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Policy Brief

Electronic Health Records: Delivering the Right Information to the Right Health Care Providers at the Right Time

William M. Tierney

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William M. Tierney, MD, is a clinician-investigator who focuses on the application of information technology in medicine and its effects on the quality, efficiency, and costs of health care. He was recently named President/CEO of the Regenstrief Institute, Inc., an internationally recognized informatics and health care research organization dedicated to the improvement of health through research that enhances the quality and cost-effectiveness of health care. He is also Associate Dean for Healthcare Effectiveness Research at the Indiana University School of Medicine, and the Chancellor's Professor and Sam Regenstrief Professor of Health Services Research, Department of Medicine, Indiana University School of Medicine. In addition, he is Chief of the Internal Medicine Service at Wishard Memorial Hospital and Wishard Health Services in Indianapolis, the largest public health care system in the country.

Dr. Tierney received his BA in biological sciences from Indiana University and his MD from IU in 1976. He completed his residency in internal medicine at the Indiana University School of Medicine in 1979.

The Herbert Lourie Memorial Lecture on Health Policy, sponsored by the Maxwell School of Citizenship and Public Affairs of Syracuse University and the Central New York Community Foundation, Inc., honors the memory of Herbert Lourie, MD, a distinguished Syracuse neurosurgeon, professor, and community leader for nearly 30 years. Generous contributions from his family, friends, colleagues, and former patients have endowed this series.

The Policy Brief series is a collection of essays on current public policy issues in aging; urban and regional studies; education finance and accountability; public finance; social welfare, poverty, and income security; and related research done by or on behalf of the Center for Policy Research (CPR) at the Maxwell School of Syracuse University.

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Policy Brief

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William M. Tierney

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> *There is no health without management, and there is no management without information.*
>
> Gonzalo Vecina Neto, Head,
> Brazilian National Health Regulatory Agency

Introduction

In 1993 I wrote:

> Communication and information management consume as much as 40 percent of all inpatient costs, yet errors still occur at an unacceptable rate. The Institute of Medicine has suggested that electronic medical records (EMRs) will help lower health care costs, maintain quality of care, and provide physicians with better information. (Tierney et al. 1993, 379)

Nearly 20 years later I'm here to tell you how far we've come toward implementing EHRs nationwide, and what we've learned from our experience at the Regenstrief Institute in Indiana University.

Most of us consider health care to be a service business, because we think in terms of a patient who goes to the doctor to get some

thing: advice, medication, devices, surgery, or physical therapy. I'm going to argue that what patients really get, and health care practitioners really provide, is information. Ninety-eight percent of what we who practice medicine do is not the end result, the end service, but the overall process of getting there.

I would also argue that medicine is more of an information business than, say, banking. With banking, if I put $100 in the bank, I know exactly how much it is, where it is, and what I can do with it, which is not the case with medicine. If you come to my hospital for a chest x-ray, the chest x-ray shows maybe there's an infiltrate, or some abnormal substance, in the lungs that could be pneumonia, could be cancer, could be...and so you get a list of things that it might be. If you have a fever and a cough with a little bit of green in it, it's probably pneumonia. I then have to figure out, is it vital pneumonia or bacterial? If it's bacterial, what kind of bacterium is causing it? What antibiotics is it likely sensitive to? And what antibiotics are available in my hospital that will likely be effective in treating it? I could go through that reasoning process appropriately and miss the fact that this pneumonia is due to the obstruction of a bronchus due to lung cancer.

Health care providers dig through patient records, gathering information based on a history, a physical exam, and laboratory test results. Physicians record information in notes and sometimes registries. They process that information, balance the risks and the benefits, come up with the most likely and least likely diagnoses, and then, based on all the various probabilities, make a series of decisions (yes—do this, no—don't do that). They transmit information about those decisions as advice, orders, communications, letters, and emails to other people. So health care is a much more information-intensive and information-fuzzy business than banking (see McDonald and Tierney 1986a, b).

And ultimately it's the doctor's responsibility to decide what to do when the various kinds of information contradict each other.

My colleagues and I did a study of over 4,000 echocardiograms (an ultrasound test to look at the inside of a patient's heart for structural problems) recorded at a large Veterans Administration medical center to assess the level of agreement between the two main diagnostic assessments of heart function that resulted from each test (Subramanian et al. 2003). We found that the numeric, or quantitative, measurements as performed by a sonography technician, and the textual, or qualitative, interpretation as provided by a cardiologist differed on the same echocardiograms a third of the time.

My point is this: the quality, efficiency, and effectiveness of health care depends on our ability to manage information. This information is messy and sometimes contradictory, and unless you're a fictional doctor on TV, like Marcus Welby, MD, and have only one patient to care for, you have to manage information electronically. It can't be done effectively any other way.

The Regenstrief Institute

The Regenstrief Institute, Inc. is a non-profit research organization with effective partnerships with the Indiana University School of Medicine and the Health and Hospital Corporation of Marion County, Indiana. It was founded in 1969 with the idea of applying the techniques of biomedical science, computer science, and industrial engineering to health care settings "to improve medical care, to provide rational methods for marshaling resources, and to foster the use of quantitative methods in medical decision and policy making" (http://www.regenstrief.org/mission/history).

In 1972, long before the Internet even existed, the Regenstrief Medical Records System (RMRS) was launched, with three goals in mind:

> (1) to eliminate the logistic problems of the paper record by making clinical data immediately

> available to authorized users wherever they are—no more unavailable or undecipherable clinical records; (2) to reduce the work of clinical book keeping required to manage patients—no more missed diagnoses when laboratory evidence shouts its existence, no more forgetting about required preventive care; (3) to make the informational 'gold' in the medical record accessible to clinical, epidemiologic, outcomes and management research. (McDonald et al. 1999, 226)

In 1994, the Regenstrief Institute extended the RMRS to the Indiana Network for Patient Care (INPC), a city-wide clinical informatics network in Indianapolis that has since grown to cover more than 70 hospitals state-wide (Biondich and Grannis 2004; Clement et al. 2005). Throughout its history, the Institute has been the leading center for randomized controlled trials of medical informatics interventions in the country. In this Policy Brief I discuss some of our research, including examples of what we learned works and doesn't work in clinical settings.

