INFORMATION TECHNOLOGY SOPHISTICATION

AND OUTCOMES OF ACUTE CARE HOSPITALS

IN TEXAS

by

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ABSTRACT

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This exploratory study tested relationships between information technology sophistication and clinical and financial outcomes of acute care hospitals. The hospital sample was Texas hospitals (N =175) with available data for a profile of their information technology infrastructure, combined with demographic and operations data from public use files for the annual 2002 reporting period. Three measures of information technology sophistication were used: functional, technical, and integration of information, with an additional composite index measure. Clinical outcomes were measured using selected Agency of Healthcare Research and Quality (AHRQ) Patient

Safety Indicators and in-hospital mortality. Patient revenues by number of days and admissions were the financial measures.

Small, but significant relationships existed between information technology sophistication and three of the seven clinical care indicators: mortality, postoperative hemorrhage, and postoperative hip fracture rates. The strongest care indicator relationships were between functional information technology sophistication, integration of information sophistication and the postoperative hip fracture rate with an adjusted R^2 of .33 and .34 respectively.

The financial models showed significantly positive relationships of information technology sophistication with patient revenues. Functional sophistication and integration of information results showed coefficients of adjusted R^2 .64 and .66 respectively.

This study confirms earlier studies of the positive relationship of information technology capability and positive financial outcomes in acute care hospitals. A relationship of information technology capability with patient care process outcomes in hospitals has not been previously reported. Further research is needed to refine the measures and confirm the relationships.

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CHAPTER 1

INTRODUCTION

Two reports by the Institute of Medicine (IOM), *To Err is Human* (IOM, 2000) and *Crossing the Quality Chasm*, (IOM, 1999) brought to public attention the safety risks and frequency of errors permeating our nation's healthcare delivery system. The IOM reports not only sounded the alarm about safety and lack of quality, but also called medical error a chronic threat to public health (Berwick, 2002). The safe delivery of health care is key to achieving overall health care quality. The IOM reports concluded that the present healthcare delivery system is incapable of providing the quality of care that is expected and called for a redesign of the entire system.

Healthcare is an information industry. Information technology (IT) products capture, organize, and make information accessible to health care providers. Every step of taking care of a patient is supported by collecting data, whether it is vital signs or the results of a sophisticated nuclear test. The data capture adds to a composite picture of the patient's recovery progress to support the next step of care by the health team. How efficiently and timely the data are captured and communicated affects the outcome of care.

President Clinton's Advisory Commission on Consumer Protection and Quality in the Health Care Industry stated the purpose of the health care system is to reduce the effects of illness, injury and disability, and improve the health level of the people of the

United States (IOM, 2001).   Information technology supports the healthcare team's ability to give quality care, capturing and communicating the vital information necessary to make decisions of care. Tracking and analyzing the care data is also a key function that IT performs. The ability to document and to show use of the data to improve performance is more important today than in any other period of health service reform. Hospital boards are working with limited revenues, and the monetary investment required for healthcare technology is enormous. Reporting requirements are increased, and performance criteria required by oversight agencies are stricter, in direct response to the challenge to address healthcare safety problems. The Joint Commission on Accrediting Hospital Organizations (JCAHO) revamped its credentialing process under pressure by the Office of Inspector General to show that its evaluation processes are effective to ensure quality patient care. Regulatory agencies and payers, including state and federal governments, have likewise increased their oversight in assuming the responsibility to improve healthcare quality in their client agencies.

The performance of health care organizations is measured by assessing clinical, administrative, and financial returns. Despite the difficulty of measuring quality outcomes in such a complex environment as healthcare, indicators of quality are now available for use and continue to be refined. These indicators are state of the art for low cost, accessible, and standardized measures for local and national benchmarking. Financial measures are numerous and these continue to be tested. What is not known is how these indicators of hospital care relate to the use of IT systems that support the ability to give care that is safe and of the best quality. That lack of information is

delaying the adoption of IT in healthcare, because informed decisions cannot be made on what IT systems and applications are the most effective for the resources available.

Purpose

The purpose of this study was to determine if a relationship exists between IT sophistication and outcomes of acute care hospitals, using indicators of care that are readily available. Health systems in Texas representing acute care hospitals were described in terms of the maturity of their IT and the ability to predict mortality, complications of care, and financial outcomes.

Background and Significance of Study

Information technology has been assumed to play a major role in the improvement of the quality of our nation's healthcare. Individual IT applications have been studied for affects on user behaviors, influence on workflow and processes, and clinical and financial outcomes. Financial outcomes have been related to IT assets and capabilities in healthcare. No studies have been identified that confirmed a relationship between the use of IT and patient care outcomes at the hospital provider level. Understanding and measuring these relationships will provide important information to help select IT systems with the best fit for the hospital's purpose and organizational goals, and to inform public policy decisions for allocating resources to contribute to improving our healthcare delivery infrastructure.

Methods used in this study provide readily accessible information for hospitals to study trends in the quality of their care and to determine the sophistication of their IT infrastructure. Information technology capabilities can be determined for individual hospitals and hospital groups if they are members of a system. Better understanding of IT and the relationship to care delivery outcomes will provide information to improve IT design and allocation of resources.

Statement of the Problem

No studies were identified in the literature that described the relationship between hospital information technology (HIT) and patient care outcomes at the system level. This information is needed to inform adoption of HIT and policy decisions on financial resources to aid hospitals to improve their IT infrastructure. The IOM reports in the late 1990s called for IT system improvement as a major implementation to prevent healthcare errors and improve patient care. Literature published since that time has shown a relationship between the use of specific IT applications and better outcomes, both clinically and financially. Few instruments are available to measure the characteristics of HIT, and no studies were identified that test a relationship between those characteristics and outcomes of patient care. Without that information, IT adoption and allocation of resources remains partially informed, relying on what is known from the use of individual applications and hardware.

Instrumentation is available to measure the IT sophistication of HIT, and it has been used in two descriptive studies evaluating the maturity of hospital IT. The current

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study used the Information Technology Sophistication in Health Care instrument (Pare & Sicotte, 2001) with available IT data to explore the relationships between IT sophistication in hospitals and indicators of patient and financial outcomes.

Conceptual Framework

The conceptual framework for this study was based on prior theory and research findings contributed by scholars in the fields of healthcare and information systems. Donabedian's framework for evaluating the quality of medical care was the theoretical basis for the assessment of hospital performance (Donabedian, 1966, 1968, 1981). Nolan and Wetherbe's Management Information System (MIS) model (Nolan & Wetherbe, 1980) provided the conceptualization of the parallel structure and process components of health care activities related to information. The work of Raymond, Pare, and Sicotte (Guy Pare, 2002; G. Pare & Elam, 1995; Guy Pare & Sicotte, 2001; Raymond, Pare, & Bergeron, 1995) was the conceptual basis for understanding how IT sophistication dimensions are operationalized in the healthcare setting. The study model is presented in Figure 1.

Figure 1 illustrates several relationships that support the activities of patient care. Assumptions were made by the researcher for the relationships that were not directly measured. The evaluation of patient care involves understanding the structure and process activities that need to be related and measured to predict the desired outcomes. The research question asked whether attributes of hospital IT (IT sophistication) were related to obtaining the patient care outcomes desired (low
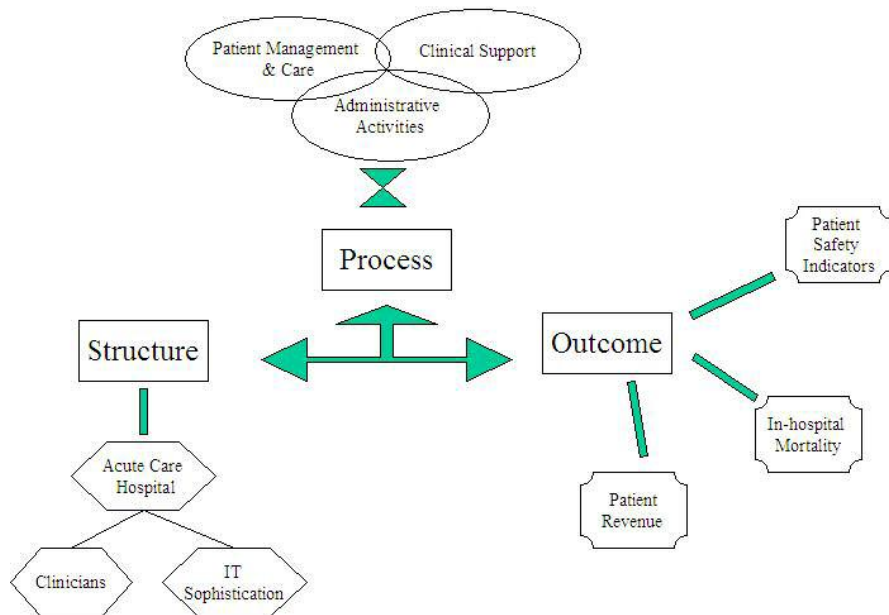
Figure 1. Conceptual framework of relationships between IT sophistication and hospital outcomes.

mortality, patient safety indicators of reduced complications, and patient revenue). Measurement of the outcome predictors involved quantifying IT sophistication levels and the ability to integrate the information to inform the care processes (patient management and care, clinical support and administrative activities). Based on the researcher's clinical experience as a nurse in both healthcare technology and Intensive Care Unit bedside patient care, the model intuitively represents the patient care episode.

The frame of the model consists of three elements: structure, process, and outcome (Donabedian, 1966). *Structure* refers to the resources and setting used to provide the healthcare: the acute care hospital setting, clinician resources, and IT

infrastructure sophistication. IT sophistication is measured in three dimensions: functional, technical and integration of information. The functional and technical dimensions of IT sophistication support the *processes* of providing patient care, the second element of the model. Patient care operations include administrative and clinical activities. These operational domains are categorized further as activities of administration at the hospital level, individual patient management and care, and clinical departmental support such as pharmacy, laboratory, and radiology. Information technology sophistication is a measurement of the maturity of the technology supporting these three domains. The third dimension of IT sophistication, the integration of information, is measured across the administrative and clinical domains. Integration of IT facilitates the interaction of structure and process as depicted in the model, supporting data flow and communication between internal departments and with exterior agencies.

The third element of the model, *outcome*, includes the result of the care to the health of the patient as well as hospital financial outcomes. Patient care and financial outcome variables were measured. Patient care outcomes included in-hospital mortality and patient safety indicators of preventable complications. Patient revenues were measured to represent financial outcomes. The development of the conceptual model is provided in chapter 2.

Research Questions

Research Question 1: Is there a relationship between the IT sophistication of acute care hospitals and in-hospital mortality?

Research Question 2: Is there a relationship between the IT sophistication of acute care hospitals and Patient Safety Indicator (PSI) 2, death in low mortality diagnostic related groups (DRGs)?

Research Question 3: Is there a relationship between IT sophistication of acute care hospitals and PSI 4, failure to rescue, i.e. the inability to prevent mortality when complications occur?

Research Question 4: Is there a relationship between IT sophistication of acute care hospitals and PSI 8, postoperative hip fracture?

Research Question 5: Is there a relationship between IT sophistication of acute care hospitals and PSI 9, postoperative hemorrhage or hematoma?

Research Question 6: Is there a relationship between IT sophistication of acute care hospitals and PSI 11, postoperative respiratory failure?

Research Question 7: Is there a relationship between IT sophistication of acute care hospitals and PSI 12, postoperative pulmonary embolus (PE) or deep vein thrombosis (DVT)?

Research Question 8: Is there a relationship between the sophistication of the IT infrastructure of an acute care hospital system and the hospital's patient revenues?

Assumptions

1. The mortality and patient safety indicators (PSI) were generated correctly by the data center supplying the data sets.

2. The use of the observed raw data, without risk adjustment, for both mortality and PSI did not cause biased results.

3. Use of retrospective data obtained from hospital's report of IT applications and hardware was equivalent to responses to survey items of the Information Technology Sophistication in Healthcare instrument administered prospectively.

Limitations

1. The IT data from the Dorenfest IHDS was self-report and voluntary, which may have caused a self-selection bias.

2. The mapping of the IT data and hardware from the IHDS to the constructs provided by the IT Sophistication instrument was limited by the data available and reflected an adaptation of the original instrument domains.

3. The researcher did not control for all possible hospital characteristics that may have influenced the research model results.

4. The sample dataset included only acute care hospitals in Texas.

CHAPTER 2

REVIEW OF THE LITERATURE

The review of literature addresses the two major conceptual areas supporting this study: HIT maturity and the measurement of healthcare performance. The first section provides an overview of conceptual work in information technology (IT) management, the measurement of IT maturity, and IT adoption in healthcare. The second section discusses the development of the measurement of performance in organizations and the use of such measures in evaluating healthcare quality. The third section discusses performance measurement and IT, with financial outcomes of hospitals as the measurement focus. Donabedian's framework of structure-process-outcome guided the literature review.

Information Technology Management and Measurement

Systems theory concepts and models from the recent literature are used to describe the use and management of information technology in the organization. This section will focus on an overview of models that provide understanding of how information is used and managed in healthcare.

The systems approach to designing systems is a decision-making process. Van Gigch (1991) defined decision-making as a "thinking process" that is at the heart of

problem solving (van Gigch, 1991, p.101). A problem presents itself and the decision

maker, using experience and knowledge, chooses from alternatives to obtain the best

outcome. Decision-making is the conversion process that takes information and

converts it into solutions, cycling the evidence to obtain a model that represents the real

world from which the problem originates (see Figure 2).
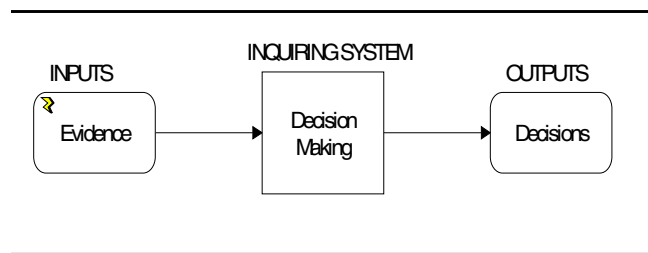
Figure 2. The inquiring system processes evidence into decisions.

In the medical model, where diagnosing problems or failures in treatment are the

inquiry, the solutions are found in understanding the relationships among system

components and their interactions. The critical focus is on analyzing the interacting

relationships of the components, not on analyzing the isolated parts of the system.

Diagnosis becomes dynamic, focusing on the process rather than the underlying

structure and content (van Gigch, 1991, p.101).

Management IT and Information in Healthcare

The system paradigm and its interacting components are the basis of Nolan and

Wetherbe's model of management information systems (MIS). Figure 3 shows a

framework for MIS concepts of managing IT within organizations. Systems theory

(Katz & Kahn, 1966) describes the relationships of healthcare organizations with their

internal and external environments understood in terms of inputs and outputs to

maintain an effective operating balance. Feedback on internal performance

(departments, costs, use of resources) is used to readjust processes to keep the

organization efficient. Feedback from the external environment (business partners,

regulators, community) concerns how effective the system is in realizing its mission and

goals (Nolan & Wetherbe, 1980).
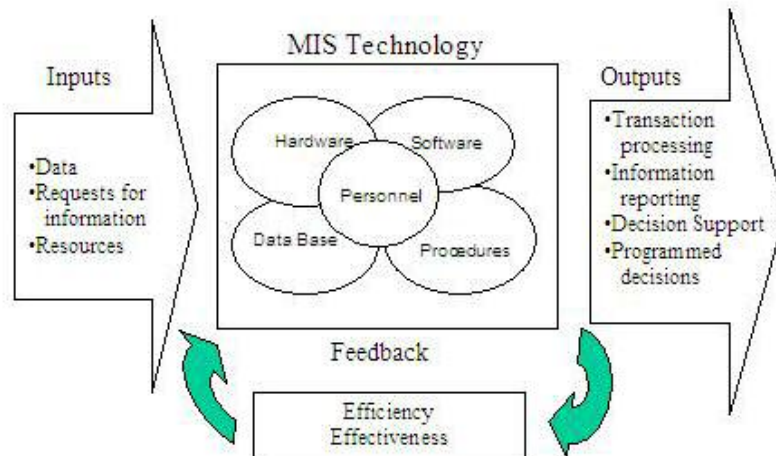
Figure 3. MIS technology subsystems and transformation process. From "Toward a
Comprehensive Framework for MIS Research," by R. Nolan and J. Wetherbe, 1980,
MIS Quarterly, p.7. Copyright 1980 by Elsevier Ltd. Reprinted by permission.

A management information system (MIS) is an "open system that transforms

data, requests for information, and organizational resources into information in the

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context of an organization (environment of MIS)" (Nolan & Wetherbe, 1980, p.6). The

technical components of the MIS do the work of transforming the data into information

and knowledge: hardware (computers, input/output devices); software (system and

application programs); database (files, records, data elements); procedures (instructions

for development and operations of IS); and personnel (operators of the MIS). The data

transformation process adds value to the data by formatting and analysis, making it

accessible, timely, and accurate. The output functions of MIS are processing the data to

information transactions, reporting the information, and supporting decision-making.

The more sophisticated the technology, the higher the level of information output that is

possible (Nolan & Wetherbe, 1980).

Healthcare informatics integrates the many disciplines involved in the delivery of

healthcare. The fields of biomedical science, computer sciences, health care policy,

management, and organization are linked, each providing its unique contribution to the

final product of health outcomes. The health informatics model (see Figure 4) is a

simple conceptualization of the data transformation process in healthcare (Georgiou,

2002). Data (facts, observations) placed in a context of patient care take on meaning and

provide information to the clinicians. Knowledge is produced when the information is

catalogued, analyzed, and supplemented by experts using their intuition, understanding,

and problem-solving skills. Knowledge gains added value through this process and

becomes a valuable resource (Bose, 2003; Georgiou, 2002).
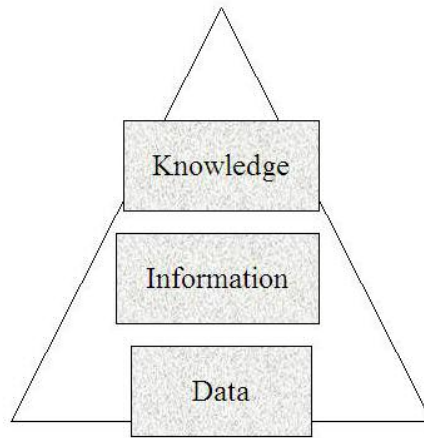
Figure 4. The informatics model.

