level could benefit from access to such data.

Additionally, flexible systems may be modified to run pilot projects responding to local needs using the EMR platform, or to evaluate innovative pilots in patient care. In these settings, data collection expenses are reduced substantially as the system generates the information needed to evaluate the interventions. EMR systems may improve data security when one or more back-up copy of data is made; however, the ease with which data can be copied opens the possibility of data being copied, compromising confidentiality.

Quantifying the impact of an EMR system is a difficult task. Outcomes are diverse, hard to measure and may take time to be observed. Comparison groups are difficult to find for programs that are implemented nation-wide. Some approaches are available, however; well-defined research questions exploring the effects on specific outcomes are most tractable. Estimating the impact of EMR usage on data quality, one of the main expected benefits of an EMR, is challenging, as it requires comparing recorded data to accurate values, which may be unknown. Data aggregated manually could be checked for accuracy against data aggregated automatically by the EMR. Bates et al. (2001) demonstrate a way to estimate the effect of a computerized order entry system for prescriptions on errors resulting from incorrect prescriptions. Pilots may be used to measure effects of new uses of EMRs on patient outcomes. Pilots underway in the IMSS are described in Section 7.

From a policy perspective, knowing that a system offers benefits is not sufficient evidence to implement one. Expected benefits must be weighed against the cost of software, hardware, and training as well as the ongoing costs of updating all three. Wang et al. (2003) use data from the implementation of an EMR system in the primary care clinics of the Brigham and Women's Hospital in Boston to conduct a cost benefit analysis. Per provider, they find that the benefits of the EMR system would have a net present value of $129,300 over five years, and that the net present value of costs over the same time period would be $42,900, yielding a net benefit of $86,400. The majority of the benefits came from improved prescription drug management, reduced billing errors and reduced duplication of medical tests. The costs do not include developing a custom system.

Care must be taken when generalizing these or any EMR evaluation results, as the expected benefits, costs and risks of every implementation vary with system design and context.

The benefits described here show the potential that EMR systems have, not a list of results to be expected in all contexts.

The costs of an EMR system include upfront and recurring costs that may be known or unknown. Upfront financial costs include developing or purchasing software, purchasing hardware, installing infrastructure to support it, and training personnel. Recurring financial costs include maintaining the network, purchasing electricity to power the hardware, training new personnel and to providing technical support. Other economic costs must also be considered. These include the opportunity cost of staff time during training, as well as lost productivity during the first months of use.

An assessment of the costs and benefits of an EMR system should also include an assessment of risks. The software used may have unanticipated glitches. If not piloted carefully, staff may reject the system. In addition, infrastructure may fail; electricity or bandwidth may be insufficient to support the system, causing it to fail or perform poorly. Storing data in digital form introduces the possibility of a data security breach. These and other risks must be taken into account before investing in an EMR system.

3. Background

3.1 Health and Care in Mexico

Mexico is an upper-middle income country, with GDP per capita just over US$10,000 (World Bank, 2009a, estimate for 2008). Life expectancy has grown steadily in recent years, reaching 75 in 2007. As in other countries in LAC, the prevalence of communicable diseases has declined significantly. Today, the country’s leading health problems include cancer, diabetes, and heart disease among adults, and congenital malformations and infections related to pneumonia or influenza in children (PAHO, 2009b). The prevalence of diabetes in the adult and young population is increasing, and is expected to almost triple from 2.2 million to 6.1 million in just three decades (WHO, 2009).

Health in LAC is marked by highly unequal distribution of burden of disease and access to care (PAHO, 2009a). Mexico is no exception. In rural areas, communicable diseases remain a persistent problem. A child in Chiapas, one of Mexico’s most rural states, is twice as likely to die before turning one than a child in Mexico City. Similarly, children under five in Chiapas are over eight times as likely to suffer from diarrhea than children in the capital (PAHO, 2009c). Chronic disease, however, is more prevalent in urban areas. Residents of Mexico City are twice as likely to be diabetic or have heart disease than residents of Chiapas.

Mexico's health care system is comprised of public and private providers. The Mexican Constitution states that the government guarantees health care for all Mexicans. An individual's eligibility for public care is determined by his or her employment status. Individuals who work in the private sector and their families are covered by the IMSS, the largest health care provider in the country, while the Public Employees Social Security and Services Institute (ISSSTE) covers employees of most local, state and federal government agencies and their dependents. The armed forces and the state-run oil company, PEMEX, have their own institutes. The Popular Insurance program covers those that are not covered by social security, including those that are unemployed or employed in the informal sector. Popular Insurance has improved access to health care, but universal coverage has yet to be achieved, as many live far from the closest public point of care. Although the entire population is eligible for care by one or more state health care providers, many choose to purchase private health care. Fifty-three percent of total expenditures on health in 2007 were spent on care given in the private sector (Mariscal Avilés, Gil García and Ramírez Hernández, 2008). Many individuals are eligible for coverage from multiple public providers, which makes planning difficult and care provision inefficient. A family may be covered by the IMSS as well as ISSSTE if one spouse works in the private sector and another works in the public sector.

3.2 The Mexican Social Security Institute

The IMSS is the largest social security agency in Latin America. By constitutional mandate, the IMSS provides for the wellbeing of its members with medical care, pension and disability benefits to private sector employees throughout the country with funding from contributions from employees, employers and the federal government. In 2008, the IMSS covered nearly 44 million individuals[1], and received over 400,000 patient visits per day (CINVESTAV, 2009). Like many public health care institutions in the region, the IMSS faces growing budgetary

[1] In addition to the 44 million individuals covered by the IMSS through private sector employment, the IMSS provide basic medical services to 10 million residents of rural areas through the IMSS Oportunidades network of rural clinics and hospitals. IMSS Oportunidades operates with a separate budget and separate administration, however, and was not included in the IMSS EMR initiative discussed here.

challenges. In the late 1990s, the anticipation of falling revenue relative to costs in coming years motivated a search for cost-saving measures within the IMSS.

