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THE ROLE OF HEALTH INFORMATION TECHNOLOGY IN HEALTH CARE DELIVERY SYSTEMS WITH HIGH QUALITY-TO-COST RATIOS

INTRODUCTION

The U.S. health care system is in the midst of extensive, rapid-pace investment in health information technology (HIT). According to many experts, investment in HIT will improve the quality of patient care and, over time, decrease its cost (Congressional Budget Office 2008). The American Recovery and Reinvestment Act of 2009 (the “stimulus” bill) included \$30 billion to encourage physicians and hospitals to invest in HIT by underwriting a portion of the costs of acquisition and implementation by providers, public health agencies, health information exchanges, and regional extension centers (American Recovery and Reinvestment Act 2009). The stimulus rewards hospitals and physicians who are early adopters with enhanced Medicare and Medicaid payments and ultimately punishes non-adopters with decreased reimbursements. The cost containment features of the Patient Protection and Affordable Care Act (the 2010 health care reform bill) are predicated on a level of health information management that necessarily requires sophisticated HIT systems. The belief in the value of HIT as a mechanism for improving quality of care and reducing cost is shared by Democrats and Republicans, and is likely to remain a central feature in the U.S. health care system regardless of politics, as it has been a component of virtually every federal health care reform proposal in Congress (Kaiser 2010). In response to these signals, public and private health care providers are escalating HIT development and revising their business strategies with HIT as a central component.

HIT in and of itself will not improve the quality of care or reduce costs; it is merely a tool that can enhance providers’ ability to achieve these goals.

The federal government has determined that it will subsidize HIT acquisition costs only for those organizations that make “meaningful use” of the HIT. The “meaningful use” criteria announced in July 2010 (Federal Register 2010) encompass a phased approach under which providers will be required to extend their use of HIT over time, ultimately exchanging data with external enterprises. People, processes, and management information systems, of which HIT can be an integral part, ultimately determine outcomes. While HIT has the potential to help health care delivery systems improve quality and reduce cost, whether these gains will be realized depends on how the HIT is utilized.

Providers and policymakers across the United States are evaluating investments in health information technology. The purpose of this paper is to provide them with insight about the opportunities realized by health care systems widely recognized for delivering value, as indicated by a high quality/cost ratio. A quality/cost ratio is determined by comparing the quality of care to the cost of delivering that care. A high quality/cost ratio is one in which the quality of care is high relative to its cost. By teasing out the ways in which these organizations use HIT, others can learn best practices as they adopt and upgrade HIT applications, and the federal government and other payers underwriting the costs of HIT acquisition and deployment can structure HIT financing to encourage best practices.

SYSTEM SELECTION PROCESS

We identified possible health care systems to examine by reviewing reports or rankings generated by HealthGrades, *US News and World Reports*, The Leapfrog Group, Thomson Reuters,

and Dartmouth Atlas. We queried these sources to discern types and methods of data collection. To rationally identify the best alternatives among the varied health care databanks and ranking lists, we then employed a Kepner-Tregoe decision analysis tool (Decision-making-confidence.com 2010). Alternatives were scored against desired decision criteria, including uniform data collection, cost measurement, measurement validity, positive institutional reputation, and intra-list organizational variability. We gave greatest weight to decision criteria such as cost measurement and uniform data collection because they are integral elements of cost-effective and high quality organizations. Conversely, criteria such as organizational reputation were given less weight, as an organization's perceived reputation may have little bearing on actual measures of cost or quality.

Based on this process, we identified several organizations with high quality/cost ratios, including Geisinger Health System, a vertically integrated rural healthcare system; Mayo Clinic, a multi-state, not-for-profit teaching institution; BJC Health Care, a not-for-profit, 12-hospital health care system comprised of urban and rural, teaching, and community hospitals; the University of California at San Diego (UCSD) Medical Center, a state-owned teaching hospital; Intermountain Healthcare, a large urban and rural not-for-profit system; and St. David's Healthcare, a system that is partially owned by the for-profit HCA system. UCSD and St. David's declined to participate in the study. BJC's participation was somewhat limited and did not include a site visit. This paper focuses primarily on Geisinger, Intermountain, and Mayo Clinic. We made site visits to each of these systems, reviewed extensive documentation provided by the systems, and interviewed numerous physicians, nurses, and information technology (IT) staff at these systems. Interestingly, these three systems were among the earliest U.S. adopters of HIT, beginning in the 1970s, and have extensive and robust HIT usage.

SYSTEM DESCRIPTIONS, APPROACHES, AND COMMON THEMES

The chart on page 3 provides basic information about the participating systems. All of the systems are operated as not-for-profit corporations governed by boards of trustees. As the chart

indicates, we examined relatively large vertically integrated systems. HIT use varied within the systems, sometimes intentionally due to differences in scope of work or leadership in system components, and sometimes due to acquisition of system components with differing IT profiles. In all cases, the systems had fully developed, robust usage of electronic health records (EHRs) for all patients in virtually all settings, even where disparate EHR applications coexisted within a system.

The paths taken to arrive at robust HIT usage varied across systems. Geisinger, for example, entered the technology world in an attempt to unify and standardize clinical practices across its operations, which included more than 50 sites in Pennsylvania. Implementation of electronic health records provided a means for practices across the system to easily share information on patients, regardless of where they were seen. Intermountain turned to technology in the 1970s as a tool to gather data for clinical decision support. Its venture predated the HIT industry and Intermountain wrote—and continues to write—its own code for EHRs and most other applications.¹ For nearly a century, Mayo had used a records management system established by Dr. Henry Plummer (a Mayo Clinic founder) that provided many of the benefits of EHRs: a record for each patient, a centralized storage space, an efficient transportation system to move the records from place to place, and an index by diagnosis and surgical procedure to search the archives. It was a natural evolution for Mayo in the early 1990s to digitize this system.