Knowledge management involves the processes that the organization uses to identify, capture, structure, share, and apply the organization's knowledge to its goals. The ability of healthcare organizations to create and manage knowledge depends on their IT sophistication. A schematic of the capabilities that organizations acquire is shown in Figure 5 (Bose, 2003, pg 65). The acquisition of capabilities is gradual and develops as the organization grows and adds new goals. The capabilities of process and integration are of special interest for the measurement of IT sophistication in the current study.

The process functions allow users to participate in the system according to their roles. IT supports their work activities, for example, by providing decision-support applications, data mining repositories or communication networks. Integration is the
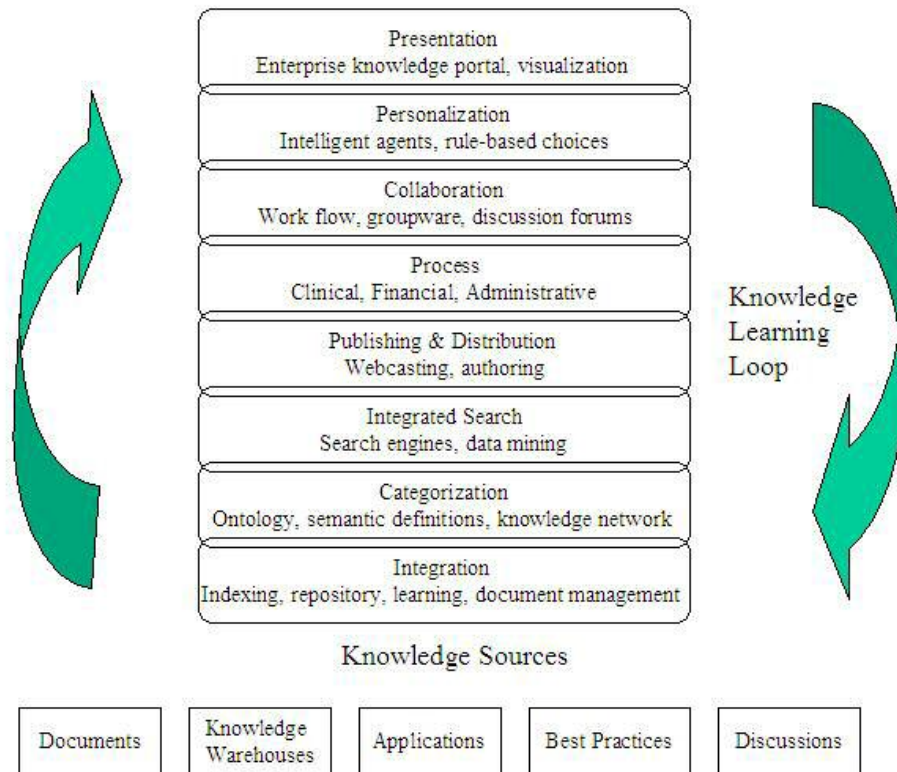
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ability to access all the systems' capabilities seamlessly, internal and external to the

healthcare system (Bose, 2003).

The production and management of information in the acute care hospital setting

supports the care processes of clinicians and administrators and the recipient of care, the

patients (Bose, 2003). MIS must be able to produce information for clinicians that is

accurate, timely, and reflects best practice. Performance expectations for administrators

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include business practice due-diligence, staff performance and retention, revenue generation, and patient satisfaction and retention. Patients' expectations include privacy, security, and a care record that is accessible through the continuum of care (Bose, 2003). The healthcare processes dictate a system that provides the technical infrastructure to provide the information, integrates the information for the users, and stores the information for sharing with vendors and ongoing system improvement.

Five components of healthcare knowledge management are (a) communities of practice; (b) content management; (c) knowledge and capability transfer; (d) performance results tracking; and (e) technology and support infrastructure (Guptill, 2005). The component of communities of practice documents individual and group roles in creating knowledge for transfer and use in the healthcare organization. Content management consists of processes to organize into libraries of the organization's knowledge: types of content to publish, security, format of knowledge, and processes for maintenance. Knowledge and capability transfer differs from managing information by the end result—knowledge sharing should result in behavior change, prompting innovation, process improvement, and better patient care. Performance results tracking is collecting outcomes and process and satisfaction measures. Technology and support infrastructure provide the support for the practice community: knowledge bases, access to expertise, eLearning, synchronous communications, discussion groups, web site access, project spaces, and knowledge desktop tools. The promise of knowledge management systems is to create cost savings, help prevent errors and make the health organization more transparent and accountable as a public resource (Guptill, 2005).

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Evolving Hospital Information Systems – Modeling Methods

The literature includes several modeling methods that illustrate the application

of the concepts discussed at the hospital level —IT management, information, and the

healthcare processes. The first method operationalizes the way that the hospital's

business and clinical processes evolve as the hospital grows. The second method ties the

choice of HIT structure and functions to the process of meeting environmental criteria

for evaluation along industry standards.

Process Modeling of Hospital Systems

Hospital IT continually changes to meet user needs, adding on to legacy

systems. Modeling the hospital's processes and involving users in validating the way

work processes are accomplished are methods for ensuring that the introduction of new

technology is successful. The introduction of technology changes work processes and

triggers increased requirements for support from the IT infrastructure. Process modeling

is a method to document the relationship of IT support and work processes in order to

plan effective changes to existing systems (Vassilacopoulos & Paraskevopoulou, 1997).

Hospital processes are information intensive, can only be partially automated,

require cooperation among the health team members, and complex in both functions

and the number of disciplines involved. The modeling process begins with describing

the processes in detail by their function, user behaviors, structure, and organizational

characteristics, to determine what supports are required. Users then validate the process

designs. Existing IS applications and infrastructure supports are identified, and a gap

analysis is conducted to determine the system requirements (Vassilacopoulos &

Paraskevopoulou, 1997).

HCIT Model and Evaluation Potential

Tan's discussion of the ideal health care information technology (HCIT) model

addresses the organization's basic goals of staying competitive and meeting the

expectations of the business and healthcare environments (Tan & Modrow, 1999). The

accountability expectations framework provides a way to assess the fit of desired HCIT

with the organization's environment. For the HCIT to be relevant for strategic purposes,

the system should link the end-users to organizational performance. Accountability

becomes clear when the organization commits to industry performance standards and

actively benchmarks against performance goals. Management decision-making is then

clearly linked to the performance measures, so the results of the operating decisions can

be evaluated. Performance gaps, on the other hand, cannot be identified and closed until

the healthcare industry provides performance standards. There is no reference for

expectations, and there currently exists no means of validating decision-making aimed

at meeting industry standards.

IT Maturity

An overview of the use of the term IT maturity and measurement in research is

provided by Larsen (Larsen, 2003) in his development of a taxonomy of IS research.

Larsen defined IS maturity as a two-concept category: strategy of project development

or maturity of the core set of technologies. Raymond's work, which is discussed later,

was defined as belonging to the first category, research on choices made in

implementing IS projects. Larsen suggested that the IT maturity research was so limited that it could not be evaluated.

Early work on concepts of computer development within organizations (Churchill, Kempster, & Uretsky, 1969) described computer application sophistication levels that were based on distinctions between clerical activities and support of management activities. Applications that supported decision processes and strategic planning by management were described as more sophisticated. Churchill et al. described the growth of understanding and skills acquisition with computer applications as a maturation process that managers experience. Determining the time periods necessary for obtaining a certain level of maturity was one of the measurement problems noted early on by Churchill. Other constructs of maturity were used to describe IT systems in terms of information and control functions (Greiner, 1972).

Nolan's (1973) hypothesized stages of computer resource development contributed a framework for managers to use to plan and control computer resources and for researchers to use to test the concepts of stage theory applied to information systems (Benbasat, Dexter, Drury, & Goldstein, 1984; King & Kraemer, 1984; Nolan, 1973). Nolan described stages of computer resource management as predictable, changing tasks that correlated with the growth of the computer budget. Control, organizing, and planning tasks were described; these task levels build a framework that implies sequential growth and maturity gains by management as they develop experience in the use of computer resources. Computer processes and worker groups become more specialized and influence management resource planning—another

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characteristic of mature systems. Maturity is achieved when computer resources are utilized to the fullest and when the resources align with organizational objectives. Nolan used computer budget expenditure as a proxy for the stages of growth of computer use in organizations and to represent the discreet variables that influenced management tasks at their different stages (Benbasat et al., 1984; Nolan, 1973). Later work by Nolan modified the original stages from four to six, evolving the concepts from descriptors of stages toward an IS management approach. Nolan's model of staged growth is the best-known and best-tested model, and even though many of his original hypotheses were disproved, his work energized the field and provided the initial organization for conceptual testing of ways that IT matures within organizations (Benbasat et al., 1984).

Critiques of Nolan's stage model over the following decade illustrated the difficulty in developing and operationalizing a model that captures all the components and relationships influenced by computing in an organization (Benbasat et al., 1984; King & Kraemer, 1984). The stage hypotheses describing user and management sophistication of IT and the progression of management control of IT functions were generally supported in empirical testing (Benbasat et al, 1984; (Mahmood & Becker, 1985). The measurement of maturity—mapping the stage characteristics and the evolutionary process itself—remained difficult, however. This process was affected by the complexity of factors influencing the shifts between stages and by inadequacies in study design that were mostly due to lack of available data (Benbasat et al, 1984; Holland & Light, 2001).

An early model (see Figure 6) of IT maturity described the relationships of IT to the complexity and interrelatedness of users' tasks (Saunders & Keller, 1983). IT was conceptualized as supporting the tasks of processing, managing, and communicating information.
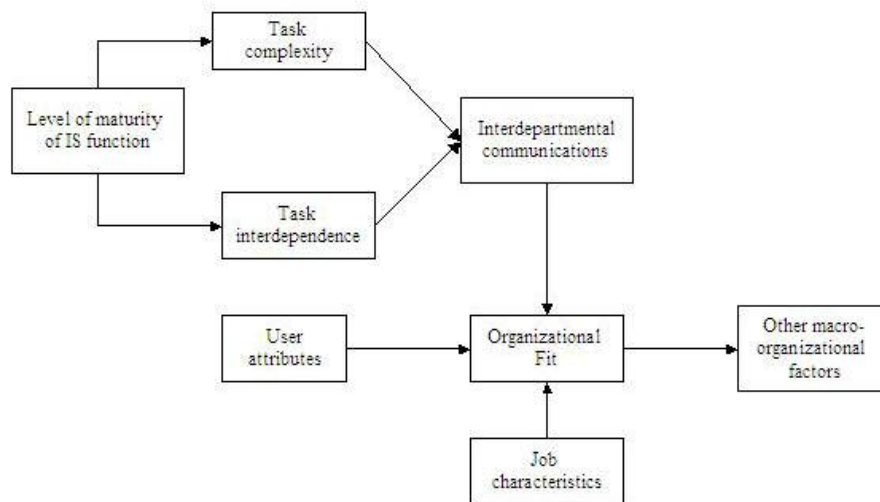
Figure 6. Model of IS function maturity and interdepartmental communications.

As the complexity of the organization increases, information needs increase, user patterns change, and the IS functions become more critical to the organization's performance (Saunders & Keller, 1983). According to this model, the best fit of the system with the organization is obtained with good matches of IT for user, job, and overall organizational characteristics. User attributes are values, experience, education, and role variables; job attributes are the technical fit such as response time, data accuracy, and ability to meet information needs; macro-system attributes are

organizational structure, communication report channels, norms, and values. As the IS function matures, the tasks increase in complexity and in user interdependence, requiring more sophisticated communication to handle information needs. Infrastructure requirements increase with maturing systems to handle increasing task information needs and changing interdepartmental communication patterns (Saunders & Keller, 1983).

Saunders and Keller tested this model with applications used in public service organizations (accounting, personnel, and client treatments). Maturity was measured by the sophistication of the mix of applications available, computer usage, and application of Nolan's growth framework to the organizational level. The information types measured were task related, accounting, procedural, and technical. Saunders and Keller found a significant relationship between IS maturity and increase in interdepartmental communication in all but the technical information categories. Task complexity increased significantly with increasing maturity; however, task interdependence was not supported. As the IS matured, increases in task complexity occurred, requiring an increase in communication support and change of communication patterns. These findings provided support for the effective use of IT resources by management, with a better understanding of task information needs and interdepartmental communication and improved overall organizational fit of IT.

Measuring IT Maturity

Continuing empirical work on the maturity concepts was performed from the perspectives of IT use and IT management, primarily based on Nolan's growth model. The first aggregate measure of IT sophistication, including both usage and management variables, was tested in small manufacturing firms (Raymond & Pare, 1992). IT sophistication was defined as a "construct which refers to the nature, complexity and interdependence of IT usage and management in an organization" (Raymond & Pare, 1992, p. 7). Figure 7 presents the dimensions of the construct; variables used to test the
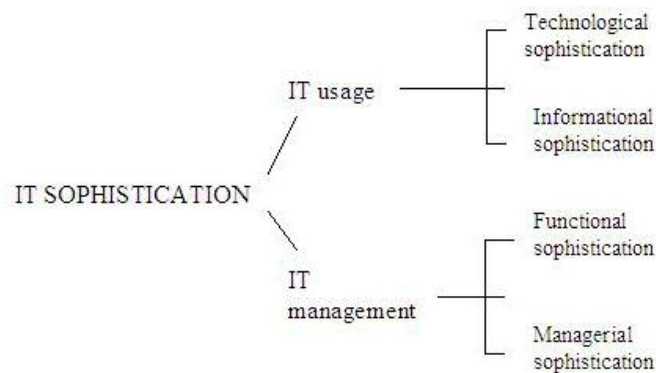
Figure 7. Dimensions of IT sophistication.

dimensions were derived from the literature (Raymond & Pare, 1992, p. 7).

In Raymond and Pare's study, technological sophistication reflected the number and diversity of hardware and software systems used. Information sophistication was a profile of transactional and administrative applications used. Functional sophistication

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related to both the IT tasking and methods of implementing IT. Management

sophistication was a measure of management processes and organization characteristics

used for IT control and planning.

Raymond and Pare's construct of IT sophistication reflects the interdependence

of IT usage and management in the organization (Raymond et al., 1995). Testing in

small manufacturing firms confirmed the relationship of IT sophistication to both

performance and structure. More sophisticated use of IT (i.e. more advanced and

diversified technology and management) was related to better organizational

performance (Raymond et al., 1995). This was the first time managers had prescriptive

support for determining the best use of IT in their organizations.

These constructs were later used to develop an instrument to measure

sophistication profiles in hospital IT. Applied to hospital information technology (HIT),

the sophistication construct was used to measure the "diversity of technological devices

and software application used to support patient management and patient care, clinical

support and administrative activities" (Guy Pare & Sicotte, 2001, p. 207)   The

integration construct was also included to measure the extent to which there was

electronic and automatic transfer of information internally and externally. The

following definitions were used to apply the concepts of IT sophistication to HIT.

Technological sophistication refers to the diversity of the hardware devices used

by HIT, including for example medical imaging, bar coding devices, data warehousing,

wireless networks, and PACS equipment. HIT devices are grouped under five

categories: office automation, human-computer interaction devices, storage and compression devices, data distillation systems, and connectivity devices.

Functional sophistication was defined as the proportion and diversity of processes or activities supported in the clinical area by IT applications. *Information integration sophistication* was defined as the extent to which computer-based systems were able to exchange information with each other internally (within departments) and with external agencies. Supporting applications were characterized as integrated if there was electronic and automatic transfer of information with other computerized systems (Guy Pare & Sicotte, 2001). For example, laboratory and operating room system integration would provide the electronic transfer of information.

The three dimensions of sophistication were measured across three activity domains: patient care and management, clinical support, and administration. Examples of patient management activity included admission and registration and bed scheduling. Examples of patient care activities included entering orders and reporting test results, recording vital signs, transcribing physician orders, and record keeping. Clinical support examples include laboratory systems that manage specimen pick-up and test scheduling or pharmacy systems that manage drug profiles, purchasing, and dispensing of drugs. Examples of the administrative domain included budget planning, staff scheduling, and payroll.

Pare and Sicotte used linear scoring of functional and technological sophistication, counting the patient care processes and clinical department activities supported by IT technology and applications. Integration of information was measured

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using a 7-point Likert scale addressing the extent to which IT applications shared electronic data.

One of the primary aims for developing the IT sophistication instrument was to assist healthcare managers in adopting and using IT. Pare and Sicotte used the instrument to compare hospital IT sophistication profiles among Canadian hospitals, and the most recent study compared the Canadian hospitals to those in the state of Iowa (Jaana, Ward, Pare, & Wakefield, 2005). Primary quantitative and qualitative data were collected by survey and used to create profile comparisons and to continue validating the instrument properties. Reliability and validity psychometrics met recommended values in both studies. Concurrent validity was confirmed for IT maturity, annual hospital budget, number of IT staff, and IT tenure.

Burke and Menichemi (2004) recently explored a new capacity measurement for IT, *IT munificence,* a construct defined to represent organizational information. This construct was based on a theory of diffusion of innovation and on strategic contingency theory. Stakeholders in this model are employees, payers, business partners, and regulatory agencies. Similar to the prior models that incorporate numbers and usage of IT applications specifically designed for clinical and administrative functions, this model creates a clinical cluster that can be scored to represent a measure of clinical capability. Burke and Menichemi defined IT technology into three clusters: clinical information systems, administrative systems, and the third cluster of strategic and enterprise integration systems. The remaining component of the IT munifcence model is stakeholder capability (made up of external clinical electronic linkage, external public

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electronic linkage, and external business electronic linkage). Preliminary testing of the

concepts with HIT, using the Dorenfest database, has given acceptable psychometrics.

IT Adoption in Healthcare

Adoption of information technology by the healthcare industry parallels the

pattern in other service industries. The first step was computerization of accounting

processes, and then repetitive tasks were automated to reduce costs and increase

efficiencies, in areas such as supply management for producing departmental products

(Ball, 2003; Collen, 1991). By the late 1960s, nurses and physicians had access to

interactive display terminals. For example, Lockheed/Technicon's HIS used a

television-tube terminal that provided a lightpen selector. By the 1970's and 1980's,

HIS terminals were available at nursing stations, and in some hospitals bedside

computers were available for data entry by the 1980s. Local terminals were linked into

local area networks. By the end of the 1980s, semi portable terminals and handheld

devices were available at hospitals (Collen, 1991). By the mid-1980s, barcoding was

commonly used for patient wristbands, medical records, blood bank sampling, and x-ray

folders.