3.3 EMR Initiatives

The IMSS began exploring the use of EMRs in the 1970s, with further significant efforts made in the 1980s and 1990s. In 1993, the Twenty-first Century Family Medicine and Hospital Systems were implemented in six primary care clinics, and three hospitals (Chong, 2002). These systems had numerous benefits, and were surely instrumental in the development of the current system. By 2000, doctors using either of the systems benefited from having legible clinical notes, more secure patient data, and automated referrals and lab requests. Several shortcomings, however, hindered their ongoing use and widespread adoption. Doctors had records of patients seen at their own clinic but were unable to access patient information entered at other clinics. The prescription drug management module automated orders to restock supplies, but did not make information on drug supply available to doctors. A persistent problem with previous systems was insufficient bandwidth or outdated hardware slowing the systems. Developing a system that could be scaled nationally to improve care and cost effectiveness was seen as a key element of a strategy to safeguard the future viability of the IMSS.

EMR development at the IMSS took place in the context of nationwide efforts to improve information on health care. A government-wide initiative, e-Mexico, was established in 2000 with the goal of using technology to improve efficiency in government services. Shortly thereafter, the initiative that gave rise to the current EMR system began at the IMSS; meanwhile, other public health providers, including state health offices and the other social security institutes also began developing EMR systems on a smaller scale. A plan of action was established to guide IMSS policy in 2001, calling for improved administration of resources, the promotion of transparency, and the integration of information technologies, marking the official incorporation of ICTs into the IMSS strategy. The Direction for Innovation and Technological Development was established at this time (Derbez del Pino et al., 2005).

IMSS leadership and the IMSS workers' union (SNTSS) agreed on specific strategies and the pace for implementation. The IMSS, the Secretary of Health, the President's Office for Innovation in Government, and the e-Mexico office collectively agreed that a new EMR would be developed that would be capable of recording a patient's medical history, and accessible online for doctors at any IMSS primary care clinic in the country—something that none of the previous EMR developments had been able to do (Derbez del Pino et al., 2005). Given that 85 percent of medical attention takes place in primary care clinics, priority was given to the development of the Family Medicine Information System (SIMF) for primary care clinics over hospital systems. In recent years, these same actors have agreed upon national standards that will regulate the use of EMRs in any institution. The Secretary of Health is expected to publish these standards as the *Norma 024* in 2010.

3.4 System Architecture

The IMSS EMR is comprised of three separate systems: one each for primary care (SIMF), outpatient hospital care (SICEH), and inpatient hospital care (IMSS VistA). Each system generates a separate patient EMR, stored locally at the clinic or hospital where it was created. A central database was created to store EMRs created in any of the systems, and provide access to any authorized IMSS user to patient data stored there. The database would also provide clinic and hospital staff access to numerous other systems known as modules. These include eligibility, appointments, blood bank, hemodialysis, lab results, imaging, paid medical leave and pharmacy modules. Hospitals with VistA would have access to surgery and nursing notes, transfer and discharge, and patient admission modules (CINVESTAV, 2009). The module model offers flexibility, permitting the addition of new modules as needed. The disadvantage is that because the information is not integrated into one program, doctors have to take time to open various modules during one patient exam.

Internationally recognized standards for interoperability[2] were incorporated into the design of the EMR systems and the modules. These standards ensure that data is recorded consistently across systems, and permit transferring data from one system to another in the future. Specifically, HL7 standards are required to transfer patient data from one system to another. This has been achieved in primary care, but not yet for either of the hospital systems. The consequences of this are discussed below.

The system's design included provisions for the confidentiality of the data as well. User accounts are one important tool to support security. Once logged in, each user accesses only the information determined by their specific profile. For example, doctors are only allowed to see

[2] The standards used include standardized catalogs of diagnoses (ICD10) and treatments (ICD9CM), DICOM for imaging, LOINC for lab results, and HL7 for the digital transfer of data between systems.

their own patients' data. Medical assistants' access is limited to patient identification data and scheduling information. Clinic directors have least restricted access, with access to all of their clinic's patients' data. The system is maintained over a private network rather than the Internet; thus, staff may only access the system at an IMSS clinic or hospital, not at home. This offers additional security, but limited flexibility for staff.

3.5 Financial Costs of the Three Systems

The total financial cost of developing and implementing the three systems between 2003 and 2008 is US$190 million, a relatively small sum when compared to other initiatives that have cost 20 to 30 times this amount (CINVESTAV, 2009). Other costs, such as lost staff productivity during training, as well as training costs should also be considered. Table 1 summarizes the infrastructure, hardware and software costs of the three systems.

Table 1. Total coverage and Cost* of the SIMF, SICEH and IMSS VistA

	Coverage			Total cost in millions of US dollars			
	Clinics, Hospitals	Users (staff)	Computer stations	Infrastructure	Hardware	Software Development	Total
SIMF	1,200	76,636	39,000	21.527	87.455	43.055	152.037
SICEH	70	154,414	4,700	3.139	10.118	6.943	20.200
IMSS VistA	58	47,050	1,925	2.601	5.983	5.983	17.913
	1,270**	278,100	45,625	27.268	106.901	55.980	190.140

*Coverage as of 2008. Total cost from 2003 to 2008. All costs in 2008 US dollars based on average 2008 exchange rate, 1 USD=11.15 Mexican pesos. (CINVESTAV, 2009)
**Summing just SICEH and SIMF since IMSS VistA hospitals are included in the SICEH total.

Eighty percent of total expenditure went toward the SIMF. Of that amount, 72 percent went to cover infrastructure and hardware. The average infrastructure and hardware cost per computer station was US$2,794 for the SIMF, US$2,821 for the SICEH, and US$6,197 for IMSS VistA. When calculated per staff user, however, it is clear that a higher investment was made in the SIMF. Infrastructure and hardware costs per user were US$1,422 for the SIMF, compared to $86 per user for the SICEH, and $254 for VistA. Software cost per computer station was much higher for the SIMF and SICEH given the relatively smaller scale. Software per station was $1,104 for the SIMF, $1,477 for the SICEH and $3,108 for IMSS VistA.

The implementation of the EMR for primary care clinics is presented first, followed by discussion of the implementation in hospitals. As will be evident, these constitute two very different processes.