All systems studied approached HIT implementation through multi-disciplinary teams generally consisting of IT specialists, nurses, and physicians. Some used a system-wide team to lead all initiatives and others used unit- or issue-specific teams. During our site visits, we met with IT and clinical staff and observed the way they moved back and forth between their unique perspectives based on their particular roles and their team mindset. In each system, the IT specialists recognized the fundamental fact that an HIT application was only brilliant if it were used, and an application would only be used if it assisted the clinicians in accomplishing their goals more effectively. The IT staff, in some cases more than clinical staff, understood that technology is a powerful tool but not in and of itself a solution to any problem.

CHART 1

	Geisinger	Intermountain	Mayo Clinic	BJC
Overview	Nonprofit institution founded in 1915; physician-led; serves 2.6 million people in 43 counties over 20,000 square miles in Pennsylvania	Nonprofit institution; established in 1975 when LDS church donated 15 hospitals; serves 5 million people in Utah and southeastern Idaho	Nonprofit institution founded in 1864; serves 3 million people in Minnesota with additional campuses in Florida and Arizona	Nonprofit institution created in the 1990s through the merger of five systems; serves 3.5 million people in Missouri and southern Illinois
Inpatient	3 hospitals; 830 beds	23 hospitals; 2,703 beds	4 hospitals; 2,515 beds	13 hospitals; 3,475 beds
Outpatient	55 clinics; 650 physician practices	150+ clinics; 750+ physician practices	12 groups; 60 physician practices	NONE
Physician Relationships	Mixed: 650 physicians are employed; 200 are affiliated	Closed: 765 physicians employed by Intermountain Medical Group	Closed: 3,700 physicians are employed	Open: More than 2,000 affiliated physicians; 1,169 with Washington University Physician Group affiliation
Medical School Affiliations	NONE	NONE	Mayo Medical School	Washington University Medical School
EHR Basics	EPICCare in 1996; EPIC EHR in 2000; CPOE in 2007	Self-developed EHR system in place since 1970s; currently partnering with GE to develop new system	Cerner Millennium in Arizona and Florida; GE Centricity Enterprise in Rochester. Phased-in beginning 1995	Clinical data repository in 1993. McKesson: Community phase-in beginning 2007 Eclypsis: Academic 2003
Health Plan	215,000 members	533,000 members	NONE	NONE
Health Information Exchange (HIE)	Participant in Keystone Beacon Community KeyHIE; \$16M grant	Participant in Utah Beacon Community; \$15.7M grant	Participant in SE Minnesota Beacon community; \$12.3M grant	Slated to be part of the Missouri HIE
Annual Operating Budget	\$2.2B; HIT budget \$100M	\$7.64B	\$4.3B; HIT budget \$314M	\$3.2B

Source: Authors' interviews and communications with health systems, June 2010–January 2011

Technology applications necessarily connote standardization: disparate data from disparate sources must be integrated, homogenized, and made uniform to be useful in the aggregate. Indeed, a substantial part of the work of the U.S. government's Office of the National Coordinator for Health Information Technology addresses standardization. From nomenclature to protocol development, commonality is expected within

: a system. At the same time, each of these
 : systems wanted to preserve the benefits of
 : individualization, sometimes to accommodate
 : personality and cultural differences within the
 : system, and sometimes to encourage innovation.
 : In the case of BJC, the system grew through
 : acquisitions and the acquired units often came
 : with well-developed HIT in place. BJC generally
 : integrated new units without requiring the

wholesale adoption of system platforms, which saved capital costs initially and preserved existing cultures and practices. To gain the benefits of standardization, BJC adopted some of the applications used by health information exchanges. Geisinger’s system includes dozens of medical practices primarily staffed by employed physicians; decisions about HIT applications, including EHR selection, are made by physician leaders in key clinical service lines working with system leadership. Mayo Clinic runs one EHR application at its main campus in Rochester, Minn., and different EHR applications at its Arizona and Jacksonville, Fla., campuses. Intermountain largely has uniformity in HIT applications across the system, but the uses of those applications within parts of the system vary widely. The flexibility in these systems enables them to take the best features of standardization and temper them with the best features of individualization. To the extent they have reconciled disparate applications for data transfer and aggregation across the enterprise, they are doing the kind of work that health information exchanges do for unrelated enterprises.²

Perhaps the most salient take-away from these systems is the underlying message about maximizing HIT: Let computers do what they’re best at doing, and let people do what they’re best at doing. Computers are good at “remembering” and analyzing voluminous data. Computers can follow instructions and patterns consistently. But they don’t respond well to change, uncertainty, or nuance. People are good at complex judgments that rely on nuanced facts and intuition, and they are readily adaptable. The best clinical outcomes involving HIT are achieved when computers are responsible for data collection and organization, and people—physicians and nurses—are responsible for complex diagnoses and creation of one-off interventions.