A 1976 survey of hospitals reported that, of the 100 hospitals that responded,

75% had administrative IT applications, with about 30% having clinical laboratory or

other patient care applications. Until the 1980s, HIS systems for different departments

were isolated systems. At that point it became possible to connect modules that used

different computers through communication networking. Administrative and clinical

support systems continued developing, with the exception of the electronic medical record. The primary barriers to development in this area were inability to accept cursive handwriting or continuous voice input, as well as to process text input for records.

The healthcare industry lags far behind other U.S. industry in adopting IT to support operations and management strategy as well as document management. Workflow and document management systems are among the deficiencies being dealt with now. Less than 10% of U.S. hospitals had adopted computerized patient records (CPR) as of 2001. Billing applications received the majority of the $20 billion investment in HIT (Goldsmith, Blumenthal, & Rishel, 2003). Only 10-15% of hospitals use computerized physician order entry (CPOE). Surveys of health system planning for IT adoption indicated these systems were being planned for (Ball, 2003; Morrissey, 1998). Fifty percent of executives surveyed in 2001 planned to add clinical decision support (CIS). Physician order entry was being added by almost 60%. The overall increase for hospital IT spending was around 6-7%, through 2004, with clinical spending increasing by 13-15% annually (Ball, 2003). The other major difference from other industries is that the health sector has not adopted common data dictionaries and data exchange standards. Health care organizations have purchased proprietary systems that not only prevent exchange of data outside the specific system, but pose problems with intra-system interfaces as well (Starr, 1997).

As late as 1997, a Texas survey indicated that IT planning for strategic use within healthcare was identified as the major problem in 34% of the organizations surveyed (Sobol, Alverson, & Lei, 1999). It is only recently that rapidly increasing costs

of healthcare services and the need for quality management in all service industries has accelerated the push of IT adoption in the healthcare industry. Public and private hospitals in Texas surveyed in 1999 showed 30 to 40% increases over a 10-year period in all areas of IT usage except patient accounting: clinical information linkage, inventory bar coding, PC networking, and linkage between doctors and hospitals. Patient accounting was already at 80% saturation (Sobol & Woods, 2000).

A large scale database study (N = 3220) explored IT adoption in hospitals, creating an IT profile reflecting the number and type of IT functions that were adopted (D.E. Burke, Wang, Wan, & Diana, 2002). The Dorenfest database of IT data from U.S. hospital systems for 1998 was used. Data showed that for the IT applications available and tracked in the database, 57% of the hospitals were using the technology. The range was dispersed, however, from 8% to 90%, showing very different patterns of adoption. Burke et al. developed quartiles to separate late from early adopters of technology and to define the applications that were chosen at the various stages of adoption. The profile application domains they included were administrative, clinical, and strategic.

Hospitals with high level of adoption showed a different profile of applications, except for strategic systems use. Those with high levels of adoption (early adopters) showed higher levels of adoption of all three types of applications. Late adopter profiles, by contrast, were dominated by administrative applications (51%). Larger hospitals were also more likely to have all three types of applications. Hospital for-profit or ownership status was not associated with the adoption of clinical or administrative IT. For-profit status was associated with the use of strategic

applications, and being a member of a system was associated with adopting clinical and strategic applications (D.E. Burke et al., 2002).

Use of IT by physicians in group practices is instructive for helping to understand their familiarity with and support for IT when staffing acute care hospitals. (Sobol & Prater, 2005) looked at the change of IT use in physician group practices over the last decade, comparing surveys conducted in 1994 and 2003. Two demographically similar Southwestern areas were surveyed, Maricopa County, Arizona (1994) and Tarrant County, Texas (2003), including the large metropolitan areas of Phoenix and Fort-Worth-Arlington. For the types of business applications used, hospital networking for small group practices (less than 10 physicians) had increased from 4% to 47%, and practice networking increased from 19% to 33%. Use of IT for patient record keeping increased from 35% to 67%, and for facility scheduling from 15% to 33%. Computer systems were networked to a greater degree (61%), a change from 35% in 1994. With regard to questions on IT savings for the business aspect of medical practice, in 2003, 70% or more physicians ranked processing insurance claims, improving patient record keeping, improving access to patient or hospital information, increasing cash flow, and reducing administrative overhead as the most important factors (Sobol & Prater, 2005).

Summary of HIT Management, Maturity, and Adoption

The literature reflects the current constructs in development and early stages of testing for healthcare IT. The combination of Nolan's stages of maturity and systems theory has produced some interesting models describing the importance of information

in providing healthcare and illustrating the complexity of measurement. Healthcare has been estimated to be 10 to 15 years behind in adoption of IT for a variety of reasons: lack of information to inform investment, behaviors of users, difficulty in modeling healthcare work activities, cost of large systems, and lack of financial incentive for investment. To provide an IT profile of Texas hospitals for the current study, the IT Sophistication in Healthcare instrument (Guy Pare & Sicotte, 2001) was chosen for use.

Performance Measurement

This section provides an overview of performance measures in organizations and describes the use of such measures in evaluating patient care and quality of healthcare. The origins of performance measurement in organizational theory and the current requirements for healthcare are discussed. The section also describes the development of the Patient Safety Indicators, a screening measure for patient care complications, which can be used as a measure of the quality of patient care.

Performance Improvement: Concepts and History

Early measurement of performance in the late 19th and early 20th centuries examined business cost accounting, work, and socio-environmental conditions. The field of public administration developed measures of performance for public services in the early 1900s, arising from the stimulus for increasing competence and efficiency in delivery of government services and for removing the lingering taint of late 19th century corruption. Woodrow Wilson's essay (Wilson, 1887) initiated the study of business and management practices, calling for the use of principles derived from scientific study to

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support organizational efficiency. Frederick Taylor (Taylor, 1912) applied scientific principles to labor. One of his tools, the foot-pound, was a unit of measure constructed in the 19th century in the initial work of the field of measurement. Taylor's "scientific management" was applied at the unit level of work, intending to find out how to work smarter by observing the steps to produce a work output. Taylor developed performance standards to measure worker productivity by analyzing inputs and outputs.

Williams and College (2002) traced the history of performance measurement techniques back to the early measurement of environmental conditions. Social surveys used in the late 1800s collected data about settlement houses in order to study poverty. In the early 1900s, The New York Bureau of Municipal Research (NYBMR) applied measurement techniques to the budgeting of municipal services. Increasing demand for public services and resistance to tax funding of resources was the principal stimulus. NYBMR applied a variety of techniques from various empirical activities: social survey, accounting, statistics, and scientific management. Service needs were identified, budget categories were named, resources were logged and service improvements were documented. Costs and services were linked with accomplishments; "functional budgeting" was able to answer questions about effectiveness and efficiency posed by government units.

Statistical quality control (SQC) and statistical process control (SPC) were other production improvement methods practiced worldwide from the 1940s through the 1960s (Williams & College, 2002). Organizational culture reform movements of the 1980s and early 1990s were instigated by U.S. industry's stymied productivity and fear

of competition from a global marketplace that developed in the 1970s (Shafritz & Ott, 1996). Credit for the source of the major reform movements belongs to W.E. Deming's work in Total Quality Management (TQM), an adaptation of SQC that was used in Japan in the 1950s (Williams & College, 2002). At the invitation of Douglas MacArthur, Deming taught quality improvement methods that helped Japan rebuild their economy after World War II. Like Frederick Taylor, Deming grounded his analysis, decisions, and practices for quality improvement in empirical data collection, (Williams & College, 2002).

It was not until 1980, when Japan presented a competitive threat to U.S. markets, that process improvement methods based on Deming's work were incorporated into the U.S. corporate sector (Shafritz & Ott, 1996). Hierarchical organizations, by their culture and structure, are not inclusive of the worker, and this factor was important in delaying the success of the techniques based on TQM in the United States. In the 1980s, participatory management and a commitment to worker-team inclusion and quality processes began to be widely adopted at all government levels to improve delivery of public services (Holzer, 1995). Because of the complexity of TQM concepts, the time required for implementation, and the nature of workers and management in public agencies, such changes have been slow to come to the public arena (Holzer, 1995;(Osborne & Gaebler, 1992).

Performance Measurement and Quality in Health Care

Florence Nightingale's practice of collecting empirical data and applying the analysis to care and management improvements was the basis of several reforms that she completed in military and civilian healthcare. The work began during her service with the British Army in the Crimean War; the report based on her extensive data collection and work experiences in the War was completed in 1857. This work supported her reform movement, which not only improved the health of army soldiers and military hospital organization and management, but also carried over to be applied to data collection in civilian hospitals. Nursing practice as well as healthcare delivery and management were impacted greatly by her work (Dossey, 2000). .

It wasn't until the 19th century that medical science and medical providers incorporated oversight into healthcare treatments. Self-regulation by the professional groups of providers grew out of concerns about safety and competency; state governments later instituted licensure requirements to address these concerns. As the benefits of medical intervention increased, public demand for increasing the availability of treatments helped to initiate the Medicare and Medicaid programs of 1965 (Palmer, Donabedian, & Povar, 1991).

In 1966, the U.S. Public Health Service initiated a study of health services, commissioning research experts to address specific issues. Avedis Donabedian was asked to contribute to this effort by evaluating the literature on quality assessment. The paper's concepts and nomenclature provided the organizing framework that is still in use today for studying quality assessment in the health services field (Donabedian,

1966). Donabedian's framework defined the relationship between good care and the outcomes of care as expected. Quality is the evaluation of the interactions of the elements of giving care and the processes used – judging whether the outcome was good or bad. The early focus in evaluating care was on the provider; this later shifted to the evaluation of the process of care in order to provide the feedback necessary to show performance of the care system (Donabedian, 1968).

Donabedian's model of the medical care process included physician behavior and the client-provider relationship. The indicators of the quality of care that Donabedian presented were characteristics of the care process setting, characteristics of provider behavior in managing health and illness, other provider behaviors related to the organization, client behaviors, characteristics of the utilization of services, characteristics of health, and other outcomes. His list of health outcomes are still used today: mortality, morbidity, disability, complications, functional and social restoration, preventable morbidities, life expectancy, and composite indices of illness or health (Donabedian, 1968).

In the mid 1960s, Donabedian remarked on the increasing role that the federal government was playing in accepting responsibility for quality oversight. Medicare oversight led to the institution of conditions for participation and utilization review procedures for health organizations accepting federal dollars, in order to oversee the appropriateness of care and hence the quality of medical care. On the state level, New York was one of the first to institute reporting related to the quality of medical care, hospital utilization, and costs (Donabedian, 1968) .

The next series of markers for performance measurement in the healthcare industry occurred in the 1970s and 1980s. Rapidly rising health care costs, mainly attributed to Medicare, triggered several changes and programs that affected measurement of care quality (Longest, 1998). In 1972, Professional Standards Review Organizations (PSROs) were established to monitor the quality of services provided to Medicare beneficiaries and to validate medical necessity for the services. In 1976-77, The U.S. Department of Health, Education and Welfare, (now Health and Human Services; DHHS) reorganized and created the Health Care Financing Administration (HCFA), responsible for administering Medicare and Medicaid. HCFA is now called Centers for Medicare and Medicaid (CMS), and it is responsible for ensuring the quality of the medical care for its clients. In 1983, again in response to costs of Medicare program, the Prospective Payment System (PPS) went into effect, with hospital service reimbursement based on diagnosis-related groups (DRGs). This was a major change from the cost-based reimbursement that hospitals had received since Medicare began in 1965.

Important for the measurement field of health services, this was the time marker for the development of outcome measures (Jennings & Staggers, 1998). Despite the move to PPS, after the initial reduction in hospital reimbursement costs, expenditures again began to rise. The variability in medical interventions to treat similar conditions was identified as a problem. Since good data were lacking, George Mitchell, then Senate Majority Leader, suggested using the outcomes of care delivery as a basis for reimbursement. With this interest in evaluating outcomes for cost management, quality

care assessments also shifted to measuring outcomes. "Outcomes research" became the method to describe the cost and effectiveness of medical care interventions. From 1989 through 1992, the Agency for Health Care Policy and Research (AHCPR), now known as AHRQ, published 14 studies that looked at various disease states and described findings for the treatment interventions being used.

The focus on improving performance for healthcare today is in large part the reaction to the widely published IOM reports on the lack of safety and quality in our national healthcare delivery systems (IOM 1999, 2001). The first report of the Committee on Quality of Healthcare in America outlined the dismal record of unsafe healthcare, and the follow-up report dealt with the overall lack of quality in delivering healthcare, calling for a redesign of the system. Problems in delivery and in the environment in which healthcare organizations must work are so extensive that the current system is not able to provide the desirable quality of care. The environment of healthcare has to be addressed nationally with new policy, funding, and regulation. Donald Berwick (2002), one of the authors of the second report, *Crossing the Quality Chasm,* provided a framework for four levels of healthcare system redesign. Comprehensive changes were called for at each level: the patient experience, the microsystems of care delivery, the function of healthcare organizations, and the environment of healthcare that affects delivery organizations.

Level 1 change, ensuring the quality of the health experience of patients and communities, speaks to the ultimate goal of redesign—to achieve patient-centered care. A goal of patient-centered care achieves the objectives of individual care needs,

resolving the cost and access barriers that now exist and eliminating the social disparities in the delivery of healthcare that go beyond economic barriers (Berwick, 2002). The current care system focuses on acute illness and disease rather than on answering the individual's holistic needs to maintain health. The delivery system is unavailable to large numbers of uninsured people, with unequal access by geographic location, financial status, and social status. Inequalities in the quality of care exist across gender, race, and cultural differences.

Changes in the other three levels address the elimination of the barriers that prevent the delivery of patient-centered care. Level 2, the redesign of "microsystems" or individual care units, for example a cardiac care unit, aims to provide care that is knowledge-based, patient-centered, and systems-minded. One of the barriers identified in the current care units is the lack of information systems that puts knowledge at the point of care—where the health team is interacting with the patient. The report characterizes our current information systems as "19-century" and recommends a complete redesign of the medical record system, not just computerization. Patient-centered care is customized care, where the patient is in control and has his or her needs for knowledge satisfied. Systems-minded care describes the coordination, integration, and care efficiency that should link across organizations, disciplines, and provider roles.

Level 3, improving organizational function, should focus on the design of systems to identify and implement best practices, better use of IT to provide access to knowledge for clinical decision-making, more investment in worker knowledge and
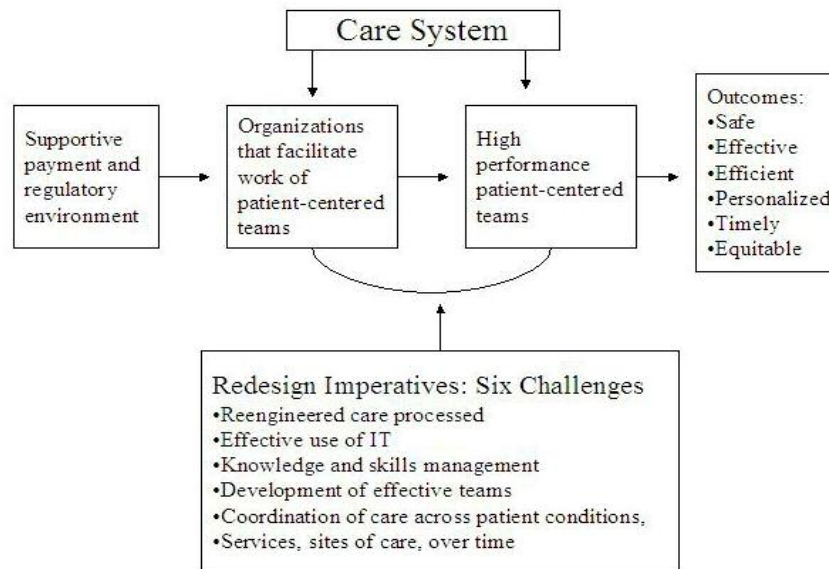
Figure 8. Changes to support quality care.   From "A User's Manual for the IOM's 'Quality Chasm' Report," by D. Berwick, 2002, Health Affairs, 21, p. 83. Copyright 2002 by Project HOPE. Reprinted by permission.

skills, more development of teamwork, better coordination of care within and across the

organization and better measurement of performance and outcomes (Berwick, 2002).

The fourth level, the environment of healthcare, is where limitations to care and

equal access to quality treatment are addressed. Healthcare centered on the patient and

family needs can only become a reality when the larger issues of financing and social

policy are addressed at the national level. The regulatory and accreditation environment

are monitoring tools to evaluate the level of care quality delivered by monies supporting

the public health systems. Figure 8 illustrates the redesign support necessary from all

the parties involved in the healthcare delivery system in order to achieve the outcome

goals: health professionals, federal and state policy makers, public and private

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purchasers of care, regulators, healthcare organizations, and consumers.

The Harvard Interfaculty Program on Health Services Improvement (PHSI) was formed to address the IOM reports by identifying research imperatives to support the work ahead (Fernandopulle et al., 2003). PHSI identified measuring performance, the adoption and use of IT, and aligning payment with quality health outcomes as the highest priorities for research. Better measurement of organizational performance in terms of quality and system attributes was the initial task identified. Quality measures that are widely used now at the organizational level include the Health Plan Employer Data and Information Set (HEDIS), the Consumer Assessment of Health Plans (CAHPS) developed by the Agency for Healthcare Research and Quality (AHRQ), and the Centers for Medicare and Medicaid Services' (CMS) measures of home health care quality.

PHSI identified particular needs for measures of organizational behavior and outcomes, more disease-specific measures, and measures of organizational attributes that affect the quality of health outcomes. A person's health is supported best by a continuum of health care services that integrates home care and community, outpatient, and acute inpatient access. It is important to develop measures of performance that cut across these care settings in order to show how well networks of health care services support this continuum. These types of measures will help determine how well the total system performs, something that is not measured today (Fernandopulle et al., 2003).