4 The EMR System for Primary Care

4.1 Implementation

Given the unique requirements for the IMSS platform, and the specialized knowledge required for its development, the IMSS put forth a call for proposals for the external development of the primary care level EMR system. The National Autonomous University of Mexico (UNAM) School of Engineering was selected (Derbez del Pino et al., 2005).

A preliminary version of the SIMF was piloted in seven primary care clinics in 2001. This version mimicked the traditional paper system in an effort to facilitate users' transition to the new system. In addition to storing patient histories and clinical notes, the system had modules for tracking appointments, ordering prescriptions and paid medical leave days, ordering referrals or lab tests, and tracking preventive care. Users' suggestions were incorporated into the version that was installed nationally after the pilot phase. Modules that were requested were added then and continuously since the initial pilot in 2001.

Implementing the SIMF in primary care required an enormous mobilization of resources, and significant efforts beyond the development of the software. The IMSS made the necessary investments in infrastructure, hardware and training to make the SIMF a viable option nationwide within six years, as shown in Table 2.

Table 2. Expansion of the SIMF: Coverage of Clinics and Patients, Versions Used

	2003	2004	2005	2006	2007	2008
Number of clinics	105	402	818	1,186	1,191	1,199
Percent of total clinics	8.7%	33.4%	68.1%	98.6%	98.9%	99.1%
Number of patient records (millions)	12.9	24.3	30.5	34.7	36.0	35.1
Percent of total patients	39.0%	75.0%	91.0%	98.7%	99.3%	99.5%
SIMF version	1	3.4	3.9	4.0	4.01	4.01

Source: CINVESTAV (2009)

Preparing the clinics for installation represented a major logistical challenge, requiring purchasing computers, servers, wiring and printers; coordinating transportation; installing hardware and additional wiring; and establishing internal networks as well as a secure connection to the IMSS virtual private network (VPN). The two central databases and servers had to be built in Monterrey and Mexico City. Additional security measures were added to some clinics to protect the valuable hardware from theft.

With hardware in place, the next stage was to train the personnel on the system. The engineering school that developed the software was hired to design the training. A “profile matrix” was used to identify what training modules would be required for each employee. The training on the primary care EMR is now a routine part of training for new employees.

A key concern at the time of installation was reducing the risk that the medical staff would reject the new system. Three strategies mitigated this risk. First, the union was involved in the development of the system, beginning with the pilot phase. Union representatives also attended the meetings at which the system was introduced; it is likely that this participatory process increased the odds of staff acceptance, and may have improved the system itself by incorporating user feedback from the beginning. Secondly, changes to workflow that were required of medical staff were minimized by adapting the system to existing workflows, and by basing the user interface on existing forms. Thirdly, the investments in hardware and infrastructure that were needed to make the system usable were made. Although the system suffered from instability and slow processing speeds at times, it was reliable enough that staff were willing to use it.

The IMSS faced little resistance to the SIMF. This may have been because staff identified ways the new system could facilitate their work at little cost. The IMSS’ efforts to facilitate the transition to the new system by mimicking the existing system may have been evident to staff. The most recent alternative EMR in primary care was the Twentieth Century Family Medicine system, which had only been used in six of the 1,200 clinics. Thus, for the vast majority of clinics, the SIMF replaced the paper-based system, and for only a few did it replace an EMR system. The SIMF may have been an appealing alternative even for those that already had an EMR, since the SIMF would connect clinics to the entire national network and other modules. Furthermore, it was clear that the SIMF was a large-scale and apparently permanent platform, increasing its appeal.

Meanwhile, the IMSS and Congress began making the legal changes necessary to recognize electronic medical records as legal documents. This required modifications to Mexican law as well as to IMSS regulations. First, new laws established basic criteria for an EMR that would meet scientific and technological standards while maintaining patient confidentiality. Further laws stipulated that digitally stored information could only be shared when ordered by specific medical authorities. Finally, new modifications to the law established national criteria to guarantee the interoperability, processing, interpreting and security of information stored in EMRs. Changes to the IMSS regulations were made as well that regulate the use of digital transfer of confidential patient information, and establish the validity of an EMR as a legal document (Mariscal Avilés, Gil García and Ramírez Hernández, 2008).

The implementation of the SIMF has been successful by any measure. It is the most widely used and fully integrated of the three medical record systems in the IMSS. It was first piloted in 2001, three years before development for the hospital systems began. The system is used in all but three of the 1,210 primary care clinics, with over seven thousand examining rooms. Not only has it been installed in practically every IMSS clinic, but it has been well received and is fully integrated into most clinics' workflow. When interviewed, medical staff from a clinic in Mexico City and several representatives from the IMSS management agreed that the SIMF had improved efficiency and quality of patient care. This is consistent with the results of the 2009 CINVESTAV evaluation, which, based on over 700 surveys of IMSS medical personnel, found that most staff had a positive impression of the system. The aspects of the SIMF that were most positively evaluated were administration of care, communication and administration of activities, resource management, and administration of business rules (all with approval rates between 65 percent and 69 percent). The aspects with lowest approval ratings included the use of standard terminology (47 percent) and interoperability (48 percent).

4.2 The Primary Care EMR in Practice

The SIMF is used at nearly every step of a patient's visit. Patient appointments and arrivals are managed in an online appointment book linked to the eligibility module. This lets multiple staff-people make appointments simultaneously using information that is updated in real time, preventing double booking.

In the examining room, the doctor can use the SIMF to access the patient's records from IMSS primary care clinics. Doctors are not generally able to see patient records that were generated in a hospital because of hospitals' limited connectivity (described in more detail in Section 5). If the patient has no record, or if his medical history is not already complete, the doctor is expected to complete some fields, and how much the doctor is able to complete is limited by the time allowed with each patient. Checking what preventive care services a patient has had is part of the routine. If a patient's EMR shows that he or she has not received recommended care, the system generates a reminder. If a doctor systematically ignores the reminders, the medical director can observe this and follow up with the doctor.

