Deploying Information Technologies for Better Laboratory Use and Patient Outcomes: 20 Years at One Academic Medical Center

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Abstract: Skyrocketing costs and an aging population are driving U.S. health care toward bankruptcy: 15 % of the Gross Domestic Product is now being spent on health care. The key to solving this dilemma will be to cut fat from health care expenditures without sacrificing vital tissue. Despite the wide availability of computers and electronic media, the American health care industry still relies mainly on pen and paper to record and transmit information at many key points. Errors on paper records cannot be easily controlled and eliminated, while storage, maintenance, and access costs can consume more than 40% of a health care institution's budget and 25% of a health care provider's time. Mature and developing electronic information technologies can help improve care and lower costs by providing both generic information (knowledge), patient-specific data, and decision-support services.

At the Indiana University Medical Center, an electronic medical record has been created that contains most patient data (numeric and coded test results, drug use, diagnoses, clinical activity, textual reports, and itemized charges) for an urban tax-supported teaching hospital, a VA Medical Center, and their outpatient facilities. At the public hospital, this information system is serviced by a network of computer workstations for processing physicians' inpatient and outpatient orders while providing them with knowledge (e.g., an electronic version of Scientific American Medicine and the American Hospital Formulary Service Manual containing more than 1000 drug monographs), timely task and patient-specific data, and automated reminder rules and clinical practice guidelines.

Such interventions are themselves expensive, however, and despite flashy technology, should prove their worth in carefully performed studies before being broadly instituted. In a series of carefully controlled randomized trials, the authors have shown that computer reminders, feedback reports, automated guidelines, prior test results, display of test charges, and identifying high-risk patients can substantially alter diagnostic testing. Reminders, feedback reports, and guidelines doubled the ordering of appropriate preventive care screening tests and tests for monitoring of drug therapy and invasive procedures. Presenting prior test results and testing charges, and identifying high risk patients using data stored in patients' electronic medical records, lowered costs by 8 to 13% while maintaining (and even improving) the quality of care delivered. The inpatient microcomputer workstations that were the focus of much of this work incorporate many of the authors' prior successful interventions. When studied in a randomized, controlled trial, physicians using the workstations exclusively to write orders had hospital bills almost $900 (13%)

lower hospital bills. Length of hospital stays were shortened by almost a full day (11 %), and delays in initiating drug therapy were lowered by an order of magnitude while simultaneously reducing drug errors by one third.

As part of the National Information Infrastructure (the federal 'Information Superhighway" initiative), the authors have developed a high-speed network to support coordinated care and improved decision-making among 6 hospitals, more than a dozen satellite clinics and neighborhood health centers, and selected physicians' offices city-wide. Funded by the National Library of Medicine, this network will allow sharing of information between institutions during clinical encounters to reduce errors and avoid duplicative ordering of diagnostic tests and previous treatments.

High-quality health care is the sum of many small, often mundane decisions for which powerful information technologies will help cut costs and improve care while maintaining the physician's role as diagnostician and provider of empathetic interpersonal care. Reaching this goal will necessitate not only installing powerful computers and sophisticated programs throughout the health care environment, it will also require rethinking providers' roles to maximize the contribution of each health care team member's unique abilities.

Introduction

Health care costs are spiraling out of control. Health care now consumes more than 14% of the Gross Domestic Product, and this percentage is still increasing.[1,2] As medical costs rise, along with anticipated aging of the US population, American health care is approaching meltdown. In response, employers, payers, health care providers, and State and federal governments are searching for ways of reigning in health care costs without sacrificing the quality of care. Innovations to date have targeted both microprocesses (individual decisions) and macrosystems in health care and have included the following:

- **Managed care** where fee-for-service reimbursement creates incentives to increase the amount of health care delivered. Managed care is based on two premises: (1) payment for services is capitated, and (2) the care is managed by the practice to reduce waste and promote efficiency.
- **Restricted decision-making** where selected high cost and/or low yield health care tests and treatments, or those that have little effect on physician decisions or patient outcomes, cannot be ordered at all (e.g., restricted formularies) or require special prior approval.
- **Practice guidelines** where, to reduce variation in decision-making, care is guided by generally accepted algorithms that suggest actions but do not take the place of clinicians.
- **Care protocols** where decisions for selected conditions are dictated by care algorithms that largely remove clinicians from making most individual decisions.
- **Physician extenders**, such as nurse practitioners and physicians' assistants, who have varying amounts of decision-making authority and who often, to varying extent, follow explicit guidelines and/or care protocols.