President Clinton directed an interagency task force on quality, the Quality Interagency Coordination Task Force (QuIC), to respond to the 1999 IOM report on

errors, in light of the federal government's roles in healthcare delivery. The government has assumed multiple roles in the nation's healthcare system: providing health care in the Veterans Health Administration (VA) and Indian Health Service; purchasing healthcare through Medicare and Medicaid; regulating health care through the Food and Drug Administration (FDA) and the Occupational Safety and Health Administration (OSHA); working with the private sector for standardization of diagnosis and procedural coding such as Diagnostic Related Groups (DRGs); and funding research, medical education, and training (Wahls, Chatterjee, Ting, & Clancy, 2002).

The QuIC endorsed the IOM's goal of reducing medical errors by 50% over five years and framed the federal response in four approaches: (a) establish a national focus to create leadership and research-based knowledge about safety, (b) utilize mandatory and voluntary reporting systems to identify and learn from errors, (c) raise standards and expectations for safety improvements through purchasers, accrediting bodies, and professional groups, and (d) implement safer practices at the delivery level (Shalala & Herman, 2000). Actions taken at these four levels are the direct stimulus to today's healthcare quality movement and to the dramatic increase in regulatory demands being made of delivery systems.

The first approach—to establish a national focus to increase understanding of patient safety—was funded in the 2001 federal budget to support research on safety and quality improvement (QI; (Wahls et al., 2002). The Agency for Healthcare Research and Quality (AHRQ) added a specific center for QI, and the VA created a research initiative to support research that identifies practice needs for interventions to improve

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quality. Development of standards for health care information technology structure was funded separately, with work continuing on an electronic patient record for use first by the Indian Health Service, Department of Defense, and VA system.

The second approach—to use reporting systems to accumulate knowledge of healthcare errors—has increased the development of mandatory and voluntary reporting systems. The National Quality Forum is developing a reporting system for deaths, major injury, and near misses. The VA is currently using a reporting system for basic research into the effectiveness of these systems and for modeling. CMS has established a new patient safety task force and will collect data on patient safety.

The third approach—to raise standards and expectations for safety improvements—is being accomplished by initiating several mandates using the regulatory power of the health agencies (Wahls et al., 2002). CMS is requiring hospitals that participate in Medicare to have medication error programs in place with recommended IT components: automated entry for pharmacy orders, bar coding for administering medication, and automatic safeguards against adverse drug interactions. The Federal Employees Health Benefits Program and the Office of Personnel Management (OPM) required health plans to implement patient safety programs as of April 2001. The FDA is placing new safety requirements on packaging and marketing of pharmaceuticals and developing new standards for labeling common drug interactions.

The fourth and final level of activity to improve quality is implementing safe practice at the delivery level (Wahls et al., 2002). As providers of care, the federal

agencies are modeling several initiatives: the VA System's "culture of safety" program, the Veterans Affairs patient safety award programs, and the use of safety checklists in high-hazard areas such as operating rooms, emergency rooms, and intensive care units. Federal providers have also increased the required employee education on patient safety to 20 hours per year for each employee (Shalala & Herman, 2000). In all of its facilities, the Department of Defense (DOD) is implementing CPR, CPOE for pharmacies, and point of service access to clinical information for patients (Wahls, et al).

The extent of these recommendations from the IOM, as well as the QuIC responses illustrate the enormous resources that are being demanded from all levels of the health care delivery system. Resistance to the recommendations is a reaction to several effects the mandated programs are having on healthcare systems (Leatherman et al., 2003). The costs to deal with these recommendations are significant, especially for individual systems that do not have the resources of corporate health systems. The healthcare industry is already dealing with competing financial priorities in order to adopt new technologies, staff facilities, and attract a market share of clients. A major concern is the lack of any assurances that these actions will pay off in benefits to safety and efficiency. Mandates for reporting systems for errors and near misses bring out the long-standing resistance of physicians and health care organizations to mandatory reporting. Legal discovery issues will have to be dealt with by legislative actions.

These issues confront both public and private sector health services. Interestingly, even the $25 million budgeted for AHRQ programs to research safety and quality is a miniscule portion of what is needed—and only a very small portion of the

billions that National Institutes of Health (NIH) receives for research (Wahls et al.,

2002). The IT infrastructure development recommended by IOM and QuIC will require

massive joint federal and private sector funding. Reporting will be better accepted when

it is tied to reimbursement, as it now happening with the CMS reporting for selected

DRGs. CMS started the reporting program on a voluntary basis to demonstrate

compliance and national benchmarking, with clinical care guidelines for several disease

states. The reporting is now tied to the receipt of the annual market basket increase for

Medicare reimbursement.

Scorecards are already in use by the federal health agencies, private vendors,

and state agencies that report for Medicare, CMS, and state discharge purposes. The

three sets of quality indicators developed by AHRQ—Inpatient Quality Indicators,

Ambulatory Care Sensitive Indicators, and Patient Safety Indicators—are in use now to

provide quality reporting by the hospitals to the Texas State Data Center.

AHRQ Quality Indicators: Patient Safety Indicators (PSI)

The AHRQ's PSI measures are the third set of quality measures developed for

hospital screening of quality care. In the early 1990s, hospitals requested measures that

were built on readily accessible data, low cost, and easy to use for screening patient care

problems and improving quality assurance programs. The PSIs recently became

available for use with administrative claims data. AHRQ also developed a module for

the statistical software SPSS in order to select cases using secondary DRGs that

represent risks for possible safety complications.

The California Medical Association performed the initial study that used administrative data to screen for complications in 1976 (U.S. Department of Health and Human Services, 2003b). Nurses and medical records administrators screened records for 18 possible indicators of complications. Those records were then independently reviewed by physicians to identify injuries related to medical management. Later studies have used complication measures validated against length of stay, comorbidity, higher mortality, and higher charges (Broder, Payne-Somon, & Brook, 2005).

Development of AHRQ Patient Safety Indicators

The Evidence-based Practice Center (EPC) at the University of California at San Francisco and Davis, collaborating with Stanford University (UCSF-Stanford), was commissioned by AHRQ to document the evidence base for the PSIs using hospital inpatient discharge data. These quality indicators were developed in response to requests for measures to use for quality improvement of care. The Healthcare Cost and Utilization Project (HCUP), started in the early 1990s, established an ongoing national database of hospital claim data, building on quality measures that were already in use at the state level or in proprietary projects. The PSIs, a subset of indicators for safety screening, were developed for identifying complications or adverse events that patients may encounter during an acute care hospital stay. The complications may be due to system or provider error and may be preventable by changing the behaviors of the providers or of the system, or by improving the care processes. PSIs are available for both the provider (hospital) level and the area level (MSA or county(U.S. Department of Health and Human Services, 2003b).

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Six areas of evidence were used to validate the measures: face validity, precision, minimum bias, construct validity, ability to foster real quality improvement, and evidence of application (U.S. Department of Health and Human Services, 2003b). Face validity (consensual validity) was evaluated using a multidisciplinary panel of expert clinician providers, including nurses and physicians. Precision referred to the amount of non-random variability at the provider or community level. Minimum bias described the effect of variations caused by the severity of patient disease or by comorbidity and also indicated whether the bias could be removed by risk adjustment or other statistical methods. Construct validity was documented based on the literature and on validation of coding using ICD-9 CM methodology developed by CMS. A panel of clinical providers helped determine the usability of the indicators and the inherent problems in real practice settings, with application to quality improvement and use with other indicators (U.S. Department of Health and Human Services, 2003b).

The AHRQ team reviewed all ICD-9-CM codes to identify codes that describe medical errors or consequences of errors. The initial candidate list of indicators was based on Iezzoni's Complications Screening Program (CSP; Iezzoni et al., 1992), which included 28 indicators of preventable complications, based on administrative data and verified by physician review of the medical record (Iezzoni, Davis et al., 1999). This initial set of AHRQ quality indicators was later modified in 2000 and 2001, with the addition of further codes and changes due to conceptual clarifications. Over 200 codes that were potentially related to medical error began the validation process. These codes were grouped into indicators and defined with a numerator—the indication of interest,

and a denominator—the population at risk. For each indicator, a specific at-risk population was defined, in order to apply the indicator to a more homogeneous population, for example, patients with major surgery. Thirty-four potential indicators were then reviewed by an expert in ICD-9-CM guidelines, a multidisciplinary clinician panel, and a surgeon panel. Changes recommended by the clinicians were incorporated, and the final group of indicators was evaluated against six criteria: overall usefulness; likelihood that the indicator measures a complication, not a comorbidity; preventability of the complication; extent to which the complication is due to medical error; likelihood that the complication is charted when it occurs; and the extent to which the indicator is subject to bias, as from case mix. Final indicators were chosen by the Stanford team using clinicians' recommendations (U.S. Department of Health and Human Services, 2003b).

The final empirical analysis used the 1997 HCUP State Inpatient Database (SID) data, which included 19, million discharges from community hospitals described as nonfederal, short-term, general, and specialist. Long-term psychiatric hospitals and chemical dependency treatment facilities were excluded. The discharge data were contributed by 19 states participating in HCUP. The latest update, Revision 3, used 2002 SID data from 35 states. The hospital performance analysis was performed to provide further information on the characteristics of the indicators, such as the frequency and variation of indicators, potential bias, and relationship between the indicators. Analysis included calculating raw indicator rates using the number of adverse events divided by the number of discharges in the population at risk. The raw

indicator was adjusted stepwise to account for differences among the hospitals in age, gender, modified DRG category, and co-morbidities. Multivariate signal extraction (MSX) methods were used for reliability adjustment, estimating the amount of variation due to random error. Multivariate methods were then applied to the appropriate indicators (U.S. Department of Health and Human Services, 2003b).

Statistical tests performed on the indicators examined the precision, bias, and relatedness characteristics of the indicators. Precision testing evaluated observed indicator variation at the level of the hospital and determined what percentage of the variation was due to systematic differences between hospitals and what was due to random noise. Risk adjustment can either increase or decrease the observed variation. If the variation is increased over observed, then provider differences will be masked by patient differences. If risk adjustment decreases the variation, differences in patient characteristics are accounting for the provider differences. Bias testing compared performance with and without risk adjustment and multivariate signal extraction. The relatedness testing asked if the indicators were related in a way that is clinically appropriate (U.S. Department of Health and Human Services, 2003b).

PSIs and Strength of Evidence for Accepted Indicators.

Table 1 presents evidence from the literature regarding the indicators included in the current study. Each indicator was evaluated in the literature for coding accuracy and acceptable association with patient care processes. Coding sensitivity is the proportion of patients not suffering an adverse event that were not coded with the adverse event. Predictive value is the proportion of patients with a coded complication who were

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confirmed to have suffered that event. The data used were discharge or Medicare claims, with verification by chart review or prospective data collection.

The explicit process construct is defined as adherence to evidence-based or expert-endorsed processes of care. The implicit process construct is adherence to the "standard of care" for similar patients, based on physician chart reviews of the care processes. For both explicit and implicit processes, hospitals that provide better processes of care should have fewer adverse events. The staffing construct is based on the idea that hospitals that offer better staffing with nurses, and physicians with a higher skill mix, should have fewer adverse events. When the evidence provides high content validity, the authors state that the process constructs become less important for validity concerns (U.S. Department of Health and Human Services, 2003b).

The indicators included in this study (see Table 2.1) are those that had more than one type of literature evidence to support their validity and were accepted as valid indicators by expert clinical reviewers. The literature evidence included combinations of coding validation and a link with failure of care process constructs or staffing constructs. Panel review findings suggested that each indicator was useful as a screen for preventable complications of care (U.S. Department of Health and Human Services, 2003b). The definitions and sources of validity for each of the included safety indicators is presented in the following paragraphs.

Table 1. *Findings from the Literature Review Regarding Selected Indicators*

Indicator	Coding	Explicit Process	Implicit Process	Staffing
Death in low mortality DRGs	+	0	+	0
Failure to rescue	+	0	0	++
Postoperative hip fracture	+	+	+	0
Postoperative hemorrhage or hematoma	±	±	+	0
Postoperative respiratory failure	+	±	+	±
Postoperative PE or DVT	+	+	+	±

Note. 0 = no published evidence; + = published evidence suggests that the indicator is valid, or likely to be valid, in this domain (i.e., one favorable study); ± = published evidence suggests that the indicator may be valid in this domain, but different studies offer conflicting results (although study quality may account for these conflicts); ++ = strong evidence supports the validity of this indicator (i.e. multiple studies with consistent results, or studies showing both high sensitive and high predictive value).

Death in Low Mortality DRGs

This indicator identifies in-hospital deaths that are unlikely to occur when the patient is admitted for certain conditions or procedures. If death results, the assumption is that an error in care was the cause of the death. The indicator is defined as in-hospital deaths per 1,000 patients in DRGs with less than 0.5 percent mortality. The cases excluded are trauma patients, immunocompromised patients, and cancer patients (Iezzoni et al., 1992); (U.S. Department of Health and Human Services, 2003b). For these low mortality diagnoses, Hannan, Bernard, O'Donnell, and Kilburn (1989)showed that the cases are five times more likely than all other patients that died to have received poor quality care that did not follow professionally recognized standards. The indicator

is risk-adjusted for age, sex, DRG, and co morbidity (U.S. Department of Health and Human Services, 2003b).

Failure to Rescue

(Silber, Williams, Krakauer, & Schwartz, 1992), who described this indicator, believed that better hospitals are able to prevent death in patients that have complications. Failure to rescue refers to the inability to prevent mortality when a complication occurs from care. The definition of the indicator is deaths per 1,000 patients that developed specified complications of care during hospitalization. Cases where the patients are age 75 or older, neonates, patients admitted from long-term care facilities, and patients transferred to or from other acute care facilities are excluded (U.S. Department of Health and Human Services, 2003b). To develop the indicator, medical records were abstracted on over 6,000 patients who underwent the commonly performed surgeries of cholecystectomy and prostatectomy (TURP). Patients who were at risk for mortality from a complication had a postoperative secondary diagnosis including cardiac arrhythmia, congestive heart failure, cardiac arrest, pneumonia, pulmonary embolus, pneumothorax, renal dysfunction, stroke, wound infection, or unplanned return to surgery. Failure to rescue, or prevent death from the complication, was independent of severity of illness on admission. Studies showed that the ability to prevent death from complication (low failure to rescue rate) is associated with the presence of surgical house staff (Silber, et al. 1992) and high ratios of registered nurses (Silber, Rosenbaum, & Ross, 1995). A recent study using administrative data related lower failure to rescue rates with higher registered nurse staffing (RN hours/ adjusted

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patient day) and better skill mix (RN hours/other licensed nurse hours). This set of

patients at risk had diagnoses of sepsis, pneumonia, acute gastrointestinal bleeding,

shock, cardiac/respiratory arrest, deep vein thrombosis, and pulmonary embolus

(Needleman, Buerhaus, Mattke, Stewart, & Zelevinsky, 2002). The indicator is risk

adjusted for age, sex, DRG, and comorbidity categories. Failure to rescue is notable

because of its high occurrence, with 131.83 cases per 1,000 population at risk (SID data,

2002;(U.S. Department of Health and Human Services, 2003b).

Post-operative Hip Fracture

This indicator screens for cases of in-hospital hip fracture for every 1,000

surgical discharges. Patients with conditions suggesting a fracture was present on

admission (medical disease, such as musculoskeletal) and obstetrical patients are

excluded (U.S. Department of Health and Human Services, 2003b). Fractures for

medical cases are usually due to comorbidities present at admission. Failures in the

processes of care were attributed to the complication for both surgical and medical

cases. This indicator is risk adjusted for age, sex, DRG, and comorbidity categories.

 Postoperative Hemorrhage or Hematoma

Cases of hematoma or hemorrhage following a surgical procedure are

sometimes the result of complications of care. The definition is the number of

hemorrhages requiring a procedure per 1,000 surgical discharges. Several studies have

provided confirmation of correct coding of this complication for major surgical cases

(Lawthers et al., 2000); (McCarthy et al., 2000); Weingart, et al., 2000). Failure to

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follow professional guidelines in surgical cases occurred with 66% of the cases

(Iezzoni, Palmer et al., 1999). This indicator is risk adjusted for age, sex, DRG, and

comorbidity categories, and excludes obstetrical patients (U.S. Department of Health

and Human Services, 2003b).

Postoperative Respiratory Failure

This indicator screens for the complication of respiratory failure following

surgery, per 1,000 elective surgical discharges. Coding correctly for this complication

was confirmed for 75% of the cases (Lawthers et al., 2000; Weingart et al., 2000). Both

process failures and staffing evidence were found related to this indicator (Iezzoni,

Palmer et al., 1999; Kovner & Gergen, 1998; Needleman et al., 2002). The indicator is

risk adjusted for age, sex, DRG, and comorbidity categories, and it excludes patients

with respiratory or circulatory diseases or obstetrical patients (U.S. Department of

Health and Human Services, 2003b).

Postoperative Pulmonary Embolus (PE) or Deep Vein Thrombosis (DVT)

This indicator screens for deep vein thrombosis or pulmonary embolism

following surgery, per 1,000 surgical discharges. Sensitivity of coding this indicator for

secondary events varied in reports from 65% (Keeler, Kahn, & Bentow, 1991) to 100%

(Geraci, Ashton, Kuykendall, Johnson, & Wu, 1995). Process of care failures were

frequent for both surgical and medical cases, 72% and 69% (Iezzoni, Palmer et al.,

1999). Nurse staffing effects were contradictory, with one study finding staffing not

related to lower rates of DVT or PE (Needleman et al., 2002) and another finding that

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increased RN hours and non-RN hours are both related to lower incidence of DVT/PE

after major surgery (Kovner & Gergen, 1998). The availability of well-known

preventative therapies for DVT or PE following surgery makes this a useful screening

indicator.

Summary of the Performance Measurement Literature

The practice of measuring healthcare performance developed from the

combination of public administration and organization theory and from Florence

Nightingale's work on the collection and use of patient care data to improve treatment

and hospital management. Collecting and reporting data for quality improvement of

hospital patient care is a late development that has been driven by regulatory and payer

oversight. Collecting healthcare data is labor intensive and costly, because of the lack of

infrastructure support for the activities required. IT adoption in hospitals still remains

slow for numerous reasons, but this is the main improvement to the hospital

infrastructure that is necessary in order to perform the QA tasks. The main drivers of

quality improvement in healthcare are government oversight of the Medicare and

Medicaid population (CMS), JCAHO credentialing, and competition in the marketplace

for limited healthcare dollars.