During the examination, the doctor may use the computer to access other modules for further information. Additional patient data may be found in the lab results, imaging or hemodialysis modules. For some common conditions, such as diabetes, hypertension or for prenatal care, the doctor may access an online clinical guide for reference information. If the patient has an illness or injury that will prevent him or her from returning to work, the doctor may use the Medical Disability Adviser™, which uses information the doctor inputs on the patient's condition and nature of the patient's work to recommend a standardized number of days of paid leave. The patient's salary for three or more rest days is covered by the IMSS, making this an area of potential cost savings. The medical director is able to use the SIMF to monitor how many paid medical leave days doctors order, enabling the medical director to intervene in cases of potential waste or fraud.

After examining the patient, the doctor records the results of the appointment in the SIMF. The doctor writes clinical notes in a free text field, but is also required to select one or more diagnoses from the list of thousands of ICD10 diagnoses. Once a diagnosis is made, the doctor is allowed to record treatments selected from the ICD9CM[3] list, and write prescriptions for medications that are linked to the diagnoses. The system does not permit the doctor to write a prescription until a diagnosis has been entered; once diagnoses are entered, the doctor is only allowed to prescribe medications that are relevant to this diagnosis. A doctor may get around this requirement by handwriting a prescription. Whereas doctors previously wrote prescriptions by hand, which was time-consuming, prone to errors, and difficult to read and track, the SIMF allows the doctor to enter multiple prescriptions on the computer and print the prescription; prescription information is sent electronically to the pharmacy. If ordering an unusual quantity or dose, the system will alert the doctor of a potential error. Before selecting a medication, the doctor is also able to use an interface with a pharmacy inventory module to check the availability of a medicine. If one medicine is unavailable, the doctor may prescribe an alternative at that time. Both medical staff and IMSS management indicated that faster and more accurate prescriptions were a main benefit of the SIMF.

[3] As noted above, the ICD10 and ICD9CM are internationally recognized catalogs of disease and treatment codes. Using standardized codes permits automated data aggregation.

Medical staff and IMSS management noted that use of the system was occasionally disrupted because of technical problems, including power outages, glitches in the system, or saturation of the network. Though these interruptions do not occur frequently in most clinics, they represent a significant disruption.

4.3 Benefits

There is little quantitative evidence to gauge the benefits of the SIMF rigorously. Quantitative evaluations have not been done on the system's effect on efficiency of care delivery, cost reductions, data accuracy or other outcomes. Despite this lack of quantitative data, evidence based on interviews with IMSS management, medical staff and the results of the CINVESTAV surveys all point to a number of benefits.

Using electronic medical records has decreased the likelihood of patient data being lost. The SIMF achieves this by providing automatic back-ups, saving the information doctors enter both locally and at the central database. Many doctors also choose to print patient records to maintain paper files, creating a third copy.

The SIMF may improve the accuracy and efficiency with which data are reported and aggregated. Data recorded in an EMR is always legible, whereas handwritten notes may not be. Furthermore, data stored digitally are not vulnerable to water damage, fire or fading that may compromise paper records. Additionally, using EMRs may decrease errors in data for two other reasons. First, the system catches some errors by warning doctors when they enter quantities outside an expected range. Secondly, data aggregation is automated with the SIMF, whereas before this was done by hand first by doctors, then manually coded by other staff. This eliminates two occasions on which errors could be made.

In addition, data aggregation can be done more quickly with the SIMF. The IMSS made use of this feature during the outbreak of the H1N1 flu when a module was added to the SIMF to track flu cases. There were technical problems during the implementation of the module, however, which resulted in slow and inaccurate compilation of data. Had the compilation gone more smoothly, this could have permitted daily updates on cases treated at IMSS clinics, representing invaluable information for policymakers deciding on school and business closures in response to the public health risk. An internal evaluation of what went well and what went poorly during that experience may yield lessons to improve future use of the system.

Doctors have increased access to medical reference data and recommendations provided by the IMSS at their fingertips with the SIMF. Clinical guides provide information and treatment guidelines for common conditions, which are more easily updated than reference books. Medical Disability Adviser provides standardized recommendations on paid medical leave days depending on patients' conditions and profession. IMSS management is able to update the recommendations offered by both of these, making them potentially useful tools for influencing medical practice. Potential fraud in writing prescriptions and paid medical leave days may have been reduced by clinic directors' increased ability to supervise doctors.

The benefits described above may translate to improvements in care for patients as well. When doctors access the online reference information that is available, this may help doctors provide more appropriate treatments in less time. Increased accuracy of patient data may decrease medical errors, with clear benefits to patients. Doctors and IMSS management have indicated that writing prescriptions is faster with the SIMF than by hand; this leaves doctors with more time to talk with the patient. Furthermore, doctors' ability to find out if a medication is in stock in the pharmacy may save patients and physicians time if this information keeps patients from having to visit multiple pharmacies to fill a prescription or from having to return to the doctor for an alternative prescription. Finally, the system for ordering paid medical leave, or *incapacidades*, is much faster than the original system. Before, it might take two months for a patient to receive salary reimbursement from the IMSS for paid sick days, but with the new system, authorized banks receive information provided by the doctors online to authorize payments within 24 hours. While these are benefits that may be present, they have not been formally evaluated.

The SIMF has changed how clinic directors are able to monitor doctors' productivity. The SIMF creates automated reports on patients seen, completion of patient records, diagnoses made, and prescriptions and paid leave days ordered. Gathering this information using the paper-based system was time-consuming, whereas with the SIMF, a clinic's director can generate a report automatically. The director may use this information to suggest that doctors use alternative, less costly treatments; to observe which doctors see more or fewer patients per day; or to identify potential fraud or abuse. Quantitative information on how costs associated with prescriptions or paid medical leave days have changed was not available, but it is clear that this capability has the potential to be a source of significant cost savings and improvements in care.

4.4 Limitations

There are several ways in which the SIMF could be improved. Few reflect weaknesses in the design of the program itself; most are the product of the environment in which it operates. In interviews, medical staff mentioned the occasional disruptions caused by the system's instability. A temporary system failure causes significant disruption. It may not be possible to resolve this problem completely; however, improvements in the system and clinic infrastructure may reduce the frequency of system failure.