Diagnostic tests are ripe for interventions to curtail their use because they have inflated

in price as fast or faster than other segments of health care and are often ordered or performed with little forethought or by inefficient general rules. Most diagnostic tests, especially those from the clinical laboratory, have little impact on decision-making and health care outcomes and are often unnecessary.[3-7] Reasons given by physicians for ordering tests with little informational content have ranged from "How do I know the patient doesn't have it [the outcome being sought]?" to "I might get sued."

A Model for Rational Test-Ordering

Physicians control more than 80% of all health care costs and order most diagnostic tests.[8] Therefore, this report will focus on ways in which physicians can become more parsimonious in their test-ordering. To enable physicians to get the most informational content out of clinical testing, Pauker has suggested a "threshold model" of clinical decision-making. Under this model, a rational clinician would order tests only if, in response to expected results, he/she would (1) neither treat nor test further (i.e., if the test is negative, the probability of disease would be so low that nothing further would need to be done), (2) treat the patient (i.e., if the test is positive, the probability would be so high that treatment should be initiated), or (3) order additional diagnostic tests (i.e., the test results in a probability estimate that is between the "no treatment/no further testing" threshold and the "treat/no further testing" threshold, as often happens with abnormal screening test results).[9] Most clinicians do not follow such a model when making decisions about testing and treatment, however, relying instead on heuristics (decision rules) that match clinical patterns of signs and symptoms with patterns of testing and treatment. Clinicians using such heuristics tend to err on the side of sensitivity (i.e., don't overlook diagnoses) and often do not fully exploit the incremental knowledge gained with each test result. By paying attention to the likelihood of disease, both before and after testing, and by having a plan of action (testing and/or treatment) contingent upon test results and patient characteristics, more informational "bang" can be obtained from the diagnostic testing "buck." Medical informatics offers tools to help achieve this end.

Medical Informatics and Quality Improvement

Information technology has been touted as an emerging tool to lower the costs of health care while improving its quality.[10] Managing medical information itself is costly: hospitals spend more than 40% of their operating costs on generating, storing, or retrieving information.[11] At the same time, physicians spend as much as 25% of their time recording or looking for information,[12] yet fail to find the needed information as much as 10% of the time.[13] The timely availability of electronic patient information could result in better testing by reducing the duplication of tests, making recent and prior results more available to multiple providers in multiple sites. Moreover, false-positive results, and the subsequent tests spent confirming or treating such results, could be reduced by targeting higher risk patients. Information technologies are expensive, however, and interventions to lower costs should themselves be cost-effective. Moreover, costs are only one outcome of interest: the impact of newer information processing systems (and the clinical systems within which they operate) on the quality of health

care should also be assessed. Therefore, information systems and electronic decision-support technologies should be studied, where possible, in controlled clinical trials before becoming widely disseminated.[14]

In the past several years, the methods of industrial quality improvement have become widely used in medicine.[15] As applied to diagnostic testing, the quality improvement model is information-intensive and requires measurements of health care processes in addition to objective and subjective (patient-centered) health care outcomes. Thus, studies of informatics interventions have used captured clinical data to both generate their interventions and assess their outcomes. Interventions to improve diagnostic testing that we have studied include continuing education, feedback of performance, generic and patient-specific reminders, and automating clinical practice guidelines. Each of these interventions have been shown to be most powerful if they were specific to the individual physician and were continuing: in our studies and those of others, when the interventions were discontinued, the physicians reverted back to their prior behavior patterns.[8] Medical informatics offers the ability to continue successful interventions indefinitely because most of their costs are front-end loaded so that, once the intervention is initiated and proven effective, there is little maintenance cost.