Canopy Computing

> The rain forest canopy is a seamless web through which arboreal creatures efficiently move to reach the edible fruits without any attention to the individual trees. Individual health care computer systems are rich with patient data, but rather than a canopy linking all the trees in the forest, the data 'fruit' come from a diverse forest of individual computer 'trees'—laboratory systems, word processing systems, pharmacy systems, and the like. These different sources of patient information are difficult or impossible to reach by individual physicians, especially from their offices. The World

> Wide Web and other standardization technology provide physicians and their institutions the tools needed for seamless and secure access to their patients' data and to medical information, when and where they need it. (McDonald et al. 1998, 1325)

What we call the *health information canopy* or *canopy computing* is an electronic nervous system through which information flows, connected to everything. I want to help you understand the density and intensity of information in health care, and how clinical data might be used—not only in caring for one patient at a time—but also to improve the systems of care, especially the quality effectiveness, efficiency, and outcomes of care.

Ideally, clinicians and their care institutions are connected by this electronic network. If the information I need to manage my patient is out there, I should be able to get what I want without having to be in the facility where that information resides. People practicing medicine in this canopy ought to expect that they can get their hands on the data they need and that it will be available for everyday decision making in practice. But in 2010, Clement McDonald's vivid rainforest metaphor from the 1990s has still not been realized.

Ideal vs. Reality

To illustrate our lack of progress, I'm going to give you two scenarios. First, imagine that a patient presents himself in an optimum health care environment where information is available at the right time, at the right place, to the right people, and can be managed in the right way.

Scenario 1: The Ideal

An 81-year-old man arrives at the emergency department in an ambulance. He's awake but he's confused. He has sustained a fall.

He is unable to give a cogent history and nobody accompanied him in the ambulance. This is not uncommon in an emergency department (ED) setting. People just show up and you don't know anything about them. But in this scenario, the physician looks up the medical history in a city-wide information system and finds:

A **neurologist's note** says the patient has a history of multiple system atrophy (MSA), which is a combination of dizziness (his blood pressure drops when he stands up), problems with balance (cerebellar dysfunction), and Parkinsonism. He had a toxic reaction in the past to low-dose Sinemet, a drug that's used to treat Parkinson's disease, which caused severe agitation and hallucinations.

Primary care notes in the same record show that the patient had a small increase in his cardiac enzymes during an earlier hospitalization for pneumonia, so his primary care physician put him on aspirin and a platelet inhibitor called clopidogrel, or Plavix. This combination increases the risk of bleeding in the brain with head trauma.

A **social service note** shows that the patient insisted on living alone in his home after his wife died. He has four adult children who live out of state and he's receiving 24-hour live-in support from non-medical personnel.

The record includes a **physical therapy note** that the patient has made great progress in weight and balance training, but he falls unless he uses his walker. Unfortunately, he has mild dementia and impaired memory, so he often forgets to use his walker. Hence the fall.

The city-wide information system shows he's on a **medication** to keep him from losing water, which works kind of the opposite of a diuretic, and is used for people with MSA. But it tends to raise his

blood pressure. He takes esomeprazole (Nexium) for acid reflux, aspirin, a multi-vitamin, and Tylenol for pain.

He has a **living will** that says he doesn't want to have any extraordinary life-prolonging medical treatments.

A physical examination in the ED shows him to have severe dizziness and his blood pressure drops when he stands up. His neurological exam doesn't point to anything in particular, although he's got a Parkinsonian tremor. He has ataxia—he staggers when he walks. He's got an enlarged prostate. He is awake and can talk, but he has a mild expressive aphasia, that is, he has trouble getting the words out.

His laboratory examination is completely normal except for a mild or moderate increase in his creatinine, meaning his kidneys don't function quite right. And a head CT scan shows he had a small bleed between the hemispheres of his brain (intrafalcial hematoma) and he's got severe atrophy of his brain, which happens to people with dementia. The bleed has not compressed parts of the brain so it should not be causing any neurological problems. The neurosurgeon sees the patient in the emergency room and says, "I want to admit him and watch him, just observe him for 24 hours. I don't think that there's anything acute going on, but let's watch him."

The ED physician calls the out-of-state daughter listed as next of kin in the city-wide medical record and informs her of her father's condition and admission to the hospital. The ED physician also collects additional data about the medical history and quality of life, as well as the patient's desire to avoid extraordinary and invasive treatments. He then e-mails the neurologist and primary care physicians to let them know the patient's in the hospital and why, and what's being done.

The ED physician calls the hospitalist to inform him that the patient is being admitted to him and discusses the condition and the plans. The hospitalist reviews the data, calls the daughter, confirms the information collected by the ED physician, and discusses plans. The hospitalist writes admitting orders using the Computer Physician Order Entry (CPOE) system, which informs him of the prior adverse reaction to Sinemet. The neurosurgeon follows up the next day, repeats the examination and the CT scan, which are both unchanged, and recommends discharge after 24 hours.

The hospitalist discusses discharge plans with the family, in-home caregivers, physical therapists, and social services or e-mails the plans to them, all of whom he can identify because they're all listed in the same city-wide record, even though they don't all work in the same hospital. The discharge note contains a summary of what happened to the patient, what was done in the hospital, and what the plans were at discharge. Follow-up appointments are made electronically with the neurologist, primary care physician, and physical therapist.

Remember that story because we'll return to it.