Doctors access data through modules that are not fully integrated into the SIMF, but separate systems that doctors may access. Opening a second or third system during a visit with a patient may be time-consuming, depending on the system's speed. Integrating more of these into one system would streamline operations. Although these are time consuming, waiting even a few minutes for a module to open is likely to be more efficient than sending for hard copies of results or relying on patients to bring them.

Several of the tools available in the SIMF are rarely used. Because doctors have little time to see patients, many are unable to consult reference information or the Medical Disability Adviser at all. Again, these features are a strength of the system, but underutilized because of limitations outside the system.

It is unclear whether the SIMF has improved data confidentiality. With the traditional system, patient records could be accessed inappropriately if offices were not secure. Although the IMSS has made an effort to protect data, by storing data digitally, the new system opens the possibility that data would be accessed inappropriately and copied. Data are not encrypted as they are transmitted over the network; doing so would enhance security.

Paper records are still used for a variety of procedures. As previously mentioned, some doctors prefer to maintain paper records in addition to EMRs. For legal reasons, doctors still must print and sign prescriptions and paid medical leave orders, necessitating a printer in every doctor's office. Changes to IMSS regulations to make the electronic signature equivalent to a paper signature are necessary to reduce these paper-based transactions. This may not be enough, however, as patients may prefer to have a paper record.

The SIMF could generate significant cost savings by reducing staff requirements at clinics. The system automatically aggregates data, a task that was previously done manually. Union requirements would not, however, permit positions to be cut; instead, staff have been reassigned to other tasks. Lack of flexibility in staffing is an important limitation to capturing the efficiency gains offered by the EMR system.

With over 36 million medical records of patients created over seven years, the SIMF contains an enormous amount of digital information on health care needs and treatments in Mexico. The potential these data offer for conducting research is one of the most important benefits of a large-scale EMR system. The system's data was combined with survey data to conduct research on the cost effectiveness of various approaches to diabetes care (Castro-Ríos et al., 2009). This is one example of the system's potential value for research. If data extraction were facilitated, much more could be done, with great benefit for policymaking. Furthermore, the IMSS could establish a protocol to permit outside researchers to access the data, facilitating a great deal of research at no additional cost to the IMSS.

Patient data could also be taken advantage of to improve quality of care at the clinic level. Doctors treating patients with chronic conditions like diabetes could use the system to track their patients' progress. The system could create requests for appointments with patients who require frequent check-ups or could be linked to mobile devices to remind patients to follow their treatment. The IMSS has begun to explore these possibilities with several innovative pilot projects. These are discussed in Subsection 6.4.

5 The SICEH and IMSS VistA for Hospital Care

5.1 Implementation

Once the SIMF installation was underway nation-wide, the IMSS turned to hospitals. The hospital initiative would differ from the primary care project in several important ways. Whereas the IMSS has 1,210 primary care clinics, there are 265 IMSS hospitals in Mexico. Although there are many fewer hospitals, the staff per hospital is three times that of a clinic on average (Dirección de Innovación y Desarrollo Tecnológico del IMSS, 2009), and they have more complex procedures. Patients go to hospitals when referred to specialists, in emergencies or for scheduled operations; they may be outpatients or inpatients, or go from one to the other. Staff carry out highly varied tests and procedures. Procuring the necessary hardware, developing software and designing training for hospitals all involve complexities not seen in the primary care initiative. Among the key differences is the cost of installing an EMR in hospitals, given their size. Furthermore, differences in workplace culture may make hospital staff less open to a new system than primary care staff.

Two separate systems were chosen for outpatient and inpatient care. Given initial indications of the SIMF's success, the decision was made to base the outpatient care system on the SIMF. The Outpatient Hospital Information System (SICEH) was begun in 2004. For inpatient care, the IMSS reviewed systems used in the US, Malaysia, Brazil and Spain before choosing the open source version of the US Veterans' Affairs system, Open VistA, because of its apparent success in various public and private hospitals in the US. This platform was available in Spanish with no licensing; because it was open source, it could be modified easily and with low upfront costs. Implementation of IMSS VistA began in 2006. IMSS VistA was installed in hospitals that also had the SICEH, but never on its own.

When implementing the primary care system, priority had been given to larger clinics in an effort to reach as many users as possible as soon as possible. In the case of hospitals, it was only possible to install the system in 70 of the 265 hospitals due to budgetary constraints.[4] First, priority was given to hospitals that had been identified as Highly Specialized Medical Units (*Unidades Médicas de Alta Especialidad*), which are tertiary care hospitals that provide highly specialized treatments and carry out research and teaching activities. Within that group, further priority was given to hospitals that already had computers and were connected to the IMSS network to make the most of a limited budget for the project. Some staff in this group of hospitals had experience using computers in the workplace. This was advantageous in that it reduced training on basic computer skills, but was disadvantageous because these users would be asked to use the new systems rather than their existing systems, which some would resist. The IMSS had an incentive to finish the installation quickly in order to have all three systems in use before the changing of administrations in 2006 to protect the system from potential changes in political priorities that might jeopardize the project's continuity. Training in hospitals followed the same strategy as in primary care.

[4] In subsequent years, 10 other hospitals have added SICEH using funds from their local IMSS office. Extending the system to every hospital in the country would have been much more expensive.

5.2 The Hospital EMR Systems in Practice

Today, coverage for both systems remains low. Five years after its introduction, one in three hospitals uses either system. Where the systems are installed, there is wide variation in the extent to which the system is used, and for what purpose. Usage within hospitals is determined in large part by the hospital director, who may encourage or require using the system, or request that it be used for specific purposes.

The SICEH and IMSS VistA offer many of the same capabilities in hospitals that the SIMF offers in primary care. Doctors may use the SICEH or IMSS VistA to see and add to existing notes on their patients from previous visits to that hospital, and may access the modules listed above. Ordering prescriptions and paid medical leave days on the hospital systems is similar to the SIMF. The systems permit hospital directors to supervise personnel just like in primary care, but hospital directors seem to use this feature less frequently. This may be due to a belief that highly specialized hospital staff require less supervision.