AHRQ developed a set of quality indicators that are in use by hospitals for

screening care quality and identifying possible risks for complications or service

delivery problems. This study uses a subset of the third set of indicators, Patient Safety

Indicators, as a measure of the quality of care outcomes in acute care hospitals.

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Performance Measurement, IT, and Finance Outcomes

This section addresses the relationship between performance measurement and IT, with a review of financial measures in healthcare. The larger literature focuses on the IT-performance relationship in terms of return on investment (ROI), assets, market share, sales revenue, costumer satisfaction, and other proxy measures for business efficiency and effectiveness. Recent findings suggest a positive relationship between performance improvement and investment in IT, but disagreements persist on the consistency and value of the findings (Devaraj & Kohli, 2000; Mahmood & Mann, 1993, 2000; Vogel, 2004). Some of the factors discussed are methodology, lack of large data sets, quality of the data, issues in determining the effect of lag time for implementation, the variety of measures and definitions used, and the use of appropriate covariant variables (Sircar, Turnbow, & Bordoloi, 2000). There is also disagreement between quantitative and qualitative researchers on the value of the findings. The complexity of sorting through the many factors that affect organizational performance is an ongoing measurement problem. Other important issues are the non-tangible effects of IT that are difficult to quantify, such as timeliness, accuracy of results, information benefit, convenience, reliability, knowledge access, and the benefits of communication transfer. The current literature is also beginning to show positive influences of IT on non-business factors that influence or relate to performance (Mahmood & Mann, 2000).

Few system-level empirical studies were found that evaluated the performance of IT in healthcare. The bulk of the studies in this area evaluate the benefits of individual IT applications. This review limits itself to IT performance in the health

industry, but it includes models and concepts that provide understanding of HIT

performance in the absence of health industry literature. Performance measurements of

quality of care were reviewed in the prior section. After presenting an introduction to

theories of IT performance, this section focuses on the effect of IT on financial

performance.

Models and Instruments: Measuring Performance of IT

Amarasingham, et al. (2006) developed a unique instrument that measures the

performance of hospital IT from the clinical user's perspective. The Clinical

Information Technology (CIT) Index is based on constructs of IT automation and

usability. Automation of IT was defined as the level of computerization of the clinical

information processes (Amarasingham et al., 2006). Four subdomains of automation

were measured: test results, notes and records, order entry, and other processes

(monitoring, decision support, and data sharing). Usability measured the extent to which

IS was easy, effective, and well supported. Convenience samples of physicians (n =

117) and CEOs (n = 3) were used for the pilot study, which took place at an academic

hospital with an advanced IT system, a major Veterans Affairs hospital with advanced

IT, and two community hospitals with low investment in IT. Physician's scores were

significantly higher for hospitals with advanced IT compared to those with low IT

investment. The CEO scores were similar to those for the physicians. Differences

between hospitals were seen for all seven subdomains. The standard deviations for the

CIT index ranged from 5.9 to 8.1 with Chronbach's alpha greater than .70 for this sample (Amarasingham et al., 2006).

Chang and King (2005) developed a model for measuring the functional role of IT in supporting the organization and that is applicable to healthcare services. Three outputs were developed: systems performance, information effectiveness, and service performance (see Figure 9).
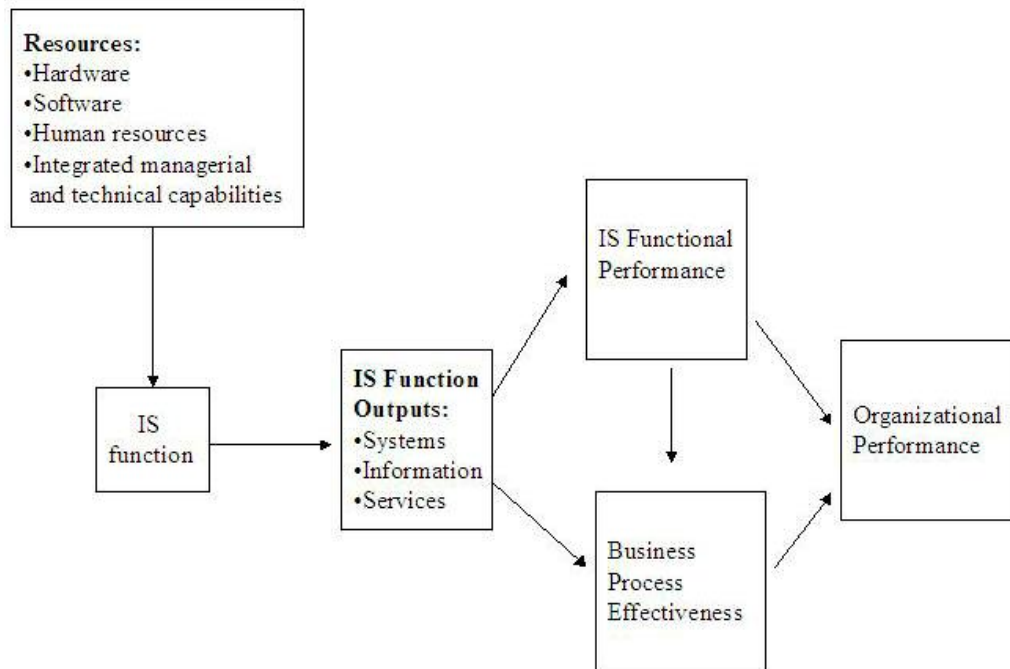
Figure 9. Input-output performance model.

Resources listed in the model mirror the inputs to the IS function in other system models discussed previously. This model clarifies the importance of integrating

management and technical capabilities, as well as the technical inputs. The IS function

products (systems, information, SNF services) affect the organization as IS functional

performance (ISFP). The IS outputs are also drivers of business process effectiveness

(BPE). The combination of ISFP and BPE determine the organization's performance

(Chang & King, 2005, p. 87).

Using the ISFP construct, Chang and King developed an instrument using new

and previously established items from the literature. The instrument was titled the IS

Functional Scorecard (ISFS), and it was intended to measure the entire IS function.

Systems performance, information effectiveness, and service performance are the major

dimensions of this measure. Systems performance assesses usability, response time, and

other attributes of the applications for the user's work. Information effectiveness

assesses the value provided by information outputs. Service performance evaluates

service request experience, for example help desk and systems development. Eighteen

subconstructs are assessed within the three dimensions. Initial data collected from 120

companies suggest that the instrument has acceptable psychometric properties. The

industries sampled included health care (7%), manufacturing (25%), wholesale (14%)

and banking/finance (11%). Chang and King suggested that this instrument could be

used for internal benchmarking of large organizations, for assessment of strengths and

weaknesses of IS functioning by IS managers, and for establishing baseline metrics

prior to or in planning for IS technology changes (Chang & King, 2005, p. 87).

Labkoff and Yasnoff (2006) developed and tested a framework to describe the

progress in developing IT infrastructure by communities that are working to

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interconnect all sources of their population's health information. Four communities were selected, based on reports of significant progress on the HII initiatives in the last 15 years. This was an emphasis that came out of the 2003 DHHS strategic framework after the IOM reports were issued. Using a 5-point scale (20% increments), the instrument assessed the degree of activity in four areas of development, which were assessed individually and with a summary score. The framework addresses completeness of information, degree of usage, types of usage, and financial sustainability. The first area assessed the degree to which information was linked across eight categories: inpatient care, outpatient care, long-term care, home health, laboratory results, outpatient medications, imaging, and insurance claims. The degree of usage measure added additional points if all providers and patients were on the system. The types of information usage included patient care, public health, clinical research, quality improvement, and healthcare operations. The fourth element, financial sustainability, reflected the percentage of budget that was generated from operational sources.

Reviewers assessed each community, a site visit was made, and a leader of the project was interviewed. The completeness of data available ranged between 40% and 53%. The maximum score for degree of usage was 60%. For uses of information, the third measure, all but one community was using their HII for all aspects. With regard to funding, three communities were financially sustainable through user fees. The highest scored community was Bellingham, Washington, with 300,000 citizens (Labkoff & Yasnoff, 2006).

Measuring Return on Investment (ROI) for IT in Healthcare

Numerous articles have addressed the difficulties in showing a return on investment for IT in healthcare. Vogel (2004) gave a brief history of IT investment outside of the healthcare industry, and, like other authors, discussed the differences in healthcare that contribute to the difficulty of measurement. Investment of IT in healthcare followed the trends for other industries beginning in the 1960s with financial systems, which generated returns in labor cost savings. From that early period until today, the investments have been made in response to healthcare industry needs: initial labor savings, increasing the efficiency of tasks in clinical areas, increasing the reporting and data handling capacity as reimbursement formulas changed from the 1980s, and the current decreases in reimbursement for the costs of healthcare. Unlike other industries, the goals of healthcare organizations are less measurable. Helping people get well is less easily measured than increasing the number of widgets produced. The commonly used ROI measures: reduction in labor costs, increases in revenue, and increased work production, does not provide good measures for productivity in healthcare (Bauer, 2004). In addition, the information product (patient record) produced by health care does not belong to the healthcare system, increase reimbursement or become an asset itself. The factor shared in common with other industries is that information is not typically the investment goal. The value of IT is its synergism in working with other system elements and work process changes to increase productivity, large profits are possible (McKinsey Global Institute, 2001).

Chaiken (2004) gives an example of the measurement issues in discussing clinical information systems (CIS). Measurement of ROI for CIS is accomplished both by effect on length of stay (LOS) and by the value to clinicians' work processes and outcomes of care. Financial cost savings result from decreased LOS, reducing the case cost and increasing utilization (bed turnover). An example of CIS affecting LOS is computerized physician order entry (CPOE) and decision-support systems (CDSS). Benefits accrue with accurate and timely communication, saving staff time on workflow and processes, and turnaround of clinical information for decisions with knowledge support—all resulting in safer, higher quality care (Krohn, 2004). CIS that tracks patient data is a valuable resource for reporting to compliance and oversight agencies, improving accuracy of the data, and saving labor. Still difficult to measure, but of high value, is prevention of medical error. Hospital systems have difficulty collecting accurate data on errors and near misses (potential errors that are prevented) with immature risk systems, and cultural changes are still needed in order to enhance reporting (Chaiken, 2004).

Hillestad, et al. (2005) built a model estimating the potential benefits of implementing electronic medical records (EMR) on health, savings, and costs. The primary source of data was the Dorenfest HIT database, which collects IS data from health agencies in the United States. The model for adoption (their lower bound estimate) included an integrated system that had EMR, clinical decision support, and a central data repository. Based on a literature survey, they could prescribe only potential efficiency savings, but they believed that their projection over a 10-15 year adoption

period represented better than a worst-case scenario. Literature and hospital supplied data were used for estimating costs of adoption. Cost estimates were based on the following specifications: one-time implementation, ongoing maintenance costs, costs related to size and operating expenses of hospitals, and the systems representing a more complete EMR, CDSS, and CPOE. A 10-15 year adoption period was used. To estimate potential safety benefits, they used medication error and adverse drug event rates from the literature to extrapolate three safety benefits, assuming broad national adoption of CPOE. Errors were distributed across hospitals and patients nationally using public data sets. Other potential health benefits estimated were disease prevention and chronic disease management (Hillestad et al., 2005).

Hillestad et al. estimated that the potential efficiency savings at 90% adoption for inpatient and outpatient care could average more than $77 billion per year. An average annual savings of $42 billion was estimated during the adoption period (10-15 years). The largest savings would come from reducing inpatient LOS, nurses' administration time, drug usage, and in the outpatient setting, reducing drug and radiology usage. The authors stated that these savings are low in comparison to present figures for other industries. The efficiencies would accrue in the long run to payers: $23 billion per year to Medicare and $31 billion to private payers. Providers have limited incentives to purchase EMRs; however, their investments result in revenue losses, with the savings gained by the payers.

The safety benefits come from alerts, reminders and other components of CPOE described in the literature. CPOE could eliminate 200,000 adverse drug events (ADE)

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and save $1 billion per year for inpatient care. Outpatient care would save $3.5 billion, avoiding 2 million events. Potential health benefits of the EMR systems are based conceptually on the communication, coordination, measurement, and decision support that would be increased by the system. Preventive care would benefit with use of evidence-based recommendations prompted for, such as screening exams, teaching points, vaccinations, and checkup appointment reminders. Chronic disease management would benefit, with better care for the 15 chronic conditions that account for more than half the growth in healthcare spending. Services would include targeting the at-risk level for proper treatment, monitoring, behavior modification, and timely adjustment of therapy—all reducing the need for acute care interventions. Savings were estimated for four conditions: asthma, heart failure, pulmonary disease, and diabetes. Assuming 100% participation, the combined savings are again in billions of dollars.

For costs of EMR implementation, cumulative costs for 90% of hospitals to adopt EMR (20% have currently) would be $98 billion, approximately one-fifth of the estimated efficiency savings. Adoption costs for physicians would be $17.2 billion, cumulative for 90% adoption (Hillestad et al., 2005).

Research Addressing Hospital IT and Financial Performance

The following research directly measured HIT and financial performance. Additional literature is provided here that reviews studies on IT and quality of care, the other outcome measured in this study. Table 2 shows the variables, findings, and citation of the studies reviewed. The studies are discussed as listed in the table.

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Table 2. *Variables of Healthcare IT and Financial Performance*

Variables Used	Findings	Citation
Cash flow: (net income + depreciation + amortization) to total assets Operating margin: operating income to total operating revenue Operating return on assets: operating income to total assets Total margin: net income to (total operating revenue + nonoperating revenue) Net inpatient revenue per day per bed: [(inpatient services revenue – total inpatient deductions from revenue) to beds] to 364 Net patient revenue: [net patient care revenue to beds] to 364 Operating income per bed per day: [operating margin to beds] to 364 Total income per bed per day:[total margin to bed] to 364 Hospital expenses per bed per day: [daily hospital services expense to bed] to 364 Total expenses per bed per day: [total operating expense + nonoperating expense by bed] to 364	Hospital sample. Positive relationships were found for all IT application clusters and the operation finances (Adj. R2 of .26 to .45). IT and case mix both significantly related to the operation variables. Positive relationships between IT and overall financial measures; positive performers with significant higher IT mean scores, except for patient safety cluster. IT use and case mix associated with higher revenues and higher expenses; case mix with stronger relationship.	(Menachemi, Burkhardt, Shewchuk, Burke, & Brooks, 2006)
Net patient revenue per day Net patient revenue per admission IT Labor expense IT support expense IT capital expense Customer satisfaction Mortality BPR	Hospital sample. Labor & capital investment have significant effect on net patient revenue. IT labor significant effect on mortality. IT capital significant effect on satisfaction. BPT and IT support, BPT and IT capital both have significant effect on revenue. BPR and IT support and labor significant effect on satisfaction.	(Devaraj & Kohli, 2000)

Table 2 – continued

Gross charges	Physician practice.	(Smith,
Net revenue	Multispecialty MD practice: IT	Bullers, &
Operating costs	spending associated with lower	Piland, 2000)
Operating margin	operating costs, lower revenue.	
	Single specialty: higher	
	operating margin.	

Florida hospitals were recently studied for relationship between IT use and
financial performance (Menachemi et al., 2006). Primary and secondary data were
studied on 82 hospitals. The IT variables were gathered from a primary survey that
queried the use of individual IT applications and financial measures reported to the
Florida Agency for Healthcare Administration. The availability of IT applications was
measured, not the actual use; applications were not ranked. The IT applications were
grouped as administrative, clinical, or strategic with a subset of patient safety
applications. Indexes were calculated by linear score for each cluster of applications, a
summary score for all applications, and a patient safety cluster.

The measures and findings are shown in Table 2. Regression analyses were
performed to determine the effects of IT usage on outcomes, with a case mix index as
the covariate. The case mix index for each hospital represented the average patient
severity of illness. Positive relationships were found between all IT application clusters
and operation performance and overall finance measures, except for the patient safety
cluster. The relationships were significant after controlling for case mix and bed size.
Higher IT use was also associated with higher expenses. (Menachemi et al., 2006).

Devaraj and Kohli (2000) completed a longitudinal 3-year study of eight

hospitals, examining monthly data to determine relationship of IT investment to

performance. The hospitals were members of a health system that had recently adopted

decision-support systems (DSS); each hospital was an independent legal entity. The

DSS was a repository for financial, clinical, and quality outcome data for each patient

admitted to any of the system hospitals over several years. The DSS stored daily care

data (e.g., what medication had been administered for what day). Benchmarking data

from a commercial organization was also stored in the DSS. Devaraj's study was

important in addressing several methodological shortcomings noted in prior studies:

single cross-sectional sampling, lack of consistency in variables used for measurement,

failure to consider the affect of time from IT implementation to measuring improvement

of processes, and failure to determine whether combining work process changes with IT

implementation affected productivity. The findings (see Table 2) showed a significant

relationship between IT investment and better hospital performance for both revenue

and quality (measured as mortality). There was evidence of profit impact at three

months or more after IT implementation. The combined effect of business process

change and IT investment also showed positive effects on profitability.

Smith and others (2000) addressed the relationship of IT investment with

medical group practice performance. The IT investment included computers,

telecommunications, and data processing services. Using voluntarily submitted data

collected over three years (1995–1997), four financial variables were studied, as noted

in Table 2. For the 1995 and 1997 data, higher spending on IT in multi-specialty

physician groups was associated with lower operating costs, but also with lower

revenue. For IT investment for single-specialty groups, more spending was positively

associated with higher operating margins; there was no significant relationship with

costs.

Research on General Hospital Characteristics and Financial Performance

Table 3 shows the different measures used in recent hospital research on

financial performance. These studies are not discussed, as their findings do not relate to

this study; however the measures were important for review. The table includes each

measure, how it was calculated, the purpose the variables were used for, and the

citation.