Indiana Network for Patient Care (INPC)

The Indiana Network for Patient Care (INPC) was launched in 1994 with funding from the National Institutes of Health and the National Library of Medicine. Its charter five major hospital systems include 15 different hospital facilities and more than 100 geographically distributed clinics and day surgery facilities in Central Indiana (http://www.regenstrief.org/medinformatics/inpc). Collectively these five systems admit about 170,000 patients, and serve about 400,000 ED visits and 2.7 million clinic visits per year. To date, more than 70 hospitals have joined INPC, which required establishing more than 1400 separate interfaces with these hospitals' information systems. All INPC facilities deliver

registration records, laboratory test reports, and selected other records for hospital admissions and ED visits to a central INPC server. The data are automatically standardized in format and coding as they arrive at the server, and patients with multiple medical records are linked. Each institution's INPC record has the same file structure and shares the same term directory that contains the codes, names (and other attributes) for tests, drugs, coded answers, and so on. There are more than 3 billion 'structured results,' individual items for more than 11 million patients, and this number doubles every four months. When a patient is seen in any of the EDs operated by the member hospitals, and the patient consents, all of the information about that one patient from all INPC facilities can be presented as one virtual medical record.

In 2001-2002, to learn how much patients migrate throughout a community, that is, obtain health care (and generate clinical data) in more than one hospital system, the INPC examined the records of nearly 500,000 patient visits to the EDs of hospitals in the five charter health care systems within the network that provide most of the acute medical care and found that of the patients who had sought ED care in one hospital setting during that period, 60 percent had clinical records in another hospital system (Finnell et al. 2003). Using data from the Centers for Disease Control they extrapolated that "20.6 million ED visits [nationwide] would have clinical information located in another, separate facility" (2003, 237).

Unfortunately, in most of the rest of the country we still don't have a health information canopy. Instead, we have freestanding, unconnected, vertical silos of information. We try to connect the silos by various means, such as a telephone call to ask for a fax of somebody's discharge summary from another hospital.

Scenario 2: What Really Happened

Now I'm going to go back through the story I told you earlier, this time telling not the idealized version, as if all the information were available, but how it really happened in a large town in Florida.

An eighty-one year old man arrives in the emergency department. That part doesn't change. The man arrives with no information. He's never been to this hospital before. There are no records available, no known next of kin, nobody to call. A physical examination shows the same thing as before: the patient is dizzy, orthostatic, ataxic, falls and can't speak very well. The diagnostic test results are the same—a bleed in the brain, abnormal renal function, and so on. The neurosurgeon's recommendation is the same; the patient is hospitalized for observation. The hospitalist discusses this information with the ED physician and writes admitting orders on paper, which at some time later are transcribed and acted upon. The patient's in-home caregiver calls the daughter to say that her father has been hospitalized. The daughter calls the hospital and is told by the nurse who represents the hospital, "Your father's in intensive care, his condition is critical, but I can't tell you any more because of HIPAA."

For those who don't know, HIPAA refers to the Health Insurance Portability and Affordability Act, which was enacted by Congress in 1996. HIPAA was supposed to make information more portable and to encourage the structured electronic transmission of health care data. However, the law's complicated privacy rules have turned out to have exactly the opposite effect. Quality of care has been sacrificed on the altar of confidentiality.

And that's what happens in this case. No information is available to the clinician, so the clinician doesn't know, for example, about the patient's previous toxic reaction to Sinemet. The daughter asks to speak to the physicians and the nurse representative says, "You can't talk to the doctors without permission from the patient,

and the patient didn't give any written permission." The fact that he can't give permission because he was hospitalized due to cognitive dysfunction doesn't make any difference to the hospital official. So the admitting order includes Sinemet for a Parkinsonian tremor. He becomes very agitated and delirious, for which he is given a sedative. The patient becomes over sedated, then vomits and aspirates—inhaling the vomit into his lungs. The patient has trouble breathing, experiences a prolonged period of hypoxia (low oxygen in his blood), and is put on a ventilator. He lapses into a coma. The next day, the CT scan results haven't changed, and the neurosurgeon repeats his exam and finds the same thing: no evidence that the small intracranial bleed is causing any problems. There are no other focal findings, and the neurosurgeon doesn't know why the patient is in a coma, except that it isn't due to the bleed in his head, so it must be something else—perhaps the prolonged period of hypoxia.

The patient's living will is not available. The patient's oldest son is finally contacted, on advice from the caregiver, and because he didn't know that there was a living will he says, "Do everything." The patient is successfully weaned from ventilation and has the breathing tube pulled out. Unfortunately, the patient vomits and aspirates again and the tube is re-inserted.

The patient's condition doesn't improve, so he is transferred to a nursing home without any accompanying information. The nursing home has no idea why the patient is there, but they think it is because he has pneumonia and Parkinson's disease. No family members are notified by the hospital or the nursing home that the patient has been transferred out of the hospital. There is no communication between the nursing home physicians and the family for a week despite frantic attempts by the family to contact them. The patient has a respiratory arrest at the nursing home, undergoes a full resuscitation effort which is unsuccessful, and dies.

The patient in this scenario was my father, and you can say in very real terms that his death was caused by HIPAA and lack of information flow between his health care providers.

The US Lags in Advanced EHR Capacity Among Developed Countries

The Commonwealth Fund surveyed primary care physicians in eleven highly developed countries and found that among doctors who reported using 'basic' electronic medical records in their practice, the Netherlands, New Zealand, and Norway were at the top (nearly 100% usage), while the United States and Canada ranked at the bottom, with 46% and 37% respectively (Schoen et al. 2009). Among those who reported using 'advanced' electronic information functions (such as electronic medical records, and electronic prescribing and ordering of tests) Australia and New Zealand led, at 91% and 92% respectively, followed by the United Kingdom, Italy, the Netherlands, Sweden, Germany, and eventually the United States at 26%. Norway, France, and Canada were at the bottom.

It isn't because we physicians don't have computers in our offices. Nearly all physician practices in the US use computers, mostly because the insurance companies demand it for billing. But fewer than half of those practices use computers for electronic records to support the delivery of care. The benefits of EHRs are not immediately apparent to many doctors.