The systems discussed in the report, particularly those of the Mayo Clinic, Intermountain, and Geisinger, were all early adopters of HIT. For each institution, the EHR—as the central repository of patient data—is the core component of HIT usage, but it is only the beginning of HIT usage for each system. Applications such as e-prescribing (i.e., sending prescriptions directly to the pharmacy electronically), as well as laboratory and radiology

ordering and reporting, enhance the EHRs by consolidating patient data into a single record. But the real benefit—to the patients, the systems, and the payers—comes from the knowledge that can be gained from the aggregation of voluminous data across patients, sites, and time. The ability to collect, organize, and review large volumes of information enables researchers and clinicians to study outcomes and processes, and draw conclusions that can only be obtained through quantitative, statistical analysis of large data sets. These three systems are so steeped in HIT that they are all working on quality/cost improvement initiatives that are based on the second or third derivatives of data analyses concluded years before. We have intentionally included in this paper HIT applications that span the spectrum from the most basic to the most sophisticated to inform systems at all stages of HIT development.

HIT APPLICATIONS ACROSS ALL SYSTEMS: REDUCTION OF ADVERSE DRUG EVENTS AND HEALTH CARE-ASSOCIATED INFECTIONS

One of the most frequent uses of HIT across the country, and in the examined systems, is to assist in the reduction of adverse drug events (ADE). Since the Institute of Medicine’s landmark 1999 report *To Err is Human: Building a Safer Health System* (Kohn 1999) estimated that ADEs were responsible for more than 7,000 deaths annually—at a cost of \$2 billion—hospitals, physicians, and pharmacies have worked hard to prevent ADEs. Approximately half of all hospitalized patients receive anti-infectives, which account for as much as half of a hospital’s pharmacy budget. Excessive and inappropriate use of anti-infectives is a cost driver as well as a patient safety issue (Evans 1998). The institute’s report cited lack of access to complete information as a significant factor in ADEs. HIT is especially useful for collecting, storing, and presenting the kinds of information that can help prevent ADEs; accordingly, ADEs are often one of the first areas in which hospitals deploy HIT.

As early adopters, the examined systems have extensive experience using HIT to reduce ADEs, much of which has been published in prominent, peer-reviewed publications. The systems studied for this paper used HIT to reduce ADEs in the following ways:

Intermountain's Anti-infective Management Program

To guide physicians ordering anti-infectives, Intermountain developed a decision support program based on a computer analysis of multiple data points from the patient's EHR and pharmacological protocols. The program presents options to physicians on the screen (there is an "explain" option that explains the basis of the computer's recommendations) and physicians select an option or choose a different drug. Once a drug is selected, the program provides information on dose, route, interval, and suggested duration of treatment. If a physician chooses a drug that was not suggested by the program, the computer makes usage recommendations and checks for allergies and drug interactions. A study comparing outcomes before the program was implemented with outcomes of patients for whom the computer advice was followed found that the program significantly reduced the number of drugs prescribed (25%), duration of administration (49%), quantity administered (50%), days of excess dosage (80%), number of microbiology cultures (53%), length of stay in ICU (44%), and total length of stay (8%). In addition to improving the quality of care by avoiding adverse events, expenditures on anti-infective agents were reduced by 70%, and total cost of hospitalization was reduced by 25%. Interestingly, the study showed that in cases where the computer advice was overridden, the outcomes were uniformly worse than the pre-program outcomes (Evans 1998, 237).

Geisinger's Medication Management for Elderly Outpatients

Geisinger uses its EHR system to monitor the medications of elderly patients as part of its effort to prevent falls. Geriatricians and pharmacists use a program that searches EHRs and finds elderly patients whose medication profile indicates that they are at risk for falls. The identified patients' primary care physicians are notified and recommendations are made regarding medication management to reduce the risk. A study showed that there was a significant reduction in new medication starts for patients in the program as compared to the control group, and the use of psychoactive drugs was reduced (Weber 2008).

Mayo Clinic's Barcoding Program

Mayo uses a system that assigns a barcode to every unit of medication. When a medication arrives for a patient, a nurse scans the barcode and confirms the patient's identification electronically at a bedside computer. The barcode provides information used by the HIT system to evaluate whether the medication, route, and dosage are correct for this patient, based on patient-specific information like allergies. The system sounds an immediate alert if there is any contraindication. As a result of this system, Mayo has reduced the rate of medication events by 36%, which simultaneously improves quality and reduces costs.

A second common application of HIT is in the reduction of nosocomial infections, also called health care-associated or hospital-acquired infections (HAI). The Centers for Disease Control and Prevention (CDC) estimated that there were 1.7 million HAIs in the United States in 2002 (Seigel 2007) and using 2007 dollars, the CDC estimated the annual cost of HAIs to be \$28.4 to \$45 billion (Scott 2009). Reduction of HAIs improves patient care and reduces costs. HIT has been deployed extensively in the examined systems to prevent the incidence of HAIs. The following are some examples.

Mayo Clinic's Focus on Invasive Line Management

Proper placement, maintenance, and removal of invasive lines protect patient health and reduce costs associated with HAIs and excessive use of supplies. Lines should be placed only on provider orders, not automatically as occurs in many clinical settings. Mayo Clinic recognized a need to better manage invasive lines and implemented a computer program to assist. The protocol begins by capturing the signature of the ordering provider. Clinicians are required to document information about the line at regular intervals and this information assists the staff in changing and removing lines at the optimum time. After institution of the protocol, the rate of unauthorized invasive line placement dropped to virtually zero because of the signature requirement. The enhanced documentation also resulted in more complete coding, which led to additional revenues for services previously not captured and therefore not billed.