20 Years of Experience in Indiana

For more than two decades, we have used the data and processes of a comprehensive electronic medical record system to improve physician decision-making in an urban teaching hospital and its outpatient general internal medicine clinic.[16,17] For example, computer-generated reminders to perform outpatient preventive care improved compliance with accepted protocols from 29% to 49% (Figure 1).[18] Moreover, timing was critical: feedback reports of patients who had been eligible for preventive care but had not received it had less effect than reminders that were delivered to physicians at the time that they were caring for eligible outpatients (Figure 1).[19] Computer-generated reminders also outperformed an intensive continuing education intervention which had no significant effect on physician behavior.[20]

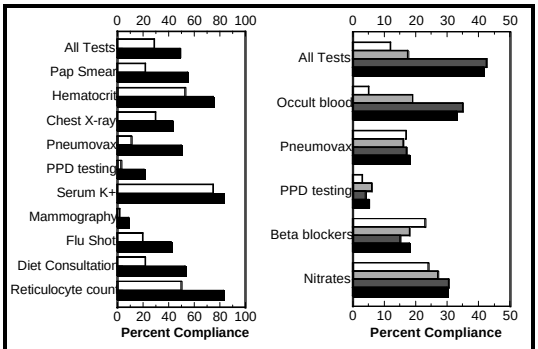

Figure 1: Controlled trials to improve compliance with preventive care. Left=Computer reminders vs. control (white bars). Right=Control (top bar) vs. feedback (2nd) vs. reminders (3rd) vs both (4th)

For increasing the timeliness of informational interventions to improve clinical decision-making, we created a network of physicians' microcomputer workstations for writing outpatient test orders.[21] Once they became the sole means for ordering outpatient diagnostic tests, the workstations could provide the physician, while he/she was writing orders for a patient, with information that was specific to that patient and the test being ordered. In a series of controlled trials (Figure 2), we found that outpatient test-ordering could be reduced, with no diminution of the quality of care, by displaying prior test results,[22] test

prices,[23] and calculated likelihoods that the tests would demonstrate the specific abnormality being sought.[24] In each case, when the intervention was terminated, test-ordering returned to pre-study levels.

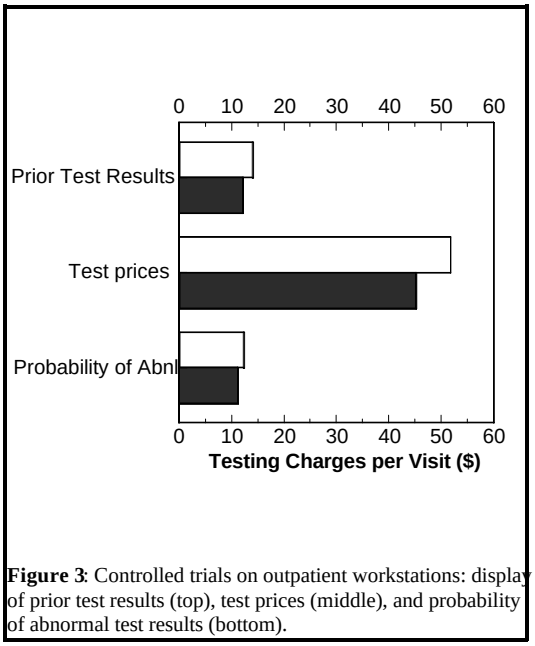

Figure 3: Controlled trials on outpatient workstations: display of prior test results (top), test prices (middle), and probability of abnormal test results (bottom).

Next, we moved to a more intensive venue: the hospital. We programmed our workstations so that physicians could write all inpatient orders using any of the workstations located throughout the hospital. The physician did not have to be on the patient's ward nor have the paper chart in hand to write workstation orders which were sent electronically to the appropriate hospital department (e.g., pharmacy). As in the outpatient studies, patient- and problem-specific information could be displayed to the physicians at the time that they were making clinical decisions. The information the workstations routinely displayed included prices, the existence of prior results, and, where indicated, "negative detailing" information meant to discourage the ordering of items deemed by our subspecialists to be costly and of marginal or no value. For many clinical problems, the menus that guided ordering contained the most common tests and treatments. In addition, the physicians could access an electronic textbook of medicine and the American Hospital Formulary Service manual with more than 1000 drug monographs.