Some years ago, I went to a wedding where a friend introduced me to the father of the bride. Striking up a conversation with him, I asked, "What do you do?" He said "I'm a family physician. And I want to tell you I'm really pissed off right now 'cause we are installing this electronic medical record system in my office and it's driving us crazy. We had a really efficient office and now we're trying to put in these computers and it slows me down—I can't

do what I want to do, and it's driving me crazy! So—what do you do?" (I'm not making this up....)

I explained what I did, having spent a career creating, installing, and studying EHRs. Then I described the Indiana Health Information Exchange (IHIE) and the INPC. I described my patient who was admitted with an infected elbow. By accessing his city-wide record I found out he had been admitted to five other hospitals in our city in the past 18 months with joints on the left side of his body infected with fecal-oral organisms. This guy was self-mutilating by injecting himself with stool. I would never have known that if his other records weren't available, even in another system.

He replied, "If I knew what happened to my patients outside of my office, then everything I'm going through to implement the new health record system would be worth it—because my biggest frustration is not knowing what's happening to my patients somewhere else."

Local Health Information Infrastructure

When Clement McDonald foresaw health information networks and canopy computing back in 1988, people didn't 'get it.' People understand this better now because of their experience surfing the Internet. We're moving to a single worldwide computer called the web, one global computer, one global mind. Apple created the model for this with the iPhone. Apple didn't have to do it all themselves. They took the approach that they would create the platform and let somebody else write applications for it. Just having the thing out there and having access to the data means people can then write innovative applications that do something with those data. We've gotten used to expecting this in every context but health care. I can find out everything I want to know about my favorite ballplayer by simply typing his name into

Google®. I think we ought to expect the same type of response in health care, too. That's what the canopy should do: provide the information I need for my patient regardless of where it was generated or stored. The future of high quality affordable care depends on such innovation.

What elements are required to build a working local health information infrastructure (LHII)?

Uniform coding system. If you have a chest x-ray done in one hospital, providers in other facilities need to know that it's a chest x-ray and what it showed, so you have to have a common code for things. You could use words, but which ones? There are many different ways of labeling things: chest x-ray, chest xray without a dash, or maybe chest radiograph. In 1994 the Regenstrief Institute developed LOINC (Logical Observation Identifiers Names and Codes) as a universal standard for identifying medical laboratory observations (http://loinc.org). It has since been expanded to include more than 58,000 observation terms, and it has been adopted by the federal government as a standard for the electronic exchange of clinical health information.

Real time data flow. The data have to flow up and into the system and down to the individual providers. To do that, you have to have a standard message format. Think of the front of an envelope: you can tell by the location and format of the information who the letter is to, who it's from, and when and where it was postmarked. There's a standard coding format called Health Level Seven International, or HL-7 (http://www.hl7.org) that will take a long string of data and turn it into something that's meaningful to a computer. HL7 is the most widely accepted standard format for health information exchange.

Data repository. This can be a single database, collecting data from all these hospitals and putting them in one database. Or you

can keep them in separate databases where a querying program can access this federation of databases and retrieve individual patient data very rapidly to create what's known as a virtual record, which is how INPC operates. Every hospital has its own database because, while hospitals are willing to share information, they prefer to maintain their own records and dictate the rules under which those records will be shared. Rarely in its 20+ year history have there been breaches of security in INPC and no major occasions when people's data have been used for nefarious purposes.

Interface engine. This provides access to the data once they're in the database. You enter the patient's name or identifying number, specify the data you want, and it displays on the screen. The information may come from several different places, but you see it combined on one screen as if it is from a single database. The system has to be usable by both people and other computer programs. My hospital may want to know how well we treat diabetes, so we identify diabetics, look at their blood sugars done by any number of different doctors, and see how effectively they're being managed. All of that can be done by extracting data from the data exchange.

Most Data Are Already Electronic

There's no longer a paper chart in our hospital. Integrated inpatient and outpatient registration and scheduling systems, diagnoses and admission, discharge, transfer (ADT) systems, lab systems, pharmacy systems, radiology systems—being able to view an x-ray anywhere—are all innovations that have come about in the last five to seven years.

When that first became available. I had a young woman admitted to me with chest pain. I looked up her x-ray on my office computer before I went to see her—it hadn't been read by the radiologist

yet—and it showed the patient had a small airway that had ruptured, causing a spontaneous pneumothorax, or collapsed lung. I immediately transferred the patient to surgery, a chest tube was inserted, and she left the hospital in a day or two. I could manage her care from a distance within seconds because I knew where this piece of information was, and could access it from a distance without having to run around to find it.

Not All Important Data Are Electronic

But you need to know that there are some important things that we providers do not record.

Past history, unless it happened within our network, is not available.

Family history.

Symptoms. We might occasionally write them in notes, but don't record them in a way that they can be retrieved by a computer.

Quality of life assessments, either formal systems such as the RAND Medical Outcomes Study 36-Item Short Form Survey (SF-36), or what I call the SF-1, the "How you doin'?" question. We don't record that, but I think we're going to have to in the future. Mental health, for example, is way ahead of the rest of medicine because they have standard instruments to assess and record important symptomatic conditions like depression.

Vital signs, if they're not done with an electronic cuff, are almost never recorded in a place where they're actually available.

Telephone communications, verbal orders, and prescriptions are often simply written on pieces of paper.

Selected outcomes, such as responses to medications. You may be able to tell what the patient is taking, but you also want to know how well they've responded to it in the past or what they have taken that they have not responded to, and the patient may not be able to tell you.

True health care costs. We know charges really well. We don't know what drugs and tests, etc. really cost patients, providers, and health care facilities. And charges are a myth, they're whatever people are willing to pay...or not. They have little relationship to what we or our insurance companies actually pay for our care.

Barriers to Using Current Electronic Data

Lack of connectivity for transporting data. If somebody goes outside of your system, outside of your network, how do you get the data to somebody else? If you're in one of the Veterans Administration's 1,719 medical centers or other health care facilities, they all have the same electronic record system. Kaiser Permanente is somewhat the same way. Not many other places can do that, and it's a problem because that's what we're aiming for with the interoperability that's demanded by the new health care act. Outside facilities may be connected to the Internet, but they don't have efficient and effective ways of transmitting data, and they often use different data models and coding systems.