Intermountain’s Use of HIT to Identify Patients at High Risk for Methicillin-resistant Staphylococcus Aureus (MRSA)

Hospitals struggle to identify patients at risk for MRSA to avoid the health risks of, and high cost of care for, MRSA patients and those whom they may infect. Patients who are asymptomatic carriers of MRSA, or who were previously infected with MRSA, present risks to themselves and others when they enter health care settings without adequate prophylaxis. Intermountain developed an enterprise-wide electronic surveillance system to identify patients at high risk for MRSA at admission and during hospitalization. At the time of admission, the program searches Intermountain’s data warehouse for patients who were identified as infected or colonized with MRSA at any time in the past at any Intermountain site. Intermountain added a computer-based alerting system to facilitate rapid, targeted surveillance—including alerts that, based on the patient’s history and a variety of data from the current admission, notify personnel and order testing for MRSA in high risk patients. Through this work, Intermountain refined the program’s ability to accurately predict a patient’s MRSA risk by five-fold.

BJC’s “GermWatcher” Program

Manual identification and review of positive cultures are still common across health care organizations. Traditional manual surveillance requires review by infection control specialists and data extrapolation from physician summaries, medical charts, and pharmacy/lab data. These manual processes are staff-intensive and introduce multiple opportunities for human error. To address these problems, BJC developed a program it calls “GermWatcher” that utilizes CDC surveillance criteria to determine whether microbiology results qualify as potential nosocomial infections. BJC has found many applications for the “GermWatcher” program. BJC successfully utilized the program to determine renal toxicity associated with the use of vancomycin in patients with MRSA-related pneumonia. Clinicians also used the program as a means to mitigate unnecessary manual surveillance of central line catheter-associated bloodstream infections (Woeltje 2008). Additionally, the program allowed leadership to assess changing susceptibilities in community-associated MRSA (McMullen 2009).

SYSTEM-SPECIFIC APPLICATIONS OF HIT

Geisinger Health System: Cost Savings Attributed to EHR Adoption

Geisinger began using an EHR in the late 1990s and by 2001 had fully implemented it in all specialty clinic and community practice sites. Access to Geisinger’s EHR by referring physicians began in 2002 and currently provides read-only access to over 2,500 users in more than 400 non-Geisinger practices. Geisinger deployed EHRs in its hospitals over several years and completed the inpatient EHR implementation in all hospitals in 2008. By 2009, Geisinger reported an average daily peak of over 7,100 concurrent users and a database of more than 3 million unique patients. Geisinger had several objectives in adopting EHRs, including cost containment; from the outset, the organization tracked data to assess cost reductions, cost avoidance, and enhanced revenues. Geisinger documented the following financial benefits that resulted from maintaining patient records in an EHR rather than a physical file. These benefits are derived from savings associated with supplies like paper; personnel costs associated with creating and handling physical files; records transmission costs; and work flow enhancements.

Chart Pulls

As Geisinger moved records to EHRs, the number of chart pulls at the system’s largest complex, Geisinger Medical Center, decreased from 1.02 million in 2001 to 250,000 in 2005. Geisinger Medical Center consists of a 500-bed tertiary care hospital and a Level 1 trauma center with more than 400 staff physicians and 250 residents, and Geisinger Clinic, which treats over 1.6 million outpatients each year. Geisinger calculated the cost of each chart pull to be \$3, including the supplies and associated labor. Over the first five years after EHR implementation, Geisinger reduced its chart pull costs from more than \$3 million to \$750,000 each year.

Printing and Faxing

Physician offices and hospitals historically have compiled and transmitted laboratory and radiology reports on paper or film that were printed, filed, faxed, or mailed. As lab and radiology reports were added to the EHR, nondigital reports were discontinued. In 2000, Geisinger Medical Center each day printed 1,600 lab reports and 400

radiology reports, and faxed 350 radiology reports. In 2001, those numbers dropped by 76%, 70%, and 74% respectively. Geisinger also had 372,000 fewer print jobs in 2001. The majority of savings were estimated to come from the time that would have been spent processing the reports by end users.

Consolidation of Forms

The standardization that necessarily comes with EHR adoption provides the opportunity to improve and streamline the use of forms for patient care and administration. Prior to EHR usage, there were approximately 15 forms per admission, or 360,000 per year, at Geisinger Medical Center. Geisinger reduced the number of forms, the redundancy among forms, and the possibility of error due to multiple opportunities to enter data incorrectly. Improvements in forms relating to orders, notes, consults, lab work, and radiology led to an annualized cost reduction of approximately \$45,000, excluding costs associated with staff time for handling the forms.

E-prescribing

Geisinger has electronic prescribing capacity at 55 sites. In one year, the system sent over 277,000 prescriptions directly to pharmacies. These prescriptions had an error rate of 0.3%, and most errors were due to lack of patient's phone number. For these 55 departments, Geisinger estimates ongoing annual savings of \$1 million a year.

Transcription

Electronic entry of provider notes has helped Geisinger contain costs directly by avoiding the costs of manual transcription and indirectly by increasing the productivity of the provider team because of the clear and prompt entry of the notes into the EHR. Over two years from July 2002 through June 2004, Geisinger reduced its use of transcription services by 2.04 million lines, or 36%, at a savings of \$438,000. Because the information in the EHR was prompt and available to the entire system, inpatient consults averaging 8,400 a month decreased by 44% and routine inpatient phone consults were virtually eliminated. The system provided more—and clearer—information, reducing the need to ask another physician for that information.