The use of the EMR systems in hospitals differs from their intended use in two important ways. First, usage of the hospital systems is far from universal, even within hospitals that have the system installed. In a sample of 19 hospitals with the SICEH, 54 percent of medical staff used the system. In six of the hospitals with the lowest usage, 11 percent or less used the system, while in five practically all staff used the system (CINVESTAV, 2009).

Secondly, interoperability among hospitals and between hospitals and clinics has not been fully realized, limiting the extent that patient data created in hospitals is shared. The two hospital systems do not yet meet the HL7 interoperability standards required for the automatic digital transfer of data between systems or to the central database. Only recently, the IMSS has begun doing back-ups of hospital patient data to the central database manually. In contrast, because the SIMF does have HL7 capabilities, its data are copied automatically to the central database and made available to the IMSS network of users.

In some hospitals, bandwidth is insufficient to support the system's use during peak hours, making the system slow. In some cases, the doctors deem the system too slow to use.

The hospital systems have been poorly received compared to the SIMF. Users evaluated the three systems in thirteen areas in the 2009 CINVESTAV survey. In each of the 13 areas, the SIMF had a better rating than the SICEH, and the SICEH had a better rating than the IMSS VistA. Sixty-seven percent of those surveyed considered the SIMF a satisfactory tool for communication and the administration of activities, whereas 50 percent did for the SICEH. The SIMF outscored the SICEH by ten or more percentage points in its usefulness for the administration of resources; measuring, analysis, research and reporting; administration of workflow; and clinical support. IMSS VistA received its highest marks for administration of resources and security, with one in two users considering VistA helpful in these areas, and its lowest marks for interoperability and standard terminology, with approval from one in three users.

5.3 Benefits

The hospital systems and the SIMF yield many similar benefits, though some are reduced in the hospital systems because of the lower interoperability and coverage. Whereas with the SIMF, benefits are system-wide, in the case of the hospital systems, many of the benefits are found only for the doctors who use them and their patients.

In the hospitals where the system is used, the SICEH and VistA enhance data security by providing digital back-ups on local servers. When hospital patient records are backed up in the central database, a second copy provides additional security. Although patient EMR data are not added automatically to the central database, data that is added to the modules, such as lab results or imaging, are backed up automatically in the central database and made available to other users. Using the system to record data offers benefits in terms of legibility and data accuracy as described above in the case of the SIMF.

The SICEH and VistA may save doctors time, though this depends on the speed of the system, which varies by hospital and from day to day. If the system is working well, writing out prescriptions will be faster and easier. Patient compliance with prescriptions ordered may be higher since the doctor is able to check availability of a drug before prescribing it. Ordering paid medical leave days online is faster and easier for both the doctor and patient.

5.4 Limitations

The key limitations of the hospital systems are low coverage, limited interoperability, and slow operating speed in some cases. All of these factors reduce the system’s usefulness to users, exacerbating some of these problems.

Low coverage and limited interoperability have kept the hospital systems from becoming a definitive source of hospital patient information. This consequence of low coverage may perpetuate low levels of use—if the system offers few benefits, doctors' incentive to use the system is reduced. The incentive to use either system is further reduced in the case of hospitals in which an alternative in-house system is available or where insufficient bandwidth makes the system slow. Where incentives to use the system are weak, one negative experience with the system may make doctors stop using the system altogether. Some staff interviewed for the CINVESTAV evaluation indicated that after failing to gain access to the system on one occasion, they gave up on the system completely. Overcoming the poor perceptions that some users have of the system may require that hospital directors become "champions" of the systems, with support from IMSS leadership. To do so, they will need to demonstrate that the systems have real benefits for staff.

Slow operating speed and poor interoperability could be improved by increasing bandwidth in hospitals or integrating useful modules into the system itself. This requires significant financial investments, however, that may not be feasible. Limitations of interoperability could be addressed by adding HL7 capabilities to the hospital systems, or increasing the frequency with which data is copied manually to the central database.

As is the case with primary care, data generated in hospitals has been of limited use for research. Another consequence of hospitals' lower coverage is that less data is made available, decreasing incentives to use the data for research. The latter may be seen as a short-term solution that may not be worth the investment. The IMSS is currently developing a new EMR system that will replace all three of the current systems. Knowing that a new system will be revealed in the near future may affect staff's willingness to learn the current system, and IMSS administration's incentive to improve existing systems. This is a temporary barrier to improving the use of EMRs in hospitals.

6. Discussion

6.1 Findings

In case study research, it is not possible to arrive at definitive conclusions about how an EMR would perform in all environments. What is possible is to identify key benefits and limitations of the case examined. The benefits found in the IMSS EMR may be interpreted as examples of potential gains, while the limitations may serve as warnings for future implementations. It is important to note that the IMSS implementation was done in predominantly urban areas; not all experiences will translate to implementations in rural areas.

- **An EMR can improve access to medical information.** The SIMF and, where successfully implemented, the SICEH, provide access to medical reference information and recommendations about common conditions. Users with access to an EMR also had access to the Internet, and all the sources of information it provides.
- **An EMR can improve administrative procedures.** The SIMF and SICEH reduced time required to write prescriptions and order paid medical leave days. The systems' interface with pharmacies provides doctors with important information that they can act on in the examining room. By reducing the frequency with which medicine that is out of stock is prescribed, this may contribute to increased rates of filled prescriptions.
- **Managers can improve supervision with an EMR.** The SIMF, and to a lesser extent the SICEH, increases the quantity and timeliness of information on doctor productivity and treatments that is available to clinic managers.
- **Primary care may be uniquely suited for an EMR**. The SIMF EMR for primary care has been more successful than the SICEH or IMSS VistA for hospital care. The SIMF may have been more successful because system requirements in primary care are simpler. In this particular implementation, limited interoperability, low coverage, and insufficient bandwidth in some hospitals made the system less useful. Other researchers have found that primary care doctors are more likely to use an EMR than are medical professionals working in hospitals (Benson, 2002).
- **Hospitals have different needs.** Despite its similarity to the primary care SIMF system, the SICEH hospital platform did not have the same success. This may be because the platform was not sufficiently modified to meet hospitals' specific needs, because its limited interoperability made it less useful, or because poor infrastructure made it too slow.