Worries about data security and HIPAA. We've held focus groups in Indianapolis with poor inner-city patients to explore their thoughts about sharing data between their health care providers (doctors and pharmacies and the like), and the most common answer we got was "You don't do that already? Why not?" They think providers ought to be sharing because most patients know they'll get better care if the information follows them when they go to get care in different places.

Competition between providers. This presents additional barriers. Doctors may say "I don't want to give you data about my patient because you may steal my patient." Controlling the patient's information can control where the patient gets care.

Inertia. This is also a problem. Many physicians don't want to do anything new. They're often incredibly busy and comfortable with the status quo, and change takes time. That's the most expensive thing in changing health care systems—not technology, not personnel, but the time it takes to re-engineer and redevelop systems of care.

The general disconnect between cost and savings. Many physicians think, "If I put an electronic medical record system in my office practice, it saves money for the insurance company and for the patient and for the employer, but it doesn't save me any money, so why should I pay for it? "

Overcoming Those Barriers

Today, computers and e-literacy are pervasive. Nearly everybody uses a computer and understands what computers are capable of doing, so we've got at least the trunks of the canopy. During a recent study of a system for capturing adverse drug events that we conducted in rural research networks in Connecticut, Texas, and Oregon, as well as urban practices in Los Angeles, we developed a completely separate system that required only standalone computers without using the Internet (Hickner et al. 2010). We even included another system that was on paper, but the standalone computer and paper versions were rarely used because everyone had access to the Internet in their offices.

In his 2004 State of the Union address, President George W. Bush announced creation of the Office of the National Coordinator for Health and Information Technology (ONCHIT) and committed the United States to going to electronic health records in the next 10 to

15 years. In 2009 the Health Information Technology for Economic and Clinical Health (HITECH) Act was enacted as part of the American Recovery and Reinvestment Act (Pub. L. 111-5, Subtitle A, Section 4104(a)). It promotes the adoption and "meaningful use" of health information technology in the US. It provides payment incentives to physicians who implement an EHR system under either Medicare or Medicaid between 2011 and 2016. Today, if you can show that you're capturing data in your practice or your hospital and you have the ability to share it with other people, and if you're using inter-operable standards of messaging and coding, then you're going to get $40,000 per physician. So now we've begun aligning costs and benefits.

By 2013, you have to show that you can do advanced care and decision supports with your system. And by 2015, you have to start showing you've improved outcomes, and you're going to get penalized, meaning getting lower payments from Medicare, if you don't use electronic medical records in a "meaningful" way.

We are beginning to see very creative uses of health information technology to solve some sticky problems in US health care. For example, some hospitals that can't afford 24/7 physician coverage in their ICUs rely on clinicians in India to monitor patients in their Electronic Intensive Care Units (EICUs) late at night, looking at the data and acting on it when needed. While some doctors may view this technology as a threat to the traditional doctor-patient relationship, it may be better than having nobody watching and capable of intervening. Besides, as Howard Bleich, one of the other pioneers of medical informatics, noted in 1985, "Any doctor who can be replaced by a computer deserves to be."

Computer-based Physician Order Entry

One of the innovations required by the HITECH Act is Computer-based Physician Order Entry (CPOE). The Institute of Medicine

(2006) recommends CPOE be used universally to write orders to avoid adverse drug events (ADEs). The National Quality Forum (NQF) lists CPOE as one of its safe practices (NQF 2008). And CPOE is one of the benchmarks that the Leapfrog Group (2000) recommends for universal adoption by hospitals to reduce serious medication errors and thereby promote patient safety.

This ought to help us improve both the quality and the safety of health care, and lower its costs. How might it help?

Providing alerts about drug interactions, drug diagnosis interactions, warnings, and duplicate therapy—identifying instances where a patient's already received this drug from somebody else.

Transmitting data electronically, and quickly, to the right people.

Providing basic clinical decision support, such as limiting tests to ones that actually exist in the institution you're working in or ordering only those drugs that you actually have in your formulary or which the patient's insurance allows without special approvals.

Aiding in dosing of drugs based on the patient's weight and kidney function. Some of us have trouble doing those calculations in our heads. This can also prevent doctors from ordering a drug in a toxic range; you can't order something that's ten times the dose, or something in milligrams when should be in micrograms, like thyroid medication.

Checking on allergies. If someone came into the ED ten years ago with an allergy to a medication, that information ought to be in the system forever so when that person comes into any system connected to that ED that information should be displayed to a doctor trying to order that medication.

Then there are advanced levels of support that you can build into CPOE systems, such as:

Identifying patients who are at a higher risk for a condition, such as heart disease, who can be targeted for specific interventions, such as behavior modification programs.

Suggesting 'corollary orders' such as a follow-up test to a change in medication.

Pointing out appropriate preventive care actions that are not being followed.

Encouraging adherence to evidence-based practice guidelines, such as tighter than usual blood pressure control in patients with diabetes .

Does CPOE Work?

Interestingly, there's only been one randomized controlled trial of the use of CPOE in hospitals (Tierney et al. 1993). It's the only one that exists for two reasons. First, such studies are hard to do because one has to set up two parallel systems for writing and managing orders without endangering patient safety. Second, given the recommendations of the IOM, NQF, Leapfrog group, and most recently the Office of the National Coordinator for Health Information Technology (ONCHIT 2010), CPOE is now the default expectation and required as part of the minimal use criteria. So there's not going to be another controlled trial of CPOE use, which is too bad because I think a lot can be learned by what happens when you put these systems in place. In our CPOE study, some of the residents, faculty, and medical student teams in our hospital used paper orders and some used a home-grown CPOE system called The Medical Gopher (McDonald and Tierney 1986a) to write orders for more than 5,000 hospital patients over a two-year period. All tasks in this system were menu driven. Menus

were problem and task-specific, so if a patient had heart failure a majority of the drugs, tests, and nursing orders were specific to heart failure. Eighty-five percent of the orders were selected from menus, attesting to the quality of the menus.