Physician Productivity

The start-up costs of EHR adoption often include a drop in productivity due to the time it takes for staff to become proficient at the new system and the practical fact that most offices and hospitals run the old and new systems simultaneously until a comfort level with the new system is reached. The drop in productivity is temporary, but many question whether EHRs ultimately improve productivity. Geisinger tracked data for 62 primary and 212 specialty care physicians for two years pre- and post-EHR implementation. For primary care practices, after a dip in productivity around the time of adoption, the net incremental revenue increased by \$43,200 for each primary care physician. When specialty practice productivity was compared to national norms, Geisinger's composite specialty physicians' ranking jumped from 61.7% to 76.6%, which translated into a \$14 million annual revenue increase across the 212 practices.

Closing the Loop on Tests and Care Gaps

Following up with patients who have outstanding matters after hospital discharge or an outpatient visit, and managing patients with chronic conditions requires diligence. Intermountain wanted to improve its rate of follow-up by using the EHR system as a tool to identify the need for follow-up and increase the likelihood that proper follow-up would occur. Intermountain conducts 47,000 Pap tests each year and piloted its "close the loop" system around this test. The Pap loop begins with a provider order; the test is conducted; the test result is entered into the patient's EHR; the result is sent to the provider's inbox; the provider follows up with the patient if subsequent action is required; any follow-up action is completed; and the follow-up action is documented in the patient's EHR. Intermountain developed a program that scans the EHR system every week to find Pap test patients for whom follow-up action was required but not completed. When such patients are found, the provider is notified. If the provider completes the follow-up and enters the data in the EHR, the loop is closed. If the follow-up is not completed or not documented, the program flags the patient the following week, and the next, until the loop is closed. A team within the obstetrics and gynecology department monitors the flags and works with providers to make sure that all loops

are closed. After piloting the system around Pap tests, Intermountain expanded its application to other tests.

Intermountain also uses this process to identify and close care gaps for 170,000 outpatients with chronic diseases. Because these patients have routine and predictable needs, Intermountain works proactively to ensure that they are receiving appropriate care. Providers developed 14 bundles of care they agreed should be provided for patients with certain conditions. The 14 bundles yielded 43 care gap measures that are tracked across the 170,000 patients via the EHR to ensure that the loop is closed for each measure. Often this involves contacting patients who require a periodic office visit, a test, or a prescription. Intermountain has a system-wide team to contact patients and schedule appointments. The loop is closed when each item in the bundle is completed or the reason for lack of completion is documented in the EHR. Last year, this system allowed Intermountain to close 50,000 care gaps. Closing care gaps improves the quality of care and may, in the short term, increase costs by providing care that may otherwise have been avoided. However, if this protocol is used only to solicit patients for evidence-based services, then over time costs of care should be reduced through prevention or avoidance of exacerbations.

Mayo Clinic

Optimizing Operating Room Utilization

Operating rooms (ORs) remain a well-recognized area for cost containment in hospitals and surgery centers. ORs often go overstaffed and underutilized. Start times are often delayed, leading to inconvenience and frustration for physicians and patients alike. If a hospital is not able to fully utilize its ORs, the fixed costs associated with those assets, including assigned staff, is amortized over fewer patients/procedures, which drives up cost per patient/procedure. While efficient OR utilization is a well-recognized goal, optimum levels of utilization are often not well defined, and cost savings and quality improvements associated with efficient utilization are not well understood (Tyler 2003).

To better understand and develop best practices surrounding OR utilization, the Mayo Clinic implemented a computer program to provide operating room data collection, reporting,

and utilization measurement. The tool promotes quick analysis at a departmental or organizational level while providing individual physician data that facilitates understanding of providers' practices. Globally, the collected data provide an electronic platform for operational, financial, and strategic decision making. On a more granular level, the program enables administrators to develop surgeon-specific scorecards to track on-time starts, volumes, in-and-out of block utilization, turnaround time, case length, and delay minutes.

Before Mayo implemented the new program, surgeon-specific operating room utilization data were not readily available and therefore allocation of ORs was not data driven. Data had to be assimilated manually across multiple systems and were not easily extracted, replicated, or consistently tracked across departments. Department chairs' requests for data were often met weeks later.

Upon implementation of the program, Mayo's administrators identified several opportunities for process improvement and resource reallocation because they had complete, timely, and accurate utilization data. Measurement of the OR process revealed the need for prospective reallocation of 215 OR days in 2009 due to surgeon absences. Daily prospective monitoring of OR resources allowed for reassignment of operating rooms to practices that were able to use additional time. Mayo also used the data to close unfilled operating rooms 48 hours prior to surgery in response to variations in the surgical schedule. Practice groups found to be underutilizing ORs developed workload plans to match allied health staff to volume.

The first reallocation of ORs resulted in the loss of two blocks for the orthopedic surgery practice due to underutilization. The practice had a backlog of cases, so it did not want to lose OR time. The department chair began using the data to understand his group's work flow and reallocated time from surgeons with lower utilization to higher-volume surgeons. All physicians began watching their utilization and, over time, the orthopedic practice recaptured its two lost blocks and gained additional blocks as it became more efficient. This benefited patients waiting for surgeries and helped Mayo better cover its fixed costs, which ultimately reduced its total costs. As a result of the reallocation, the department realized a 25% growth in professional and facility

gross revenue from 2008 to 2009, and department utilization of ORs increased from 12% to 82%.

A study of the impact of this HIT application at Mayo Clinic's Arizona hospital also showed improvements. Combined reallocation led to a 6% increase in surgical patients, an 8% improvement in block utilization (to 79%), a 32% reduction in first case delays (8,800 minutes saved), and a 74% improvement in first case on-time starts. Corresponding financial benefits included a \$25 million rise in net operating income and a 67% direct margin increase (to 24.2%). When HIT enables a provider to increase revenues, an opening is created for system-wide cost reduction.