- **Resistance to change may be overcome with careful pacing and participatory development.** A common theme mentioned by numerous IMSS representatives was the importance of addressing resistance to change. Many medical staff were content with their existing paper-based or electronic systems. Two IMSS strategies appear to have been successful. First, union and worker representatives were heavily involved in the development of the SIMF. Feedback of users may have contributed to a better product and a more open attitude among users. Secondly, The IMSS took care not to change more than was necessary with the implementation of the EMR. The user interface was designed to mimic familiar paper forms and maintain the existing workflow. No staffing changes were made. In hospitals, where staff is comprised of more specialized personnel, greater efforts will be needed to induce adequate use.
- **Union requirements can limit benefits.** An EMR offers enormous potential time savings, particularly in the aggregation of data. Manual data entry of information from doctors' paper records may be completely eliminated with a fully integrated EMR. Union agreements may prevent the cost-saving elimination of unnecessary positions. At the same time, unions' support may be critical to success. Hence, taking into account political economy constraints, involving unions in the process may be optimal.
- **Political realities affect time frame.** Building off the work of previous governments' initiatives, all three current systems were designed and implemented during one presidential administration. The development of the hospital platforms may have benefited from a longer, more participatory process; it was desirable to have the system installed before the change of administration, however, to protect the advances from potential changing priorities of a new administration.
- **Legal framework affects implementation.** In Mexico, the medical record is a legal document. Storing legal information digitally, and authorizing the use of electronic signatures has required legislation. Further legal changes will be used to standardize EMRs nationally.

- **Threshold effects.** The SICEH and IMSS VistA hospital platforms both have considerable strengths and potential for improving care. However, it is possible that they did not meet staff needs *well enough* to be useful. Building a platform that is 80 percent complete, for example, will not generate 80 percent of the benefits of a more complete platform. A system must meet a minimum threshold of functionality to be considered beneficial enough to be widely used.
- **Network effects.** The benefits to any individual user of an EMR system are determined in part by how many others use the system. If the system has complete coverage, it becomes a definitive source of patient information. If multiple systems are used, users must use multiple sources to find patient data.
- **Benefits of data must be sought actively.** Data captured in EMRs offer enormous potential benefits for doctors as they track patient progress and policy-makers attempting to identify epidemics or forecast disease and budget trends. EMRs' potential for tracking epidemics were was shown in the use of EMRs during the H1N1 outbreak. Taking full advantage of this information, however, is not automatic. It requires storing data in a way that facilitates analysis, and training the appropriate personnel on how to use the data. Intentional strategies to promote using the data for analysis are likely to be necessary.

6.2 EMR Systems: Hospitals vs. Clinics

The SIMF system has been more fully integrated into care delivery than either of the hospital systems. This is likely to be the consequence of lower levels of investment in the hospital systems. However, this may also be representative of a more general phenomenon—that EMR systems are more difficult to integrate in hospitals than clinics because of inherent differences between those environments. Key differences are outlined here.

First, as previously mentioned, hospitals are more complex environments than primary care clinics in a variety of ways (Benson, 2002). A wider variety of patient conditions, treatments, administrative procedures and staff are found in hospitals. Finding an EMR that is appropriate in this dynamic context is more challenging.

Second, in primary care, doctors expect to see the same group of patients multiple times over the years. In this case, the benefit of tracking information on current medical care for future reference is clear. In a hospital setting, when a patient is referred to a specialist, it may be less clear that the patient will return.

Third, staff in hospitals are more specialized than in primary care, and specialists may on average be older than primary care doctors. In the CINVESTAV evaluation, older users were found to be less likely to have a positive opinion of any of the systems. Making the system appealing to older users may often be more of a challenge in hospitals than in primary care because of differences in user ages. Furthermore, specialized staff may be less willing to accept interference from IMSS administration on how to do their job.

Each of these factors may have played a role in the IMSS implementation. These differences could be understood as generating greater costs associated with implementing EMR systems in hospitals. This may be true in almost any implementation of an EMR system in hospital care.

Moving forward, the IMSS may have more success in implementing an EMR in hospitals if it is able to improve the functionality of the system and its perceived usefulness. Investing in increased bandwidth and network stability will reduce basic user frustration. Adding HL7 capabilities to the system will enable hospitals to access information about their patients from their visits to other hospitals, increasing the system's usefulness. Finally, encouraging hospital directors to champion the system and promote its use will make it a more useful tool for all IMSS users.

6.3 The Future of EMR in Mexico

Two major EMR initiatives are underway in Mexico. First, in light of some of the problems found with the IMSS EMR, the IMSS is developing a new EMR, called the NECE (*nuevo expediente clínico electrónico*), to be introduced in 2010. Secondly, the Secretary of Health is developing legislation that will regulate the use of EMRs in Mexico with the goal of achieving full interoperability among institutions.

The NECE will have an interface similar to the SIMF, but include functionality for hospital care as well. What are now three separate systems will become one. If successful, the NECE will reduce the time required for doctors to pull up patient charts and reduce the need to consult multiple systems for patient information. If a patient is referred from primary care to a specialist, and is then hospitalized, the information recorded along the way will be recorded in one patient record rather than three; any IMSS doctor the patient sees would be able to see the complete record in one system. The immediate advantage of the new design is speed, as the doctors will not have to track down information from multiple systems to see a patient's complete EMR. Interfaces with other modules will also be more integrated into the system. The implementation of the new system will take place first in the hospitals that currently use no EMR system before expanding the system to the hospitals that currently have the SICEH and VistA.

A challenge of introducing the NECE will be addressing resistance to learning a new system. In the first installation, efforts were made to encourage acceptance. Involving users from primary as well as hospital care in development of the NECE may be an effective strategy in improving the functionality of the system while increasing the probability of acceptance. Once designed, an awareness campaign of the benefits offered by the new system may motivate doctors to learn and use the system.