Half of the orders were written away from the patient's ward. In cases where you don't have CPOE, if you want to write an order on a patient who's on a different floor, you either have to physically go there, spend precious time trying to locate the chart, and write the order down, or you have to telephone the ward nurse and give a verbal order which you hope will be written down and carried out correctly, all of which increases the chance of errors. However, with CPOE you could write orders anywhere in the hospital, even outside of the hospital, for somebody inside the hospital. The orders were then automatically sent not only to the ward, but to other places such as the pharmacy and the lab. The orders were legible, contained dates and times they were written, and were signed electronically. Physicians could search a patient's electronic record, including numeric and coded data along with text reports, while writing an order.

The system displayed and printed EKGs and their interpretations. It linked to our inquiry program to get data from prior tests, treatments, dictated reports, and so on from outside practices and institutions, when available. This was the beginning of the Indiana Network for Patient Care back in the late 1980s. Users also had access to patients' advance directives, the American Hospital Formulary Service (ASHP) manual, selected electronic medical journals, and to the National Library of Medicine's PubMed.

We found that during this two-year period there was a 13%, or $900 per admission, reduction in charges among CPOE users. Length of stay dropped by almost a full day. There was a twelve-fold reduction in the time (from 6 hours to 30 minutes) it took for a patient to receive the first treatment after being admitted to the

hospital, and the number of drug-related incident reports were a third lower among CPOE users. We also performed a time-motion study where observers followed interns on admitting days when they were really busy. We found that it took the interns an extra half-hour a day to write orders by computer, about five minutes per patient per day. But it also decreased by five minutes to six minutes per day the time they spent looking for information. After we finished the study in 1991, the system was mandated hospital-wide and has been in continuous use ever since to write all inpatient and outpatient orders in the largest public hospital system in the country.

Reminders for Preventive Care

We performed another study looking at reminders to physicians from interactive medical records, which showed that if you reminded physicians to do appropriate preventive care—occult blood testing, mammograms, prescribing weight reduction diets, administering vaccines—they did them almost twice as often (McDonald et al. 1984). As Francis Bacon said, “Men more frequently need to be reminded than informed.” The biggest increases in adherence were to physician-authored guidelines for preventive care.

Monitoring for Adverse Events

There was a study of corollary or follow-up orders to monitor initial test results or treatments (Overhage et al. 1997), which I mentioned before. You order a drug; it’s got to be followed up with a test. For example, an increase in the dose of heparin (a blood thinning medicine given intravenously) should be followed by a test to measure blood clotting time. What if the system gave you the option to order that test automatically when the drug was ordered? We found that with reminders about corollary orders doubled the ordering of the appropriate drug-monitoring tests. The system made it easy for physicians, in that they didn’t have

to worry about remembering to order the follow-up tests later. It is important to note that when this intervention, like others before it, proved successful, it was broadly implemented as 'usual care' throughout our inner-city health care organization.

Evidence-Based Suggestions for Care

Not all studies proved successful, however. In a study involving about 700 patients with chronic obstructive pulmonary disease and asthma in our outpatient practice, we provided care suggestions based on local evidence-based practice guidelines (Tierney et al. 2005). For example, if a patient with asthma that was more than mild wasn't on an inhaled corticosteroid, the doctors got a reminder in the middle of their outpatient CPOE ordering session. At the same time, the system would write an order for a beclomethasone oral inhaler; if you hit the return button, the order was processed, but if you hit any other button, it was not. We did this for a comprehensive set of guidelines for asthma and COPD.

The suggestions failed miserably. They had no effect on physician adherence to the guidelines, patient adherence to the target medications, exacerbation of the disease, costs, quality of life, or satisfaction with care. Why? Well, physicians felt guidelines were good for some things: they were a convenient source of information and a good educational tool. However, they also felt that the guidelines were too rigid to apply to an individual patient of theirs. They were concerned that they were enforcing 'cookbook' medicine; that is, with the computer telling them what to do, they no longer had the autonomy that they wanted. They also worried that the suggestions were simply a means to decrease costs, rather than being about increasing quality of care. Interestingly, these were the same physicians and practices where computer reminders increased preventive care. Apparently, physicians don't mind decision aids for preventive care, but they do mind when they suggest treatments.

We repeated this same study of computerized treatment guidelines for two other conditions, heart disease (Tierney et al. 2003) and hypertension (Murray et al. 2004), and we found the same thing. Why didn't they work?

For one thing, we didn't focus on the right patients. When patients had mild disease, doctors apparently reasoned that unless the patient was doing badly, there was no reason to 'rock the boat.' Even if the evidence-based guidelines suggested this patient really ought to be on some other medication because it would prevent bad events, they didn't want to change meds if the patient seemed to be doing okay.

We also got the workflow wrong. Doctors wrote orders at the end of the visit, after the patient had already left the exam room. So if they wanted to change something they had to bring their patient back into the room and talk to them again. It was too hard; it's easier to say, "I'll do it next time." But during the next visit, they didn't remember to discuss changing treatment until reminded again after the patient was out of the room, so some things just didn't get done. We didn't figure out how to fit this decision aid into their daily practice of medicine.

And finally, it was just the wrong approach. Perhaps we didn't involve the physicians enough in the process. Again, it seemed to be the computer telling them what to do, rather than their using the computer as a tool to help them tell themselves what to do. A better approach might be to present primary care physicians with a set of rules for which the computer could remind them, with the physicians having input into the triggers (e.g., the level of elevated blood pressure or the number of elevated blood pressures that were necessary before the computer suggested increasing the dose of that patient's antihypertensive medication).