Pain Care Specialist Ordering System

Most hospitals obtain pain scores from patients throughout a hospitalization, and many record them in the patient's EHR. The data may be used by attending physicians and nurses to address pain issues, including seeking a pain specialist consultation. A pain care specialist at Mayo Clinic recognized that his service could use pain scores to rapidly identify opportunities for intervention in patients with elevated pain scores as recorded in their respective electronic medical records. Improved monitoring of patient pain scores could lead to increased patient satisfaction while facilitating the healing process.

Champions of the pain scale-monitoring concept within Mayo Clinic formed a multi-disciplinary team of physicians, anesthesiologists, clinical pharmacists, and clinical nurse specialists. This team's goal was to determine how the medical record captures and tracks inpatient pain, tease out the scoring methods that are easily categorized and analyzed, and measure pain scores to provide a salient report to the pain care service to improve pain management.

To ensure that pain scores were being captured in a manner that facilitated computer analysis, Mayo eliminated the free text fields in the EHR and required a numeric value. The team studied aggregated data to develop rules for when to intervene based on multiple factors such as level and duration of pain. The goal was to enable the hospitals to focus on patients in the greatest need of pain management by identifying those patients and notifying their providers of the opportunity to intervene. Patients are often in the most intense pain hours after surgery, and prompt and regular

review of data enables rapid intervention. Patients with less intense but sustained pain also benefit from routine review of pain scores. For patients suffering from chronic pain, clinicians established "comfort goal" values, and the program would report on those patients only if the "comfort goal" values were exceeded. The rules were adjusted when experience dictated a need for increased or decreased sensitivity.

The reports generated by the program were sent to the pain care service and shared with other providers caring for identified patients. The service used the report to prioritize units and patients within units for first visits. Providers expressed appreciation for the pain scale report and found the data helpful in developing interventions.

Mayo tracks patient pain experiences in routine satisfaction surveys on a quarterly basis. Surveys showed improvement in satisfaction ratings relating to pain and pain management after the program was implemented. After using this program for three years, the number of patients whose pain profiles result in their inclusion on the list has declined substantially as pain was better managed on an ongoing basis. Mayo's patients benefitted from better pain management while Mayo deployed its resources more efficiently.

Intermountain Health Care

Ventilator-disconnect Surveillance System

Modern ventilators are equipped with highly accurate alarms that sound when patients become disconnected or experience other critical events such as water in the tubing or unintended extubation. Yet even when the alarms sound, they often do not trigger rapid intervention because they blend in with other noises or staff is not close enough to the alarm source to hear the sound. The large number of false-positives further inures staff to the alarms.³

Prior to the development of the new surveillance system, Intermountain staff depended on the ventilator alarm to notify them of disconnects. The longer a ventilator is out of service, the more likely a ventilator-dependent patient is to experience harm. Yet at Intermountain, the amount of time between the disconnection and the correction was not known. And the fact of a disconnection was not routinely recorded in the patient's chart. Respiratory therapists were responsible for completing paperwork regarding

disconnects, but they often were not present when a disconnection occurred, and the incident often went unreported. Intermountain wanted to develop a system that would (1) maximize prompt attention to critical ventilator events to prevent adverse outcomes, and (2) track data regarding disconnects to discern root causes of the events to reduce their occurrence.

Intermountain's IT staff developed an application on an external computer that surveys the bedside computers every five seconds to detect alarm activations.⁴ If an alarm is detected three times in a row, meaning it has been activated for 10 to 15 seconds, this information is transmitted to the unit server, which then runs a program on all unit computers. This program essentially takes over all the computers in the unit with an eye-catching "disconnect" message and a distinctive, annoying alarm that sounds until the ventilator event is corrected. The occurrence of the event is simultaneously logged into the EHR system, which is designed to require a respiratory therapist to enter information about the event. Once recorded in the EHR, the information becomes part of Intermountain's enterprise-wide data warehouse. Reports of all ventilator events are generated regularly and reviewed by a task force team that uses the data to discern root causes and design preventive interventions.

Intermountain tested this application in one ICU at one of its largest hospitals in mid-2004 and subsequently conducted a six-month pilot in all 60 ICU beds in that hospital (Evans 2005). The pilot enabled Intermountain to ascertain, for the first time, the number of ventilator disconnects, their duration and, in many cases, their causes. The staff was enthusiastic about the new system—despite the annoying computer signals and sounds—and the application has been deployed in 10 ICUs at four hospitals and, ultimately, will be implemented system-wide.

Because Intermountain did not have sufficient data about ventilator disconnections prior to this program, it is impossible to compare the number or length of such events to the pre-program time. Since the program has been in place, Intermountain has recorded approximately 3,500 alerts among the 10 ICUs. Intermountain is continuing to refine the application and has obtained a patent.

Computer-assisted Identification of Patients at High Risk for Venous Thromboembolism

Venous thromboembolism (VTE)—including deep vein thrombosis and pulmonary embolism—is associated with hospitalization and has significant effects on morbidity, mortality, and cost of care. There are many evidence-based guidelines for VTE prevention, and protocols are easily embedded in HIT applications to support clinicians in following the guidelines. Intermountain was concerned that even with this level of knowledge of and support for best practices, clinicians were not using the guidelines adequately because of the difficulty of identifying the patients at highest risk of VTE. In order to improve the rates of VTE prophylaxis, Intermountain wanted to develop a reliable method for predicting risk that could easily be integrated into the routine process of care.