Table 3. *General Hospital Characteristics and Financial Performance*

Variables used	Purpose used	Citations
Operating profit margin	Hospital sample. compared hospitals by operating margins and described possible factors related to low margins	(Hayden, 2005)
ROI: $$ investment to $$ returned over time (years)	Hospital sample. cost benefit analysis prior to implementing CIS	(Snyder-Halpern & Wagner, 2000)
Patient profit: (patient revenue – total expenses) to patient revenue *100 Total profit: (total revenue- total expense) to total revenue *100	Hospital sample. best profitability of hospital by size, demographics and strategic planning activity	(Kim, Glover, Stoskopf, & Boyd, 2002)

Table 3 - continued

Liquidity: total current assets to total current liabilities Revenue to expense ratio Return on assets: net income to total assets Return on equity: net income to total net worth Administrative cost: total admin expense to total expenses Debt to total assets: total other liabilities to total assets Days in unpaid claims: claim pay x 365 to expenses	HMO sample. compared the organizational forms of HMOs to determine differences in efficiencies and financial results.	(Sobol, 2000)
Operating margin: [operating revenue-deductions-operating expenses] by [operating revenue – deductions] Total margin: [(net operating income) + (net nonoperating income) / [(total revenue – deductions)] ROA: (total net income) / total assets	Hospital sample. Affect of system membership on financial performance	(Tennyson & Fottler, 2000)
Operating margin: [(net patient revenue-operating expenses) by net patient revenue] Markup ratio: gross patient revenue by operating expenses Total margin: (total revenue-total expenses) by total revenue HMO penetration: (enrollment/population) Length of Stay: patient days by discharges	Hospital sample. Changes in performance related to profitability, volume, and efficiency for teaching hospitals during the 1990's	(Rosko, 2004)

Table 3 - continued

Cost per adjusted admission: (total expenses by CPI) by (admissions adjusted for outpatient volume)		
Total profit margin or excess margin: net income by total operating revenues	Hospital sample. Demonstrate how hospital revenue, profit, credit measures are overvalued due to DSH funds intergovernmental transfers	(McCue & Draper, 2004)
Operating profit margin ratio: operating income from operations by operating revenue Cash flow margin ratio: cash flow from operations by total revenue Debt service coverage: net income before interest and depreciation expenses by annual principal and interest payments Net patient revenue per adjusted discharge		

Research on IT in Healthcare and Quality

Hartman, Fok, Fok, and Lee (2002) studied relationships between health and

non-health managers in their organization's adoption of quality management (QM)

programs and general IS programs. Their research questions were intended to determine

whether there were differences in the maturity of QM between the two settings (how

they implement QM), in how they perceived their organization's culture and

effectiveness as a result of their QM maturity, and in their perceptions of overall IS

support for the users. Managers attending graduate level QM training at universities were sampled. The non-health respondents were from service organizations. The authors had noted from the literature that the healthcare organizations were believed to be behind in sophistication of QM management and IS support compared to non-healthcare settings. No significant differences existed between the settings in this study. Changes in IS for both settings were detected, however. Both health and non-health managers agreed on the positive relationship between IT use and the maturity of the QM programs at their organizations. For healthcare, QM maturity related to both effectiveness of IT and IT use. Team culture was positively related to IT effectiveness. Organization performance related to QM maturity and IT effectiveness as well as to satisfaction with technology. The unexpected finding was that in both settings, as QM matured, the culture relationship was less supportive, with stronger findings for the health care managers. The authors posited that with QM maturity, perhaps the culture becomes less tolerant of errors and more result-oriented rather than people-oriented.

Ball, Weaver, & Abbott (2002) described the impact of CIS installed and in use at Our Lady of Lake Hospital, Baton Rouge, Louisiana. The use of CIS was commissioned for the system's patient safety objectives. The workflow redesign that accompanied their enterprise-wide integration ensured that all clinicians had access to the clinical data repository (CDR), rules engines, and decision support tools. The functionality included wireless laptop devices that allowed nurses to use point-of-care documentation and access the data repository, electronic medical records (EMR), and a pharmacy database. The system included an ADE package (adverse event), which is a

rules package that targets the most common causes of mortality and serious morbidity. Patients are identified if they are at risk for falls, decubitus ulcers, and other potentially preventable medical errors. When one of the rule sets is compromised, the system fires an alert from the clinical documentation for protocols and sends orders simultaneously to multiple departments: dietary, central supply, nursing, respiratory, or the physician. Rules are fired when triggered by nursing or other clinician documentation.

Some of the outcomes of the CIS installation and use are that incidence of decubitus ulcers fell from 9% to less than 1%, and falls decreased from 4.45 to 3.70 per 1,000 in-patient days over a 12 month period. In February of 2002, the system added "push" technology that suggests standards of care to implement based on provider assessment of the patient. The real-time contact the providers have with the medical record via laptop or handheld device closes the loop of information.

Tucker (2003) conducted an observational study of operational failures on hospital nurses. Operational failures were defined as disruptions in information or supplies. One hundred ninety-four (194) failures were logged, with the majority involving medication or material supplies. Tucker recommended that reducing operational errors should focus on (a) designing work systems that facilitate coordination and communication between clinical workers and (b) instilling the ability in the processes to address failures that stem from other clinicians. These recommendations are design elements for CIS applications for patient safety strategies.

Computer physician order entry (CPOE) is another advanced application being adopted widely, according to interviews with system executives (Ball, 2003). Specific

results measuring outcomes either in time-series studies or randomized controlled trials (RTC) show a direct impact on preventing complications such as post-operative pulmonary embolus or deep vein thrombosis (Teich, Hurley, Beckley, & Meg, 1993). Compliance with drug monitoring and preventive care guidelines was significantly improved ($p < 0.001$) for an intervention group that received reminders of the standards (Overhage & Tierney, 1996). Two studies on antibiotic usage showed significant results for improving Vancomycin treatment ($p < 0.04$) and decrease in adverse drug events (ADEs) of dosage error ($p < 0.01$; (Kuperman & Gibson, 2003). A POE system and electronic pharmacy administration record showed significant decrease in turnaround times, elimination of transcription errors and decrease in length of stay. Interestingly, in a later study by Overhage and Tierney, computerized guidelines displayed were not found to improve adherence to the guidelines by physicians in the primary care setting. There were no intervention- control differences in quality of life, medication compliance, health care utilization, costs, or satisfaction with care (Tierney, Overhage, Murray, Harris, Xiao-Hua, Eckert, Smith, Nienaber, McDonald, & Wolinsky, 2003).

Patients are at high-risk for medication errors. Bates et al. (2001) described some of these errors and noted that technology can anticipate risk and prevent error occurrences. According to Bates et al., multiple sources of error exist: laboratory systems do not communicate directly with pharmacy, there is a lack of electronic links between medication system modules, and reliance on paper systems risks error from illegible orders and lost documentation. Poor communication among team members

also results in medication error: confusion in care assignment and loss of information in hand-off; missing pages sent by clinicians needing support; receiving orders verbally, and the inability to obtain a pharmacy consult when needed. Bates et al. indicated that these events were not usual—they were generic patterns of communication that place patients at high risk. IT solutions are available for all of these errors (Patterson, Cook, Woods, & Render, 2004).

There are now numerous technologies that have been introduced to improve safety in the pharmacy delivery area: computerized order entry (CPOE), unit-based dispensing systems, robotic unit-dose dispensing and barcoding to verify dispensing and administration of the correct medication. A survey of community hospitals (56 returned) found that 89% of the pharmacies were using at least one technology; 70 % indicated the use of three or more safety technologies (Schumock, Nair, Finley, & Lewis, 2003). One barrier wider installation of technology was lack of staff and time to administer the program. Managers who were interviewed perceived that errors had decreased and the majority (84%), thought that electronic medication administration records reduced errors the most.

A large survey of 964 hospitals (65% response rate) reported only 9.6% of the hospitals surveyed were using CPOE technology in 2002. Comments indicated that some hospitals considered themselves too small for the systems, felt they were too costly, or the order entry was still done by a clerk (Ash, Gorman, Seshadri, & Hersh, 2004).

A 2005 study (Brooks, Menachemi, Burke, & Clawson, 2005) examined the difference in adoption rates of technology that is related to improving patient safety for urban versus rural hospitals locations. Patient safety IT included pharmacy IS, CPR, nurse staffing, outcomes and quality management, pharmacy dispensing, CPOE, barcoding, decision support, PDAs, and clinician alerts. Hospitals were surveyed in Florida for the use of the safety technologies. The findings indicated that 30% of rural hospitals used the applications while 48% of urban hospitals did so. Rural hospitals had lower use of outcomes quality management, nurse staffing, clinical decision support, and bar coding for medication management. Pharmacy IS was used in the majority of the hospitals, but the differences were significant between urban and rural locations (68% vs. 93%, $p = 0.001$). Some exceptions were handheld PDAs, CPOE, and CPR.

Jiang, Friedman, and Begun (2006) studied factors associated with hospital performance, sampling data from acute care, non-federal hospitals in the United States using the Healthcare Cost and Utilization Project (HCUP) State Inpatient Databases for 1997 and 2001. Final samples contained 1,369 and 1,351 hospitals respectively. Data were combined with American Hospital Association (AHA), county level data, and AHRQ Inpatient Quality Indicators (IQI). HCUP data are administrative discharge data submitted to AHRQ by 27 volunteer states, which are used for healthcare research. The AHA data are annual survey data, an operations report submitted by health agencies, usually required and issued in combination with state oversight reporting. County data were market characteristics from the Area Resource File (ARF) and HMO County Surveyor. AHRQ data uses administrative discharge claims to screen for mortality in

common medical conditions and procedures. This study used 10 indicators: acute myocardial infarction, congestive heart failure, gastrointestinal bleeding, hip fracture, pneumonia, stroke, aortic aneurysm repair, coronary artery bypass, craniotomy, and hip replacement. Cost data were adjusted using severity of illness by APR-DRG.

The purpose of the study was to identify characteristics of the best performing hospitals on quality of care and financial measures. Hospitals were grouped into quality and cost categories, i.e. high-quality/low-cost performance. The high quality group comprised 8% of the total sample, 6.6 to 8.7 % across peers. Average mortality of the high performing hospitals was 50-60% lower than that for the worst performers. In analysis, the predictors for best performers were for-profit status, system affiliation, hospital competition, number of HMOs, and percent elderly population. The number of physicians per capita, HMO penetration, and system membership were related to the best performers for the 1997 data.

Public, teaching, or large non-teaching hospitals were significantly less likely to be among the highest performers for 2001. The positive association of hospital competition (2001) and HMO penetration (1997) with high performance was greater for public hospitals. For for-profit (2001) hospitals, HMO penetration was negatively associated with high performance; the likelihood of high performance decreased in markets with high HMO penetration. At the average level of competition, there was no significant difference between public and nonprofit hospitals. In markets with high competition, public hospitals were more likely to be high performers than nonprofits.

Overall, for-profit hospitals were more than twice as likely to be in the high

performance category compared with non-profit hospitals.

Summary of IT in Healthcare and Performance

The review of the literature has provided the beginnings of an understanding of

the purpose and management of IT in the healthcare setting. Literature from other

industries, primarily manufacturing and finance, has formed the basis for this

understanding, and studies are now generalizing to the healthcare industry. Only a few

instruments were identified that directly addressed characteristics of IT in healthcare

and can be used for developing measures to test successful management and operations.

A wealth of literature from the mid to late 1990s to 2006 describes information

technology systems, applications, and hardware implemented in various healthcare

settings. Equally numerous are articles projecting the benefits that may accrue from IT

investment, based on needs identified within the industry and on vendor descriptions of

individual applications or systems. Studies with individual applications and

departmental systems have documented positive relationships to components of the care

processes. Applications have been linked successfully with care improvements through

error reduction, decrease LOS, improved workflow, accuracy in communication, and

availability of knowledge for improving support of decisions. Only a few studies were

found that went beyond description to actual measurement of the relationships between

HIT and hospital level operations and outcomes. Measurement of the performance of IT

has, as in other industries, been slow to confirm a positive relationship to improved

productivity. The lack of effective measures, the numerous factors involved in providing healthcare, and the lack of understanding of the best implementation methods and evaluation issues were the summary reasons found for the delay. Recently, two studies of HIT have confirmed improved financial outcomes and positive relationships between HIT investment and finances, customer satisfaction and mortality. A study of medical group practice also looked at finances, finding that IT investment lowered operating costs.

There remains a lack of literature at the system level documenting hospital performance on outcomes of care and financial outcomes. Numerous reasons can be suggested that contribute to the problem, other than the difficulty of measurement. Within the application studies, there is a lack of measurement consistency in the variables chosen for study, but this may be a reflection of the cost and availability of data. This was a major reason for the development of the AHRQ quality indicators.

Merging data sets to combine organizational, financial, and operational characteristics results in the loss of valuable cases due to incomplete data, influencing the power of studies to detect relationships. Recently, several models and taxonomies have been contributed that will be useful to help organize the vast amount of literature being generated regarding IT implementation across industries. For adoption of IT in healthcare, more definitive studies are needed at the system level to show benefit prior to investment. This study has benefited from the wide variety of literature that is now available on IT and healthcare in refining the concepts important to this study: information and technology management that supports clinician access to the

knowledge to provide quality care, applications affecting prevention of error, and

performance characteristics of the relationship between IT and organizations.

Development of the Conceptual Model

The purpose of this study was to explore the relationship between IT

infrastructure and outcomes of care for the acute care hospitals. Donabedian's

framework for evaluating the quality of medical care was the theoretical basis for the

assessment of hospital performance in relationship to IT (Donabedian, 1966, 1968,

1981). The frame of the model consists of the three elements of structure, process, and

outcome (see Figure 10). All three elements were included in the measurement of
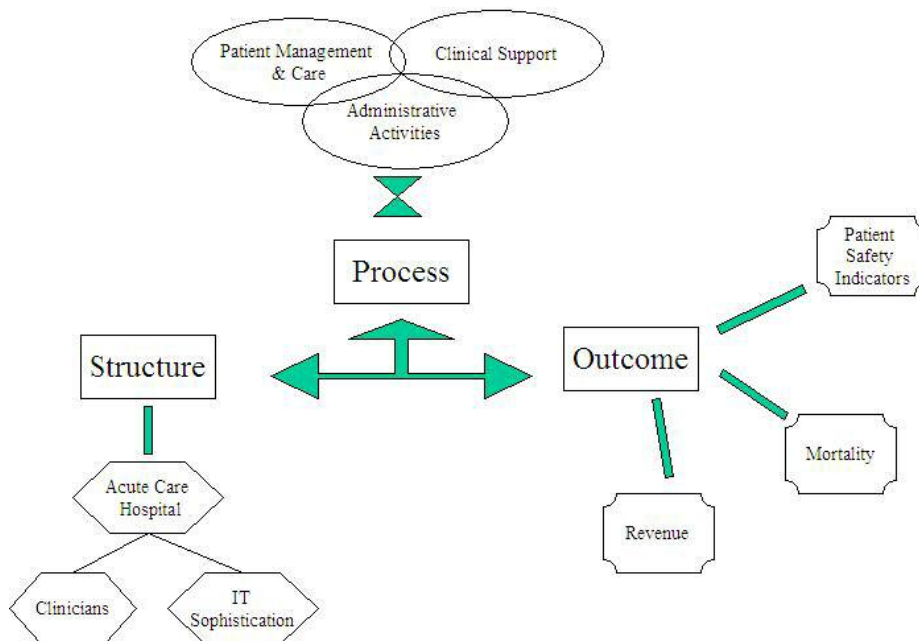
Figure 10. Conceptual framework.

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hospital performance. The model depicts the hospital structure and process components that support clinical and management activities to deliver patient care outcomes.

Nolan and Wetherbe's MIS model (Nolan & Wetherbe, 1980) provided the conceptualization of the way that structure and process models for information management can be superimposed on a model for conceptualizing health care activities. The vital ingredients in both, data-information-knowledge, follow a parallel course to produce the desired outcomes. Information and knowledge outcomes are achieved by MIS by building the appropriate IT infrastructure and following sound management processes. The information product feedback is used to improve both structure and processes of information management within the organization. In the healthcare quality model, the outcomes of care are considered to be high quality when the structures and resources of the healthcare setting are provided and the processes are followed by the care providers and their supporting clinical departments. Outcomes feed back to improve both structure and care processes to improve the quality of care.

The first healthcare model element, s*tructure,* refers to the resources and setting used to provide the healthcare. The acute care hospital setting, clinician resources, and IT infrastructure are the structural components. The clinician resources (i.e. provider staffing, types of roles, and experience with computers) are necessary components of the structure element in the model; these relationships were assumed. IT infrastructure completes the structure components as the hospital component of interest. The instrument, Information Technology Sophistication in Healthcare (Guy Pare & Sicotte,

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2001), is used to measure the maturity characteristic of the hospital IT infrastructure, the predictor variable.

The literature review provided the conceptual linkage between computer resource development in organizations and the affect on the processes used by administrators and clinicians in hospitals (Benbasat et al., 1984; Saunders & Keller, 1983). Measures of the maturity of IT infrastructure were developed and tested, with positive relationships between user tasks, communication between users, profiles of IT applications, and organizational performance and structure (Raymond & Pare, 1992; Raymond et al., 1995; Saunders & Keller, 1983). These relationships were adapted and tested in the hospital setting by Pare, Sicotte and Jaana (2001, 2005).

The model element of *process* refers to the care activities of the medical care team and the patient actions. The development of the IT sophistication instrument as described in the literature provided the conceptual linkage between HIT and the model elements of structure and process. The measurement of IT sophistication in hospitals was divided into three domains: administrative, patient management and care, and clinical support (Guy Pare & Sicotte, 2001). These domains describe the process activities involved with the total care of the patient in an acute care hospital setting. The IT sophistication instrument measures the domains separately to better describe and discriminate between the applications and hardware that support each type of activity.

The recent pilot of the CIT Index by Amarasingham, et al. (2006) links patient care processes such as monitoring, decision support, order entry, and data sharing to physician user constructs. The pilot showed a positive relationship between more

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advanced automation of care processes (a proxy for maturity) and higher physician rating of the technology supporting their patient care.

The IT sophistication instrument measures integration of information across the administrative and clinical domains, adding a further dimension to the affect of IT maturity in supporting the structure and process elements. Integration of IT facilitates and supports the interaction of hospital structure and care processes as depicted in the model, based on the conceptual development of the IT Sophistication instrument (Guy Pare & Sicotte, 2001). The later instrument described by Burke and Menachemi (2004) also explores clusters of IT and their function within organizations, including the integration concept.