So we tried a different approach in a study involving 720 outpatients with chronic heart failure in two Veterans Affairs medical centers in Indianapolis and Seattle, Washington, in which we did engage the physicians (Subramanian et al. 2004). We met with VA physicians and asked them how the computer system might improve their care of patients with heart failure. They helped write the guidelines and how to identify patients who would be eligible for care suggestions. We then used mailed questionnaires to assess the patients two weeks before each visit—their functional class and symptoms and how they did since their last doctor visit. Then we added a reminder sheet that clipped to the patient's paper chart before the doctor got to that patient. If your patient was in the intervention group, you got information about their current symptoms and whether they were doing better or worse. The reminder sheet included symptom information, the date of the test which had documented the patient's heart failure, and "care options at this time" rather than suggested treatments. That is, instead of writing orders for treatments in the computer, the paper form contained a list of actions that you might consider doing. The control group was just given the information that their patient had heart failure.

Unfortunately, symptom information and care suggestion reminder sheets had no effect on physicians' treatment decisions or patient outcomes, even among those patients who were not doing well, although the intervention patients were significantly more satisfied with their physicians and the care they received. We think the reminder sheets engendered discussion between the doctors and the patients because they presented information about symptoms of those patients. However, they didn't result in more intensive heart failure treatment and may actually have harmed the patients: there were more than double the number of hospitalizations at six months and at twelve months among the intervention group, although this could have been because intervention doctors were

paying more attention to symptoms and hospitalizing patients who needed it who would not otherwise have been hospitalized.

Reminders to Discuss Advance Directives with At Risk Patients

Not all our studies had negative outcomes. In a study of reminders to discuss end-of-life care, we enrolled 1,000 patients who were at risk of needing such discussions because of their age (>75 years) or because they had serious medical conditions such as heart, lung, liver, or kidney disease, cancer, or stroke (Dexter et al. 1998). The computer suggested that doctors talk to their patients about advance directives, using either what we call instruction directives ("Do you want to have a ventilator; artificial nutrition; surgery, if it's indicated medically but you're in a situation where you're terminally ill and not likely to get better?") or proxy directives ("Who do you want speaking for you? Who do you want to be your health care representative?") Physicians got either reminders to talk about advance directives, reminders to talk about proxies, both or neither.

After every visit the patients were asked, "Did your doctor talk to you about end-of-life care?" and how satisfied they were with their doctor and the visit just completed. Among patients whose physicians did not receive reminders, doctors talked to them about advance directives only 2% of the time, a little more often if they got reminders for proxy directives, and a little bit more for instruction directives. When physicians received both reminders, more than 20% of them talked to their patients, and two-thirds of the time that they talked to their patients an advance directive form was filled out. In this case, a simple computer reminder increased the likelihood of doctors talking to their patients about the prickly issue of end-of-life care. Importantly, even though a lot of times doctors are kind of uncomfortable broaching the subject, patients preferred that their doctor talked with them about advance directives and end-of-life care in the primary care clinic rather than

in the ICU and were more satisfied with their doctors and primary care when such discussions occurred.

Enhancing Communication between Providers

We've performed studies in other settings besides hospitals and doctors' offices. In one study, we assessed the effectiveness of a pharmacy-based care program for patients with asthma or chronic obstructive pulmonary disease who went to one of 36 community drugstores to refill their prescriptions (Weinberger et al. 2002). The pharmacists received patient-specific data from patients' electronic health records on peak expiratory flow rates, past use of breathing medications, and recent ER visits for breathing problems. They were also given customized patient educational materials and resources that were to be used by the pharmacists to inform those patients whose were not doing well. In one control group, patients received peak flow meters, instructions in how to use them, and monthly tracking of meter readings, but this information was not provided to their pharmacists. In the second (usual care) control group, patients interviewed monthly to see how they were doing, but they received no meters and their pharmacists received no information about them. Pharmacists in both control groups had a training session informing them about asthma and guidelines for self-care but received no patient data or educational materials. At the end of the study, patients who received the intervention from their pharmacists seemed to have better lung function, and they were more satisfied with their care. However, there was no difference in their adherence to care guidelines, and they were twice as likely to be hospitalized. So, as in the earlier study, the information provided to the pharmacists may have caused harm to the patients, or alternatively, it may have sensitized pharmacists to patients who were ill and needed more intensive treatments.

Evidence about the benefits of enhanced patient communication is still up in the air. It's still not clear what effect electronic health

records are going to have because we're still working on the process of managing the system.

Unintended Consequences of CPOE

In October 2002 the Children's Hospital of Pittsburgh, a tertiary-care level facility with many infants transported from other hospitals into their ICU, implemented a CPOE system in response to the IOM's (1999) landmark report and the Leapfrog Group's (2000) promotion of this technology, which we had studied a decade earlier and had been using hospital-wide ever since. Eighteen months later, researchers found that, as expected, "CPOE implementation...resulted in significant reductions in harmful adverse drug events (ADEs)" (Han et al. 2005). However, they also found that the hospital also experienced an unexpected increase in mortality from 2.8% before CPOE implementation to 6.6% after implementation. They ruled out demographic or clinical factors and then focused on changes in the usual "chain of events" when a critically sick infant was being admitted to the ICU after CPOE implementation. They found that the medical team's response time was slower, some doctors and nurses were being pulled away from the patient's bedside to operate computer terminals, and critical face-to-face interactions between physicians and nurses had declined. These things happened because the CPOE system was hard to use and occasionally overburdened, suffering processing delays. Sometimes the information didn't go to the right person so there were delays in getting things done, which in a newborn ICU can make the difference between life and death.

From this we learned that technologies are tools for improving the health care system, but they're not standalone fixes. You can't just throw medical records and clinical decision support tools into health care settings and expect something good to happen. Information technology has to be part of a careful and complete re-engineering of the health care system that learns how to

function efficiently and effectively and use electronic information. Sometimes there's too much reliance on technology and 'geeks' and not enough on clinical acumen and common sense. The best use of health information technology incorporates all of these into enhanced systems that are more efficient and safer, but this takes diligence on the part of those implementing such systems.