To enhance identification of high risk patients, Intermountain developed a computer program that searches the system's data warehouse, which contains the EHRs of all patients, at least daily for data indicative of VTE risk (such as high BMI, hormone replacement therapy, etc.). The program then assigns each patient a scaled score based on pre-determined criteria related to VTE risk. A report is generated for the clinical staff responsible for each patient. Intermountain validated the positive predictive value of this tool by comparing the risk assessments generated by the program to risk assessments conducted by experienced clinicians who reviewed the charts of the same patients. Manual chart review of 600 patients identified 109 (18%) to be at risk for VTE. The computer program found 107 of those 109 patients, as well as an additional 131 previously unidentified patients, at risk for VTE. Clinicians reviewed the 131 "extra" patients identified by the computer and concluded that all but one were properly identified by the computer and had been missed by the clinical staff. The positive predictive value for the program was 99% (Evans 2010).⁵ While there were additional costs of prophylaxis for the newly identified patients, there was corresponding cost avoidance when VTE was prevented.

Intermountain's ability to achieve this result with a computer program was enhanced by access to its large data warehouse. The data warehouse is an enterprise-wide compilation of information about five million patients served at Intermountain's hospitals, clinics, and affiliated

physicians' offices over decades of operation. Some of the risk factors that enabled the computer to classify a patient at risk were found in the data warehouse in records from previous admissions at other locations. While this information would have been available to the clinicians had they searched for it, a review of the patient's current chart would not have revealed this information. While inter-institutional health information exchange is beyond the scope of this paper, the foregoing example illustrates the opportunities available when data can be collected and analyzed over time and place.

Organism-specific Isolation Precautions

Since 1970, the CDC has published and updated guidelines for isolation precautions that form the basis of isolation protocols in most U.S. health care settings (Siegel 2007). Hospitals and other health care settings use a variety of mechanisms for incorporating the protocols into patient care. The level of isolation applied impacts the cost of care and the patient experience. Under-isolating can lead to HAIs and their attendant costs; over-isolating can result in unnecessary expense and patient dissatisfaction. Intermountain wanted to develop a system that would lead to the correct level of isolation for each patient and facilitate compliance with the appropriate protocols.

To ensure that the correct level of isolation is used, Intermountain assigns isolation levels based on the organism to be contained, rather than the patient's diagnosis or symptoms. The organism is identified by decision-making criteria written into the EHR system, which reads EHR data and determines the organism(s) implicated. The EHR queries the clinicians in a variety of ways, prompting the entry of data needed to identify organism(s). The clinicians do not have to know the name of the organism; the computer makes that assessment based on indicative data.

Once the organism is identified, the program proposes the corresponding isolation order. If accepted by the clinician, the system automatically incorporates the CDC guidelines into the record and orders the appropriate supplies/isolation cart. If another isolation order is already in place, the clinician is prompted to reconcile the two orders to avoid duplication. Once an isolation order is discontinued, the program notifies the supply and billing departments.

A DIFFERENT HISTORY: BJC HEALTHCARE

Geisinger, Mayo Clinic, and Intermountain are vertically integrated and have longstanding histories of system-wide HIT. Many of their high-value HIT applications evolved over time and are examples of the power of technology in addressing improvements in quality of care and cost reduction. Many health systems across the United States are only beginning to contemplate the myriad applications HIT may have within their respective organizations; some have yet to fully implement an EHR. Moreover, most organizations begin with disparate uses of HIT within their systems. For systems newer to HIT and for those who are reconciling disparate applications within a system, the experience of BJC Healthcare may resonate.

BJC is the product of mergers of five organizations (Barnes Hospital, The Jewish Hospital of St. Louis, Christian Health System, Missouri Baptist Medical Center, and St. Louis Children's Hospital) over several years in the mid-1990s. Today, BJC is a 13-hospital system comprised of two academic institutions and 11 community hospitals. BJC's first challenge was to reconcile extreme variability in HIT usage among its members. Parts of the system had longstanding robust EHRs and other applications in place, while other parts of the system had relatively little, if any, clinical HIT in place. And among those parts with clinical HIT, disparate EHRs and other applications were common.

To account for the variable use of HIT applications across its members, BJC created a unified clinical data repository that could accommodate asynchronous data. This data repository allowed for a common system superstructure and normalized data across BJC's many organizations. A team of medical informatics experts sifted through data to create meaningful reports for the system and organizational decision-makers.

BJC moved to standardize EHRs across its 11 community hospitals as it became evident that the ability to get the most value out of the data would be greatly enhanced through common applications. System leaders also deployed a clinical workflow initiative to optimize workflows across BJC's 11 community hospitals. As a by-product of these initiatives, BJC implemented one common EHR

across its community hospitals while maintaining a separate EHR unique to its two academic institutions.

BJC still uses different EHR programs in its academic hospitals, and does not currently plan to move to a single program. The history and culture of these two hospitals, including their academic affiliations, make top-down standardization less likely to occur. Even with disparate systems, BJC is able to use HIT to achieve some of the same objectives as other systems who run consistent applications. The challenges of reconciling asynchronous applications, which ensures interoperability, ultimately will be encountered by all systems as regional, statewide, and national health information exchanges develop.