The third element of the model, *outcome*, is the result of the care to the health of the patient and financial outcomes. The literature review provided numerous financial measures for performance of organizations. Unlike other industries, measuring ROI is difficult when the product is patient care. Devaraj and Kohli (2000) explained why one of the best financial productivity measures for hospitals was patient revenue. These revenue measures were used in an early 2006 study by Menachemi, et al. that confirmed a positive relationship between revenues and higher IT use. Patient care outcomes used in prior studies were in-hospital mortality and patient satisfaction. The use of the AHRQ quality indicators as an outcome measure, predicted by IT maturity, was introduced in this study.

The control variables for the model include the hospital organizational characteristics that may influence the availability of IT or the performance of IT in the

hospital setting. A number of organizational factors are frequently included in the empirical literature on hospital performance: hospital bed size, occupancy rate, teaching status, ownership types, metropolitan location, membership in an integrated system, and inpatient composition such as percentage of Medicare and Medicaid cases (Daniel E. Burke & Menichemi, 2004); (Devaraj & Kohli, 2000); Kim, 2004; Menachemi, et al., 2006). Availability and use of IT has been found to be related to size of hospitals, measured in number of beds (D.E. Burke et al., 2002; Devaraj & Kohli, 2000; Menachemi, Burke, & Brooks, 2004; Sobol et al., 1999; Sobol, Humphrey, & Jones, 1992). Urban and teaching status of hospitals have also been related to hospital size, as most teaching hospitals are large and located in urban areas. Financial outcome studies related to IT have also used casemix, overall profitability, IT labor, and capital as organizational factors to consider in analysis (Devaraj & Kohli, 2000). Hospital ownership (public vs. private) has been shown to influence the cost-consciousness of administrators and may influence adoption of costly technologies, including IT (Sobol & Woods, 2000).

CHAPTER 3

METHOD

Research Model Overview
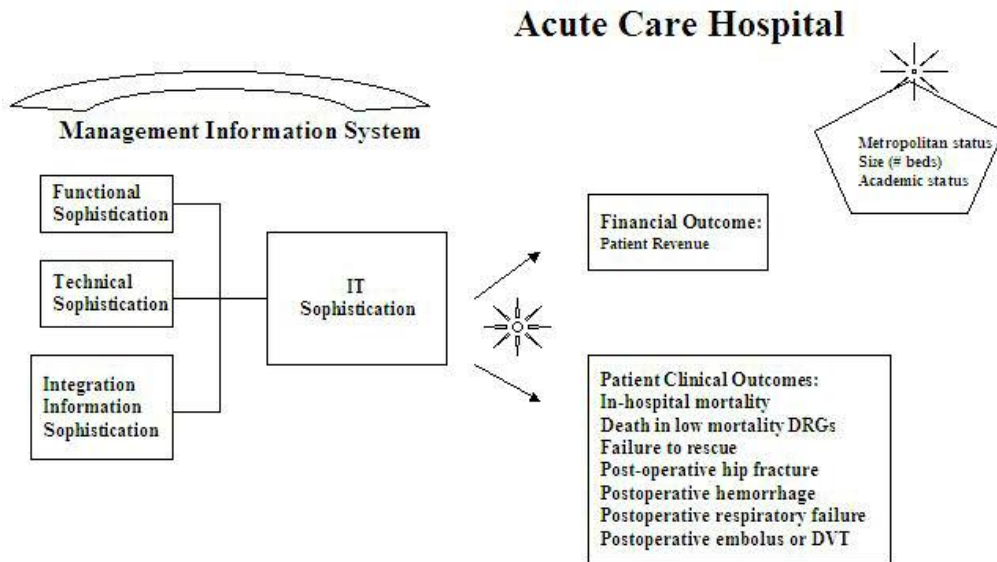
Figure 11. Research model of IT sophistication and hospital outcomes.

The research model depicted in Figure 11 includes the predictor, response, and control

variables used to answer the research questions. This study explored the relationship

between IT sophistication (maturity) of acute care hospitals (predictors) and hospital

performance (response). Three components of IT sophistication: functional, technical,

and information integration, as well as a composite index, were the maturity metrics used. Hospital performance was evaluated using quality of patient care and financial outcomes. Measures of the quality of patient care included in-patient mortality and screening indicators of patient safety. Patient revenue was the measure of hospital financial outcomes. Control variables were metropolitan status, hospital size (number of beds) and academic status.

Healthcare is an information dependent industry, not only for business resource and strategic planning, but also at the point of patient care. At the bedside, the quality of patient care given is dependent on the quality of the information available to make treatment decisions. Hospital information technology (HIT) provides that information to the clinicians and administrators to complete tasks of patient care efficiently, effectively, and safely.

Management information systems (MIS) support the information needs of the healthcare team in processing, managing, and communicating information (Vassilacopoulos & Paraskevopoulou, 1997). As healthcare organizations adopt the latest advances in technology for patient diagnosis and treatment, re-learning occurs, and work processes become more complex, with new demands for information new demands on the healthcare team. Management IS must respond with a more sophisticated communication and networking infrastructure (Holland & Light, 2001; Saunders & Keller, 1983). This study explored the relationship between the sophistication of HIT and the hospital's outcomes of care. Table 4 presents the variables used in this study to explore that relationship and the source information for the

Table 4. *Study Variables and Source Documentation*

Predictor Variable	Definition	Literature citations	Metrics
IT sophistication	Diversity of technological devices and software application used to support patient management and patient care, clinical support and administrative activities.	(Jaana et al., 2005); (Guy Pare & Sicotte, 2001); (Raymond & Pare, 1992)	Linear scale 0-100; survey
Functional Sophistication	The proportion and diversity of processes or activities available in the clinical area as a function of the IT. Domains assessed: patient management, patient care, clinical support.	(Jaana et al., 2005); (Guy Pare & Sicotte, 2001); (Raymond & Pare, 1992)	Linear scale 0-100; survey
Technical Sophistication	The diversity of the hardware devices used by hospital IT. Domains assessed: patient management, patient care, clinical support.	(Jaana et al., 2005); (Guy Pare & Sicotte, 2001); (Raymond & Pare, 1992)	Linear scale 0-100; survey
Information integration Sophistication	The extent that computer based systems can exchange information with each other internally and with external applications.	(Jaana et al., 2005); (Guy Pare & Sicotte, 2001); (Raymond & Pare, 1992)	Likert scale, 1-7: survey
Response Variable	Definition	Literature citations	Metric
In-hospital mortality	Number of deaths per all discharges per reporting period; observed rate; no risk-adjustment	(Texas Department of State Health Services, 2004)	Rate calculated from discharge claim file
PSI 2 Death in low mortality DRGs	In-hospital deaths per 1,000 patients in DRGs with less than 0.5% mortality. Excludes for any code for trauma, immunocompromised, and cancer patients. Risk adjusted for age, sex, DRG, comorbidity. Observed rate used.	DHHS, 2003; (Hannan, Bernard, O'Donnell, & Kilburn, 1989)	Rate calculated from discharge claim file

Table 4 - continued

PSI 4 Failure to rescue	Deaths per 1,000 patients having developed specified complications of care during hospitalization. Excludes patients' age 75 or older, neonates in MDC 15, patients admitted from long-term care facility and patients transferred to or from other acute care facility. Specific exclusions to each diagnosis. Risk adjusted for age, sex, DRG, comorbidity. Observed rate used.	DHHS 2003; (Needleman et al., 2002); Silber, et al. 1992;	Rate calculated from discharge claim file
PSI 8 Postoperative hip fracture	Cases of in-hospital hip fracture per 1.000 surgical discharges with an operating room procedure. Multiple exclusions, MDC 8, 14 and principal dx of hip fracture or secondary dx with risk of fracture increased. Risk adjusted for age, sex, DRG, co-morbidity. Observed rate used.	DHHS, 2003	Rate calculated from discharge claim file
PSI 9 Postoperative hemorrhage or hematoma	Cases of hematoma or hemorrhage requiring a procedure per 1,000 surgical discharges with an operating room procedure. Excludes obstetrical patients in MDC 14. Risk adjusted for age, sex, DRG, comorbidity. Observed rate used.	DHHS, 2003.	Rate calculated from discharge claim file
PSI 11 Postoperative respiratory failure	Cases of acute respiratory failure per 1,000 elective surgical discharges with an operating procedure. Excludes patients with respiratory, circulatory diseases and obstetric patients in MDC 14. Risk adjusted for age, sex, DRG, comorbidity. Observed rate used.	DHHS, 2003; (Iezzoni, Davis et al., 1999); (Needleman et al., 2002)	Rate calculated from discharge claim file
PSI 12 Postoperative PE or DVT	Cases of deep vein thrombosis (DVT) or pulmonary embolism (PE) per 1,000 surgical discharges with an operating room procedure. Excludes obstetrical patients in MDC 14. Risk adjusted for age, sex, DRG, comorbidity. Observed rate used.	DHHS, 2003	Rate calculated from discharge claim file
Net patient revenue	Estimated net realizable amounts from patients. Medicaid disproportionate share payments, third-party payers and others for services rendered, including estimated retroactive adjustments under reimbursement agreements with third-party payers.	(Texas Department of Health, 2002)	Revenue reported; annual AHA survey

Table 4 – continued

Net patient revenue per day	Ratio of the net patient revenue realized by the number of days in the period under consideration	(Devaraj & Kohli, 2000)	Ratio using AHA survey reporting
Net patient revenue per admission	Ratio of the net patient revenue realized by the number of admissions in the period under consideration	(Devaraj & Kohli, 2000)	Ratio using AHA survey reporting

Control Variable	Definition	Literature citations	Metric
Metropolitan status	Metropolitan versus rural location	(Texas Department of Health, 2002)	Binary, survey
# Beds – hospital size	General medical-surgical care beds: provides acute care to patients in medical and surgical units on the basis of physician's orders and approved nursing care plans	(Texas Department of Health, 2002)	Count; survey
Academic status	Coded from facility type: academic vs. non-academic	(Dorenfest, 2002)	Binary; application data; dummy coded

measures. Additional characteristics of the hospital sample were measured because of the interest in the way that hospitals perform on the sophistication measures.

Population and Sample

The population for the study was acute care hospitals. The sample of Texas hospitals was obtained from the Dorenfest Integrated Health Care Delivery System (IHDS) Database (Dorenfest, 2002). The IHDS database extraction for Texas included IS data from 272 acute care facilities that voluntarily submitted IS data to the Dorenfest Corporation for the year 2002. Two additional datasets provided the demographic and outcome data and were obtained from public use files provided by the Texas state data

center. The Dallas Fort Worth Hospital Council (DFWHC) provided the Agency for

Healthcare Research and Quality (AHRQ) PSI public use file in response to the

researcher's request. The final sample included 175 Texas acute care hospitals after

datasets were merged and cleaned.

<div align="center">The Data Sets</div>

<div align="center">*Dorenfest Integrated Health Care Delivery System (IHDS) Data*</div>

The IT database, a market intelligence product, has been collected by Sheldon

Dorenfest & Associates, a corporate research firm, for the past 10 years. The database

was made available by the Health Information and Management Systems Society

(HIMSS;(HIMSS Foundation, 2005). A HIMSS Foundation, The Dorenfest Institute for

Health Information Technology (HIT) Research and Education, approves requests for

use of the Foundation's HIT databases.

The Dorenfest 3000 Database tracked U.S. community acute care facilities on an

annual basis. The purpose of the database was to reflect automation changes in the

healthcare industry. The data tracking Texas hospitals was extracted from this market

product for the year 2002. This was the latest year available. Data tables provided

demographics and individual hospital IS profiles. The data were also used to validate

the other demographic and operations data obtained from the Texas state sources. Data

sources for the IHDS included the original Dorenfest 3000 database, research,

interviews, and surveys of planning, marketing and IS officers of the IHDS. Interviews

were supplemented by web site searches, marketing materials, and other resources.

Assumptions made by Dorenfest were that every hospital was an integrated system,

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providing health care services to a defined population and service area. Short-term, acute care, non-federal facilities with 100 beds or more were selected for inclusion in the IT product (Dorenfest, 2002).

Annual Survey of Hospitals

Demographic and financial data were obtained from the 2002 Annual Survey of Hospitals, a combined questionnaire given to all licensed hospitals from the Texas Department of Health (TDH), the American Hospital Association (AHA), and the Texas Hospital Association (THA). The original raw data extraction included data for 208 acute care hospitals. Hospitals report annually for compliance oversight to TDH. The survey aggregates financial, utilization, and other operating and demographic data per individual hospital. All hospitals were included in the Annual Survey of Hospitals, and the data were complete.

Mortality and AHRQ Patient Safety Indicators (PSI)

The mortality and PSI file was built from 2002 Texas hospital discharge data on administrative claims, submitted to the state by legislative requirement. All hospitals except those owned by the federal government are required to submit data unless otherwise exempted. Some rural providers are exempted after the state approves an exemption request. Rural providers are those defined by limited county population (less than 35,000) or with limited licensed beds (100 or less), meeting certain ownership requirements and not located in an urbanized area, as determined by U.S. Bureau of the

Census. The administrative data are analyzed by the AHRQ PSI algorithm, and rates are computed. The original PSI dataset contained PSI data for the 23 PSI indicators for 439 hospitals.

IT Sophistication

Hospital IT sophistication was the predictor, measured on three dimensions: functional, technical, and integration of information, with a composite index as well (Guy Pare & Sicotte, 2001). *Functional sophistication* refers to the support of healthcare processes or activities by computer-based applications (Guy Pare & Sicotte, 2001). Daily care of the patient is accomplished through the activities of the health care team. Examples of activities include nurses taking vital signs, nurses giving medications, physicians dictating reports, and staff doing scheduling. *Technical sophistication* is the hardware technology used, for example: barcoding for medication or identification bracelets, medical imaging such as ultrasound, wireless networks and handheld computers, and radiology equipment for sending digital images over networks. The *sophistication of information integration* is the extent to which the computer-based applications are integrated, internally and externally (Guy Pare & Sicotte, 2001). For example, well-integrated database systems containing patient data (either interfaced or shared in common) allow clinicians to access patient information across departments. The ability to review a patient's recovery progress by obtaining lab results, viewing post-operative chest images, or viewing the nursing flowsheet to check vital signs or medications administered is an example of internal integration within and

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across departments. External integration might involve having access to the Internet to download literature on a best practice for wound care or using a telemedicine system to consult with a nurse practitioner in a rural clinic. The *composite index of sophistication* includes scoring for all three clinical dimensions.

<center>*IT Sophistication Framework and Instrument*</center>

The framework included three core activity domains: patient management and care, clinical support, and administrative activities (see Fig. 12). The administrative domain was not included in this study. The three dimensions of sophistication (functional, technical, and integration of information) were measured
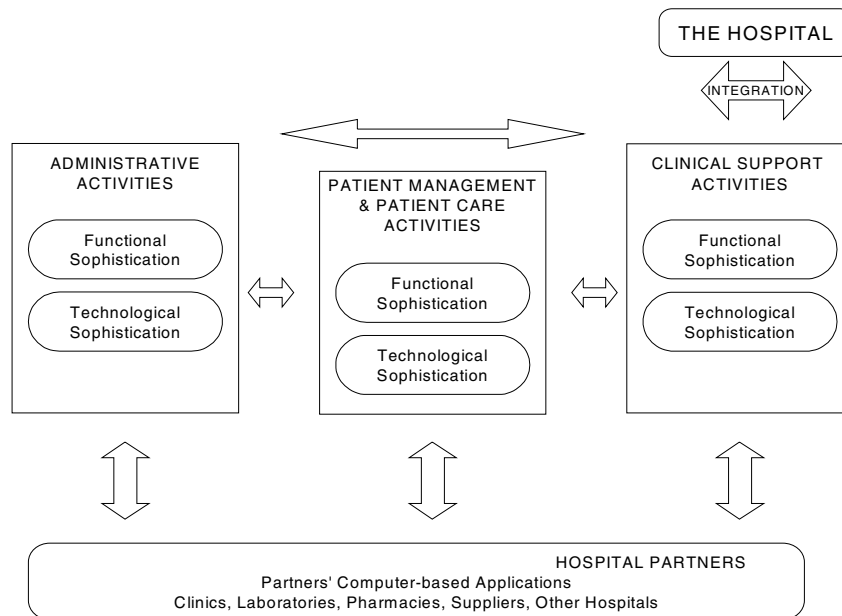
Figure 12. IT sophistication framework in hospitals. From "Information Technology Sophistication in Health Care: An Instrument Validation Study Among Canadian Hospitals," by G. Pare and C. Sicotte, 2001, *International Journal of Medical Informatics, 63,* p. 208. Copyright 2001 by the Management Information Systems Research Center of the University of Minnesota. Reprinted with permission.

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across the two remaining clinical domains. The applications and IS technical hardware tables that were available in the information profile database dictated the measurement of the domain activities. Table 5 provides a summary of the applications and hardware mapped from the IT database to the IS sophistication domains. A linear scoring tool was developed to score each domain individually and calculate a summary score for each dimension of sophistication. The denominator for each domain activity was the total number of applications and hardware elements tracked in the IT database. Each element of application/hardware was assigned one point. The numerator was the total number of application/hardware elements in use by the hospital. The decimal score was then multiplied by 100 to obtain a linear score that ranged from 0 to 100. For instance, for functional sophistication, Hospital A used 3 of the 3 applications for patient management; 6 of the 7 applications for patient care, and 4 out of 4 applications for clinical support. The total denominator was 14, with total numerator of 13, for a functional sophistication score of 93. Measures of technological and integration sophistication were obtained in a similar manner. An overall sophistication score was obtained by adding the total applications/hardware elements in use and dividing by 31, the total possible applications/hardware elements tracked by the hospitals for the three dimensions of sophistication. Each sophistication dimension was equally weighted; the literature did not offer support to apply unequal weights.

Table 5. *Domain Activities Measured for Sophistication Dimensions*

Sophistication Dimension	Domain Activity	Application or Hardware Description
Functional	Patient Management	Patient registration, scheduling, patient index
	Patient Care	Order entry, results reporting, clinical documentation, outcomes & QM, nurse staffing, OR system, ER system
	Clinical Support	Pharmacy dispensing, Pharmacy administration, laboratory system, radiology system

Total Number of applications/hardware (denominator) = 14

Technological	Patient Management	Barcoding, document imaging
	Patient Care	MD: clinical decision support, dictation, handhelds, transcription
		RN: unit, ICU bedside computers, handhelds
	Clinical Support	PACs, telemedicine imaging, handhelds

Total Number of applications/hardware (denominator) = 12

Integration of Information	Computerized Medical Record
	Intranet, Internet
	Enterprise Resource Planning
	Nolan System Integration (Network, Integration Engine)

Total number of integration items (denominator) = 5

Total Number of applications/hardware for composite (denominator) = 31

Reliability was measured using Chronbach's alpha coefficients of internal consistency. The functional sophistication domain consisted of 14 items, with alpha = .57. The technological domain consisted of 9 items, with alpha = .57. Integration of

information domain consisted of 5 items, with alpha = .46. Overall composite

sophistication included the total of 31 items, with alpha = .75.