The Secretary of Health's initiative addresses interoperability of EMRs at a sector-wide level by creating a national repository for electronic medical records, and the legal framework to support it. Motivated by the success of similar projects in Australia and the United Kingdom, the goal of this project is to create an information system that increases the efficiency with which government health care is provided. As previously mentioned, many Mexicans are eligible for coverage from multiple public institutions. Currently, these institutions do not have the ability to share patients' medical records. Efficiency gains are crucial in the health sector, as Mexico as a whole faces similar budgetary challenges as the IMSS. Congress authorized funds for the project to be released in 2010.

The new initiative has two components: the software and hardware infrastructure to receive and provide information from diverse EMR systems, and a legal framework to regulate EMRs and guarantee their interoperability. The new law will regulate EMRs by limiting what EMR software is allowed to be sold in Mexico. After a six-month grace period, any entity selling EMR software that does not comply with HL7 standards and other requirements of the law could be fined for selling a non-compliant product.

If successful, the new system will allow doctors from any institution in the country to access their patient's complete EMR. As long as the EMR meets interoperability requirements, health providers will be allowed to use any system they choose. The Secretary of Health compares the system to the networks of personal banking information that automatic teller machines are able to access. Health information will be housed in patients' local clinics or hospitals, similar to someone's local bank. If a patient's doctor must retrieve information at a distant clinic, as long as the new clinic is connected to the system, it will be possible to retrieve the information securely. Although data will be stored in different locations, it is hoped that it will be possible to aggregate and disaggregate anonymous data to conduct research and analysis. Patient data from four institutions have been successfully combined in a pilot of the new platform. The estimated cost of this new initiative is US$450 million over five years.

6.4 IMSS EMR as a Basis for Future Research

As the development and use of EMRs evolve in this emerging field, research and evaluation have an important role. At a conference for leaders in e-Health in Bellagio, attendants agreed on seven next steps. Two relate to future research: document e-Health's impact on access to, affordability of, and quality of health services; and provide funding for pilot projects and adequate evaluation (Gerber et al., 2010). The existing IMSS EMR provides an important source of data that could be exploited for research in several ways. First, pilot programs may be evaluated at much lower cost, as data on many health outcomes of interest are already in the EMR. Second, moving forward, data that are in the EMR may be used for policy analysis. Specifically, data on demand and supply of medical services may be analyzed to inform the allocation of scarce resources. Third, data in the EMR permit research on the effectiveness of alternative treatments. Immediate opportunities for each of these are discussed in greater detail here.

Pilot projects are underway at the IMSS to evaluate how the existing EMR may be used to improve medical care. Two pilots use mobile phones to improve treatment for increasingly prevalent chronic conditions: diabetes and hypertension. In each of these, devices that measure either glucose or blood pressure are adapted to have Bluetooth capabilities such that when the patient self-administers the glucose or blood pressure check, the result is sent to the patient's mobile phone, which then generates a text message that is added to the patient's electronic medical record. This has several potential benefits. This method may be more convenient for the patient if the new method is faster or more portable. It may improve care by improving doctors' access to patient data. Data will be added to the patient EMR in real time, keeping the doctor from having to record summary comments on patients' glucose or blood pressure history. It is easy to imagine how this could be altered to automatically generate alerts if a patient fails to register a check, or if results indicate a health concern. Reliable quantitative evaluations of patient-level interventions to treat chronic conditions are made possible by randomly assigning a group of interested patients to treatment or control groups, then comparing patient outcomes. Using what might be a useful methodology, Safran et al. (1995) evaluated a program that generated alerts when HIV patients had lab results that needed attention or missed an appointment.

Telemedicine pilots are underway as well. In these initiatives, videoconferencing and other equipment are used to allow doctors and patients to communicate with specialists in another location. These are facilitated by EMRs, as both the local doctor and the remote specialists are able to access and contribute to patient EMRs. The benefits of telemedicine may include increased access to specialized care, to the extent that patients receive care that otherwise would not be able to travel to a specialist; and time and financial savings to patients who could travel for care but would rather not. Doctors benefit as well, as local doctors learn from the specialists they consult. This initiative could be evaluated by using a difference in difference methodology. Changes in outcomes over time for patients with similar conditions in two locations—one with access to telemedicine and another without access—could be compared. If it is assumed that changes in patient outcomes would be parallel in the absence of the treatment, any difference in the change between the treated and control group communities could be attributed to the telemedicine intervention.

In a third pilot, data stored in various parts of the IMSS' system will be restructured into a "virtual data warehouse" (VDW) to permit the analysis of the quality of care and outcomes for the eight most common conditions treated in primary care. The aim of the VDW is to extract information from different IMSS platforms (EMRs, affiliation, and pharmacies) to analyze outcome associated with different types of care, or different doctors, for common conditions.

An evaluation of this experience will be useful to learn how such an approach might be expanded for further analysis of care with the NECE. Understanding two components will be key: first, how conducive the virtual data warehouse approach is to analysis and how it might be improved; and second, identifying internal procedures to promote the use of data for research.

Defining how research is initiated, what is researched and who is responsible for it may facilitate future research.

7. Conclusion

The implementation of electronic medical records in nearly all of IMSS clinics and a third of IMSS hospitals, with over 30 million patient EMRs, is an important achievement. The SIMF is a success on many counts; many of the benefits that have been found with previous implementations of EMR systems were found in IMSS clinics and hospitals as well. Where the system is used, patient data are more legible, less likely to be lost, and may be more accurate. Doctors and patients alike benefit from improved communication between pharmacies and clinics. Patients especially benefit from faster processing of paid medical leave days. While the hospital systems show room for improvement in ease of use, coverage and interoperability, the experience in hospitals provides valuable information to the development of a new system. The continual improvement of the EMR system may provide long-term savings and improvements in the quality of care for many Mexicans. The system will increase benefits to all users if it succeeds in extending coverage to all hospitals. Many more important contributions will be made if doctors, clinic and hospital directors, and policymakers at the IMSS take advantage of the data for improved patient tracking, medical research, and policy analysis.

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