CONCLUSION

Limitations of HIT

The examples above illustrate just a few of the many HIT applications deployed by systems with high quality/cost ratings to positively impact quality and/or cost of care. In our work with each system, clinical and IT staff talked about the limitations of even the best HIT applications. Each system recognized the potential for “alert fatigue” and worked hard to avoid this problem. “Alert fatigue” occurs when the HIT applications provide too much information, poorly timed information, or irrelevant information resulting in providers’ disregard of information. For example, in the case of Mayo’s pain care specialist system, if the algorithm resulted in the identification of too many patients, its value would be reduced. Intermountain’s ventilator disconnect alert system, which is activated each time a ventilator is disconnected for as long as five seconds and alerts every person and computer in the unit, could have resulted in alert fatigue had the program designers not worked closely with the clinicians to ensure that this aggressive alerting program would not backfire. Often these systems would run a program silently for a period of time before actually turning on the alerts to make sure the alerts would be helpful and not become nuisances to be ignored.

BJC’s experience in “right-sizing” its pharmaceutical order alerts is illustrative. BJC developed a program to reroute asynchronous alerts to pharmacists for resolution. At first, when a small number of drugs were included

in the program, the alert was triggered for a relatively small number of orders each month. When BJC added more than 1200 drugs to the program, the alert rate shot up to 7.28% and became unmanageable, and therefore not helpful. BJC employed several strategies to find the right balance: it implanted buffers or margins for error associated with patient weight, creatinine clearance, dosage calculation, and minimum/maximum acceptable doses; it implemented changes to avoid duplicative entries of the same order, which triggered additional alerts; and it employed a frequency multiplier rule to suppress alerts associated with some exceeded doses per day. As a result of the implementation of these strategies, BJC realized a new alert rate of 1.2%, which protected patients and was manageable by staff (Resetar 2005).

The greatest limitation in the application of HIT is the flip side of its strength: It lacks the ability to comprehend and process nuanced language and intuition. Software developers are continuously improving the ability of programs to collect and order our language. Voice and handwriting recognition software is readily available, and allows anything a doctor says or writes to be captured in an EHR. There are also programs that pull information from the doctor’s written entries into digitized, quantitative data sets. Programs can search provider notes to detect and extract discrete information to identify patients with particular characteristics or disease patterns. But the nuance of language—the tone, the feel, the intuitive insight—is not readily captured electronically. If we force doctors to speak only in ways computers can understand, or if we use only what computers can manage to diagnose and treat, we will be missing out on the art of medicine. The ability to improve the quality of care and reduce the costs of care can be greatly enhanced with HIT. Our challenge will be finding the ways to harness the data gathering and analytical power of HIT and put it to use by dedicated health care providers.

Health Policy Implications

The systems analyzed in this report, particularly Geisinger, Intermountain, and Mayo, represent some of the most robust and creative uses of HIT in the United States. Each system has been engaged in HIT for a relatively long period of time and is distinguishable from the many hospitals, clinics,

and physicians who are just now selecting basic business office and clinical systems.

Widespread implementation of electronic health records will be spurred by the federal government's implementation of HITECH, a \$19 billion program implemented as part of the American Recovery and Reinvestment Act of 2009. HITECH promotes the adoption and use of HIT and especially electronic health records (Blumenthal 2009). Under HITECH, physicians can receive extra Medicare payments for the "meaningful use" of an electronic health record that can exchange data with other parts of the health care system. For example, eligible health care professionals could earn up to \$44,000 from Medicare, or \$63,750 from Medicaid, in extra payments between 2011 and 2015 under this new program.

To receive these federal payments, health care providers will be required to satisfy "meaningful use" standards set by the federal government. These "meaningful use" standards were designed to improve the quality of health care delivery and include, for example, the ability to identify drug-drug and drug-allergy interactions in EHRs; recording each patient's smoking status; and the ability to generate patient lists by specific conditions to use for quality improvement (Blumenthal 2010).

The "meaningful use" requirements will phase in over time, beginning with relatively simple exchanges of data such as electronic generation and transmission of prescriptions from providers to pharmacies and maintenance of up-to-date allergy, medication, and diagnoses lists (CMS 2010). While the health care systems we reviewed in this report are well positioned to meet the objectives required of providers to achieve the first "meaningful use" milestones in 2011 and 2012, they will each have some work to do toward the goals. For example, Intermountain expects to use 60 full-time employees to ensure system achievement by the end of 2012. Geisinger is confident about the objectives through 2012 but expressed concern about the ability of the industry, including the IT vendors, to meet the preliminary objectives of subsequent "meaningful use" milestones. The challenge for policymakers will be to keep the momentum going so that full "meaningful use" is achieved as quickly as possible, while taking into account real barriers; this will indeed require a delicate balance.

ENDNOTES

1. The Intermountain IT team has carried the system for 30-plus years, with many of the original members still working but nearing retirement. Intermountain is partnering with General Electric to develop a fully integrated system that will accomplish all that the current system provides, including purchased applications, for commercial use.

2. Intermountain, Geisinger, and Mayo are all part of health information exchanges and received "beacon grant" funding from the stimulus because of their leadership in developing, operating, and expanding exchanges.

3. The challenge to find the right balance between too much information and too little was raised frequently in our discussions with all of the systems.

4. Intermountain's ventilator alarms sound when 25% of the delivered gas is not returned to the machine. While disconnection is only one cause, the other events that trigger the alarm (water in tubing or obstruction, for example) pose similar risks to patients who are ventilator-dependent. For a full discussion of the IT application, see Evans (2005).

5. Intermountain also developed a technology solution to detect and monitor VTE.

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