CPOE Can Lower the Cost of Health Care

In the early 1980s, we looked at our local data and found that many outpatient tests were often repeated for no obvious reason, so in 1987 we studied whether using our outpatient CPOE system to display previous diagnostic test results would lower the ordering of subsequent diagnostic tests (Tierney et al. 1987). Half of each physician's patients were randomized as control patients and half were randomized so that when physicians ordered one of the eight most commonly ordered diagnostic tests in our practice, the CPOE system displayed the most recent previous results for that test. Compared to the pre-study period, when physicians saw their patients' previous test results, they ordered 17% fewer tests compared to a drop of 11% when the past results were not displayed. As a result of fewer tests, the costs associated with those patients' care also dropped significantly. Unfortunately, as soon as the previous test result display was discontinued, test orders began to return to their previous levels. This told us that we weren't just educating physicians about the number of tests they were ordering—they also needed the constant display of past results. Ever since, we show the most recent result (and its date) whenever any outpatient diagnostic test is ordered.

We performed a similar study in which we developed statistical equations to predict the probability of an abnormality being detected as a result of eight commonly ordered diagnostic tests (Tierney et al. 1988). We divided the subject patients into intervention and control groups, and whenever the physician

ordered one of the tests for a patient in the intervention group using the outpatient CPOE system, the computer displayed the likelihood that the test would show the abnormality that the physician had selected as the main one of interest. "For example, if the physician ordered a serum electrolyte panel and listed hyperkalemia as the abnormality of concern, the computer presented the probability of hyperkalemia" (p. 1196). After viewing the computer's prediction, the physician could choose to cancel the test or continue to order it. Physicians did not see probabilities for their control patients. Among the 112 physicians and more than 9,000 patients involved in this study, there was a significant, although small, reduction in testing when they got the probability information, but it was mainly among tests with a low risk of abnormal results. This was the first study showing that physicians would respond to specific numeric probability predictions. Once again, after the intervention was discontinued test ordering returned to the pre-study levels.

Finally, our simplest intervention was when the computer display just said "This is what the test you just ordered costs, and here's the total cost of all of the tests you've ordered today" (Tierney et al. 1990). When we did that, there was a 13 percent reduction in test ordering. But once again, "the effects of this intervention did not persist after it was discontinued" (p. 1499).

Given the potential financial benefits (and significant costs!) of EHRs, do they ultimately cost money or save money? Samuel Wang and colleagues in the Harvard group conducted a cost-benefit study to analyze the financial effects of EHRs on health care organizations, using data from their own institution and a previously published literature review (Wang et al. 2003). They concluded that over a 5-year period, the average net benefit was $86,400 per provider, "primarily from savings in drug expenditures, improved utilization of radiology tests, better capture of charges, and decreased billing errors" (2003, 397). However,

they noted that "The magnitude of the return is sensitive to several key factors" (2003, 397). They were being optimistic.

The RAND group reviewed all of the studies that looked at the cost of implementing health information technology (HIT) using data from a large survey of health care facilities' adoption of and plans to adopt HIT (Hillestad et al. 2005). They included in the adoption category organizations that had contracted for but had not yet installed an EMR system, and they surveyed the literature for evidence of the effects of HIT. They noted that,

> In general, the currently useful evidence is not robust enough to make strong predictions, and we describe our results only as 'potential'...[that is,] 'assuming that interconnected and interoperable EMR systems are adopted widely and used effectively.' (p. 1104)

They concluded,

> [E]ffective EMR implementation and networking could eventually save more than $81 billion annually—by improving health care efficiency and safety—and that HIT-enabled prevention and management of chronic disease could eventually double those savings while increasing health and other social benefits. However, this is unlikely to be realized without related changes to the health care system. (p. 1103)

Maybe Electronic Health Records save money, maybe they don't. But I'm going to argue that's not why we're installing them. We're putting them in because we have to communicate. Using EHRs is the only way to do so in the 21st century with its increasingly complex and disconnected health care.

Looking to the Future

So where's the edge of the water? The high speed Internet is going to increase our capability of communicating through EHRs. We're going to be able to show real x-ray images, displaying the same dense images anywhere in the country as in the hospital that generated them. So we can actually have people reading your x-rays who don't have to sit in your hospital. This could be good (i.e., having world-class specialists reading x-rays) or bad (i.e., physicians not having a local radiologist to discuss the x-ray with). HIT is a two-edged sword.

There will be better provider-computer interfaces, better graphic design, touch screen technology, portable devices, voice recognition, etc.: this is all coming. Much of it is already here. The radiologists in my hospital use a voice recognition system to dictate x-ray reports. And we get the results in the patient's electronic record less than an hour after an x-ray is taken. Better devices, wireless technology, small tablet computers, and better health information technology will all improve how we practice medicine.

Everybody uses the Internet browser, right? How many of you ever took a course in how to use it? Why not? Because it's obvious how to use it. Well, our health-related technology needs to be obvious too. You shouldn't need a manual. You shouldn't need instructions. You should be able to sit down, log in, and know right off the bat how to use it. It ought to be obvious, and it's getting to be that way. There will also be lots of new options for devices and platforms. If I'm working in the emergency department, I need to be mobile. If I'm working in radiology, I don't want to be mobile. So let's have different options that fit people's workflow.

We need better actionable care guidelines. What needs to be done better? What data do we need to capture to do it better? And how

do we get that information to the right people at the right time? How do better prepare clinicians, facilities, computer information officers, etc., to take full advantage of electronic media and not be hamstrung by it? We all have to be willing to accept these changes in our work environment. We have to expect to have the right information at the right time and be willing and able to work together to make all this happen. In this new era of health information technology, some will consider it to be heaven while others will think it's hell. But like it or not, the dawn of a new era is here. Some of us have been in this era since the 1970s; the rest of US health care is entering this world now, too. I don't know where it's going to take us, but it's going to be an interesting ride. I can't predict how it's going to go, and it's been painful for a lot of people. But in my mind, the benefits will ultimately be worth the costs.

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