In a 16 month randomized, controlled trial involving more than 5000 inpatients, physicians using the workstations generated hospital bills $887 less per admission than control physicians who used paper charts to write all orders.[25] Similar reductions were found separately for diagnostic tests, drugs, and facility charges. Intervention patients were discharged almost a full day earlier and had one-third fewer drug-related incidence reports. Moreover, no difference was found between intervention and control patients in post-discharge outpatient or emergency room visits, outpatient charges, or hospital readmissions. We concluded that using workstations to both write orders and receive patient- and order-specific information could result in lower charges without compromising, and arguably improving, the quality of care delivered.

Once proven to be useful and cost-saving, the workstations became the sole means for writing all orders on the inpatient and ambulatory general internal medicine services and thus provided a medium for subsequent interventions to lower costs and/or improve the quality of care. We next studied clinical practice guidelines where the workstation system would continually process information for all inpatients and create guideline-specific "suggested orders" that the physicians could select with a single keystroke (or ignore if they disagreed with them). In a six-month randomized,

controlled trial, half of the physicians received suggested orders generated by guidelines for monitoring of drug therapy.[26] For example, an order for an aminoglycoside antibiotic was followed by suggested orders for bi-weekly renal function tests and trough and peak aminoglycoside levels.

When provided with suggested orders, the intervention physicians complied with drug monitoring protocols 49% of the time compared with 29% for control physicians (Figure 3).

Simply displaying information and encouraging behavior however, is not sufficient to engender a response in physician behavior. Physicians must also agree with

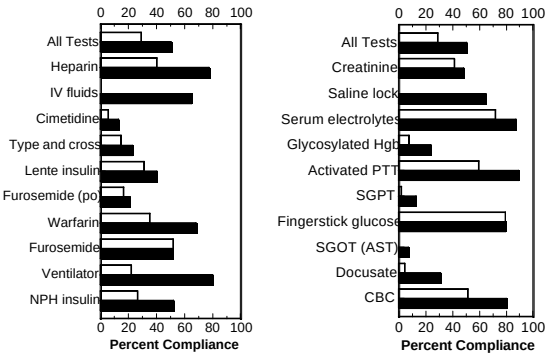

Figure 4: Results of controlled trial on inpatient workstations of automated guidelines for monitoring of drug therapy showing results by triggering orders (left) and suggested orders (right).

the protocol's content. For example, when we programmed the workstations to suggest orders for inpatient preventive care, using the same protocols to which the physicians responded to in the outpatient clinic,[18,19] no significant differences were found between intervention and control physicians.[27] In response to a survey, the physicians stated that they did not feel that the inpatient service was an appropriate venue for performing preventive care. Thus, in addition to being timely, the underlying algorithms must be acceptable to the physicians.

Lessons Learned

What have we learned from 20 years of work using electronic medical records to improve physician decision-making and diagnostic testing?

- Physicians respond to various informatics interventions that are delivered in a timely manner, represent acceptable clinical decisions, and are patient- and problem-specific.

- Physicians can be encouraged to both increase the ordering of under-used tests (e.g., for preventive care or monitoring of inpatient drug therapy) and reduce the ordering of over-used tests.

- Inserting electronic information management into the processes of care provides an opportunity to provide generic and problem-specific information at the very moment that physicians are making clinical decisions.

- Physicians will not only use computer workstations,[28] they will respond to interventions during on-line order-writing to lower costs and improve the quality of care.

Future developments should further broaden the reach of electronic record systems in order to move large amounts of

medical knowledge and patient information between geographically separated health care venues. As electronically stored data become more detailed and plentiful, better guidelines and systems for implementing them will be developed that will further reduce variation and waste in health care. Provider roles and time commitments will evolve away from spending enormous amounts of time on recording and extracting information and towards information synthesis and providing humanistic care. In such a way, one of the most technologically sophisticated aspects of medicine, electronic records, may not only improve the quality of care and control costs but also positively affect one of health care's least technological aspects: the doctor-patient relationship.

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