Hospital Outcome: Mortality

Mortality is expressed as a rate: the number of deaths (numerator) divided by the

number of discharges for the time period under study (denominator). The mortality data

used were observed rates calculated from data coded for all diagnosis related groups

(DRGs); there were no data exclusions. Risk-adjusted mortality data that adjusts for

characteristics of the hospital population was not available for study. Because the task

of this study was exploring relationships at the aggregate level, this was not a major

concern. The assumption was made that using the raw data without risk adjustment

would not bias the analysis. This measure was used to address Research Question 1—Is

there a relationship between the IT sophistication of acute care hospitals and in-hospital

mortality?

Hospital Outcome: Patient Safety Indicators (PSI)

The Patient Safety Indicators (PSI) used in this study were calculated using an

algorithm developed by AHRQ to create a set of in-hospital screening measures of

complications, based on discharge administrative data. The data used to develop the

PSIs were obtained from administrative discharge claims reported by acute care

hospitals to the Texas state data center for the year 2002. The indicators are measured as

rates: the number of complications (numerator) divided by the number of admissions

for the procedure or condition (denominator; (U.S. Department of Health and Human Services, 2003a).

<center>*PSI Development*</center>

The Agency for Healthcare Research and Quality (AHRQ) developed 23 PSIs to be used at the provider (hospital) level (U.S. Department of Health and Human Services, 2003b). This study used 6 of the 23 safety indicators, chosen based on the stability and validity of the measures as documented by the AHRQ development process and by additional literature published following release of the 2005 PSI revision. The development was discussed in detail in the literature review.

<center>*Considerations in Using the PSIs*</center>

A SPSS™ computer software module developed by AHRQ was used to analyze the hospital administrative data and produce the PSIs. The software generates observed, risk-adjusted, and smoothed rates (i.e. reliability adjusted) for the provider indicators. Observed rates are the raw rates and are considered the baseline measure of performance. Risk-adjusted rates are derived from applying the average case mix and rates of a file from the Healthcare Utilization Project, year 2003, State Inpatient Data (SID) for 27 states—this database reflects a large proportion of the U.S. hospitalized population. Overall means and regression coefficients from the baseline database are applied to the observed rates in the risk-adjustment process. The risk-adjusted rates then reflect the age, sex, modified DRGs, and comorbidity distribution of data in the baseline file, rather than the distribution for each hospital. After risk adjustment, the rates reflect

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provider performance as if each provider had the average case mix in the sample (U.S. Department of Health and Human Services, 2003a, p. 17). This study used both the observed (raw) rates and the risk-adjusted rates in the analysis to obtain the best distribution fit prior to analysis.

PSI 2: Death in Low Mortality DRGs

This indicator identifies in-hospital deaths that are unlikely to occur when admitted for certain conditions or procedures. The diagnosis related groupings (DRGs) of these conditions or procedures have been shown to have a mortality of less than 0.5 percent. The assumption is that mortality for these DRGs results from error. This indicator excludes cases that are at high risk of mortality: patients with trauma, those that are immunocompromised, and cancer patients. The indicator is risk-adjusted for age, gender, DRG, and comorbidity. The definition of the indicator is in-hospital deaths per 1,000 patients in DRGs with less than 0.5 percent mortality (U.S. Department of Health and Human Services, 2003b). This measure was used to address Research Question 2—Is there a relationship between the IT sophistication of acute care hospitals and PSI 2, death in low mortality DRGs?

PSI 4: Failure to Rescue

This indicator screens for deaths (per 1,000 patients) that have occurred as a result of a complication of care. The source of this indicator (Silber et al., 1992) suggests that better hospitals are able to prevent death in patients that have

complications. This indicator is risk adjusted for age, gender, DRG, and comorbidity categories (U.S. Department of Health and Human Services, 2003b). This measure was used to address Research Question 3—Is there a relationship between the IT sophistication of acute care hospitals and PSI 4, failure to rescue?

PSI 8: Post-operative Hip Fracture

This indicator measures cases of in-hospital hip fracture after surgery (per 1,000 surgical discharges). Patients with conditions suggesting that a fracture is present on admission and obstetrical patients are excluded (U.S. Department of Health and Human Services, 2003b). Failures in processes of care were high in this complication for both surgical and medical cases. This indicator is risk adjusted for age, gender, DRG, and co-morbidity categories. This measure was used to address Research Question 4—Is there a relationship between the IT sophistication of acute care hospitals and PSI 8, postoperative hip fracture?

PSI 9: Postoperative Hemorrhage or Hematoma

This indicator screens for hematoma or hemorrhage after a procedure requiring a surgical repair (per 1,000 surgical discharges). Surgical cases with this complication indicate failure to follow professional guidelines (Iezzoni, Davis et al., 1999). This indicator is risk adjusted for age, gender, DRG, and comorbidity categories and excludes obstetric cases (U.S. Department of Health and Human Services, 2003b). This measure was used to address Research Question 5—Is there a relationship between the

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IT sophistication of acute care hospitals and PSI 9, postoperative hemorrhage or hematoma?

PSI 11: Postoperative Respiratory Failure

The acute respiratory failure screening identifies cases of respiratory failure after surgery (per 1,000 elective surgical discharges). Patients with respiratory diseases, patients with circulatory diseases, and obstetrical patients are excluded. Both process failures and staffing evidence were found to be associated with this complication (Iezzoni, Davis et al., 1999; Needleman et al., 2002). The indicator is risk adjusted for age, gender, DRG, co morbidity categories (U.S. Department of Health and Human Services, 2003b). This measure was used to address Research Question 6—Is there a relationship between the IT sophistication of acute care hospitals and PSI 11, postoperative respiratory failure?

PSI 12: Postoperative PE or DVT

This indicator identifies cases of deep vein thrombosis (DVT) or pulmonary embolism (PE) after surgery (per 1,000 surgical discharges). Process of care failures were found for both surgical and medical cases with this complication (Iezzoni, Davis et al., 1999). Nurse staffing effects were contradictory, with one study finding staffing was not related to lower rates of DVT or PE (Needleman et al., 2002) and another finding that increased RN hours and non-RN hours are both related to lower incidence of DVT/PE after major surgery (Kovner & Gergen, 1998). This measure was used to

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address Research Question 7—Is there a relationship between the IT sophistication of acute care hospitals and PSI 12, postoperative PE or DVT?

Hospital Outcomes: Financial

The variable used to measure financial outcome included patient revenues, which were adjusted for number of days and number of admissions in the annual reporting period to remove bias for either factor (Devaraj & Kohli, 2000); see Table 3.1). The organizational impact of IT on financial outcomes for industry has been measured most often using total costs, profitability, return on investment, revenue growth, sales, and assets (Bharadwaj, 2000); (Byrd, Thrasher, Lang, & Davidson, 2005); Hitt, 1994; (Mahmood & Mann, 1993); (Sircar et al., 2000). Most industries rely on cost and profit margins to measure improvements or a competitive edge to their business performance. Profit and cost measures are difficult to obtain for use in healthcare for several reasons: (a) hospitals use cost to charge ratios (RCC) to determine the cost of services; RCC is a transformation of revenue and not a direct reimbursement measure; (b) costs are affected by contractual agreements that give discounts and charity write-offs; and (c) managed care contracts change the ways that profits and expenses are calculated and complicate comparison (Devaraj & Kohli, 2000).

In contrast to cost and profit measures, revenues are not affected by these factors. The AHA data included revenues by payers, separated by hospital system components (acute vs. long-term care facilities). Patient revenue, including disproportionate share, is separated from other revenues collected by the hospitals for

operations other than patient care. Disproportionate share (Dispro or DSH) are payments from the Medicare and Medicaid programs, combined with state matching, to help offset the care given to low-income patients that is uncompensated. Safety-net hospitals, such as the hospital districts established in Texas, and rural hospitals are the low-income providers. The Dispro payments represented two-thirds of the $22.3 billion in uncompensated care costs reported by hospitals in 2002 (National Health Policy Forum, 2004, p.3). Net patient revenue per day and net patient revenue per admission were calculated for the current study. This measure was used to address Research Question 8—Is there a relationship between the sophistication of the IT infrastructure of an acute care hospital system and the hospital's patient revenues?

Controlling for Organizational Characteristics

Performance of hospitals associated with IT investment may be affected by organizational characteristics, as well as differences in operations and process changes made in preparation for IT implementation. The literature supports controlling for the following variables for hospital level studies: labor intensity (FTE), payer type, profit status, urban vs. rural location, teaching/academic status, and bed size (D.E. Burke et al., 2002); (Devaraj & Kohli, 2000); (Jaana et al., 2005); Sobol, 2000; Sobol, et al., 1992). The data available in the AHA annual hospital survey for 2002 and used in this study included ownership, metropolitan vs. rural location, and bed size. The academic status was obtained from the Dorenfest computer application database, recoded from facility type.

Manipulation of the Data

IT Sophistication Variables

The IT sophistication variables were created using the 2002 Dorenfest IHDS dataset and the IT Sophistication in Health Care instrument developed by Pare and Sicotte (2001). Published validation studies of this instrument included tables and discussion of the three sophistication dimensions (functional, technological, and integration) with examples of the healthcare domain activities measured in hospital IT (Jaana et al., 2005; Guy Pare & Sicotte, 2001). A copy of the survey instrument and permission for use in this study was obtained by email communication with the primary author (Guy Pare, 2002). This instrument was used as the model; the inclusion of actual items depended on the retrospective data available.

The Texas hospital IT application and hardware data were mapped to the two clinical activity domains, patient management and care and clinical support, based on the literature and the model instrument. See Table 6 for the data used in the mapping process. The mapping framework was reviewed by the principal author of the second study (Jaana et al., 2005). Valuable feedback helped clarify how to operationalize the sophistication constructs using the secondary data and to refine the mapping methods (Jaana, 2006). After eliminating hospitals that did not have matching Dorenfest data for the outcome datasets, IT sophistication scores were calculated for 182 Texas acute care hospitals.

Table 6. *IHDS Tables with Breakdown of Application and Hardware*

Type of Data	Name of Table	Variables
Demographics	IHDS facility information IHDS facility look-up IDHS main table	Facility name, ID, city, bed size (staffed), type facility
Information system details	IHDS facilities application IHDS hardware(handheld) IHDS hardware table IHDS information system IHDS networking & integration IHDS technology Other IS applications Patient safety applications Patient safety initiatives	Application and hardware data for mapping to IS Sophistication instrument

Applications and Hardware tracked (only those included in study)		
Patient registration Patient scheduling Enterprise resource planning Clinical decision support Outcomes & quality management	Computerized medical record Master patient index Transcription Clinical documentation Emergency department Intensive care (critical care bedside computers) Dictation	Laboratory Pharmacy Pharmacy dispensing Point of care (medsurg bedside computers) Radiology PACS Surgery Telemedicine

Outcome Datasets: Mortality, PSIs, and Patient Revenues

The three datasets for demographics and outcome variables were merged to the

IT data to give a final data file for 182 acute care Texas hospitals. Hospitals were

removed after merging the IT, AHA and PSI datasets when application and outcome

data were not present across all three sets. Hospitals with duplicate AHA data were also

removed. The duplication occurred with merging of the AHA and PSI data. The state

data center assigns a new state hospital ID when hospitals are bought or sold; the PSI data had been calculated on partial year discharges. Specialty service hospitals serving solely pediatric and obstetric populations (n = 7) were removed to leave 175 hospitals for data analysis.

Data Analysis

Data were analyzed using Minitab, Release 14 for Windows and SPSS for Windows, release 10.1.3, for all research questions. There were no missing data for IT sophistication scores. For the outcome data sets, missing data were identified by Minitab, and the cases were deleted from that specific statistical test. Missing data were not replaced. For the PSI measures, rates with fewer than 30 cases in the denominator were assigned a missing data code to delete them from the analysis.

All variables of the model were assessed for normality (modality, symmetry, and kurtosis). The distributions were examined using histograms and statistics for skewness and kurtosis. Boxplots were used to identify outliers. Normality was tested using Anderson-Darling (AD) Normality, an empirical cumulative distribution function based test; a modification of the Kolmogorov-Smirnov (K-S) test. Thirteen variables were assessed, and all but two had significant p values (less than 0.10) for underlying non-normality. Box-Cox transformations were attempted unsuccessfully to fit the remaining 11 variables to a distribution. The IT sophistication measures were all negatively skewed, with the largest coefficients from functional sophistication (-0.86) and integration sophistication (i.e. higher sophistication scores). Both technical and

integration sophistication and the composite sophistication measure were distinctly bimodal, which accounted for the platykurtic distribution. The flat distribution for integration, however, was probably influenced as well by the few items that comprise the score. After two outliers (very low scores) were removed, functional sophistication developed a negative kurtosis coefficient and a slightly flatter distribution. Using histograms with AD test and skewness coefficients as guides, outliers were identified and removed if appropriate, and the measures were retested. Data were rechecked to assure that they were error free. During instrument scoring, the researcher identified low scores across the sophistication measures, earned by the same hospitals; these may be an indication of multivariate outliers (Pett, 1997). The sophistication measures remained non-normal ($p < 0.005$) but with less negative asymmetry (-0.003) to (-0.49) after removing outliers.

Logarithmic transformations were used successfully to obtain better fits to the normal distribution for most of the outcome variables. After eliminating the worst offending outliers, transformations were performed and the variables were re-tested. Patient revenue (by day) obtained the best fit ($p = 0.035$) with moderate skew (-0.39). The PSI measures had mild positive and negative skew, with three of the six meeting normal AD criteria for normal distribution after log transformations.

All linear regression test results were checked for goodness-of-fit using ANOVA and Anderson-Darling test statistics. The regressed model was rejected if the underlying distribution was rejected as non-normal at significance level 0.10.

Frequencies, means, and standard deviations were computed to describe the hospital sample and the IT sophistication variables. Descriptive statistics were computed in order to determine relationships between the hospital organizational and operational characteristics and the IT measures. The organization and operation variables were regressed on themselves to determine if any significant collinearity existed. The sophistication measures were tested for interaction among the dimensions. T-tests for hospital characteristics and Pearson correlations for sophistication measures were computed.

Protection of Human Participants

This research was considered exempt from review for human research protection. The data sets were secondary data and available for public use without human participant identifiers. The exempt status was obtained from the Institutional Review Board of the University of Texas at Arlington.

CHAPTER 4

PRESENTATION, ANALYSIS, AND INTERPRETATION OF DATA

This chapter presents the demographic information describing the hospital

sample, analysis of the data, and findings related to the eight research questions.

Description of the Sample

Summaries of acute care hospital characteristics are given in Tables 7 and 8.

Table 7 gives frequency data for the participating hospitals. The majority of the 175

participant hospitals were non-profit hospitals located in metropolitan areas. A small

number were government owned, with 11 academic teaching hospitals.

Table 7. *Hospital Sample Characteristics—Frequency Data*

Variable (n = 175)		Frequency	Percent
Metropolitan status			
	Metro	134	77
	Non-metro	41	23
Academic status			
	Academic	11	6
	Non-academic	164	94
Ownership			
	State, city-county	6	3
	Hospital authority	22	13
	Non government: Not for profit	80	46
	For profit	67	38

Table 8 shows data for hospital internal operations stratified by metropolitan status. Medicare dollars accounted for 27.6 % of total revenues, and Medicaid revenues accounted for 11.9%. The hospitals were compared by metropolitan location and academic status, and significant differences were found in hospital size (number of beds) and corresponding number of admissions and revenues generated. Hospitals designated as academic had a significantly higher number of staffed beds ($M = 381$, $SD = 258$), admissions ($M = 19652$, $SD = 10517$), and total revenue ($M = \$326$ million, $SD = \$227$ million). Pearson correlations were positive between metropolitan location, academic status, and hospital size ($p \leq 0.002$).

Table 8. *Descriptive Statistics by Metropolitan Status*

Status	Number of acute care admissions		Total number of beds		Total revenue[a]		Medicare net[a]		Medicaid net[a]	
	M	SD	M	SD	M	SD	M	SD	M	SD
Metropolitan	12061	9575	245	200	$161	$174	$43	$44	$20	$43
Non-metropolitan	4109	4440	95	94	$45	$60	$15	$19	$3	$3

Note. [a] Dollar figures are reported in millions of dollars.

The acute care hospitals that were included in the sample were compared to those not included because of missing data, (primarily the IT profile report). The results showed significant differences. The AHA data were used to study the demographic differences between the groups. The total number of hospitals (N = 365) with complete

AHA data for this analysis included 190 hospitals not eligible for the study sample, compared to the final sample of hospitals that were included (n = 175). Significant differences (*p* = 0.000) were present for metropolitan location, number of acute care beds, and profit and government status (see Table 9).

Table 9. *Comparison of Sample Hospitals to Non-Sample Hospitals*

Variable	Metropolitan location	Mean number of acute care beds	Nonprofit operation	Government ownership
Sample hospitals (N = 175)	76.5%	109	64.0%	10.8%
Non-sample hospitals (N = 190)	36.8%	48	82.1%	56.8%

IT Sophistication Scores

Figure 13 presents boxplot data for the IT sophistication scores. The distributions for the variables functional sophistication (FUNCT) and integration of information (INTEG) were negatively skewed. The scores for the variable technology sophistication (TECH) were positively skewed, with median = 25. Several outliers (low scoring hospitals) in both technology sophistication and integration of information accounted for the asymmetry. Histograms of the sophistication scores showed bimodal characteristics for all three sophistication dimensions. The box plots do not show the bimodal effect, but the modality is likely affecting the distribution picture here. The integration of information scale had fewer items, causing a flattening, or platykurtosis,

of the distribution shape. The variable all sophistication (ALLSOPH) is a composite

measure, and the plot is unremarkable.
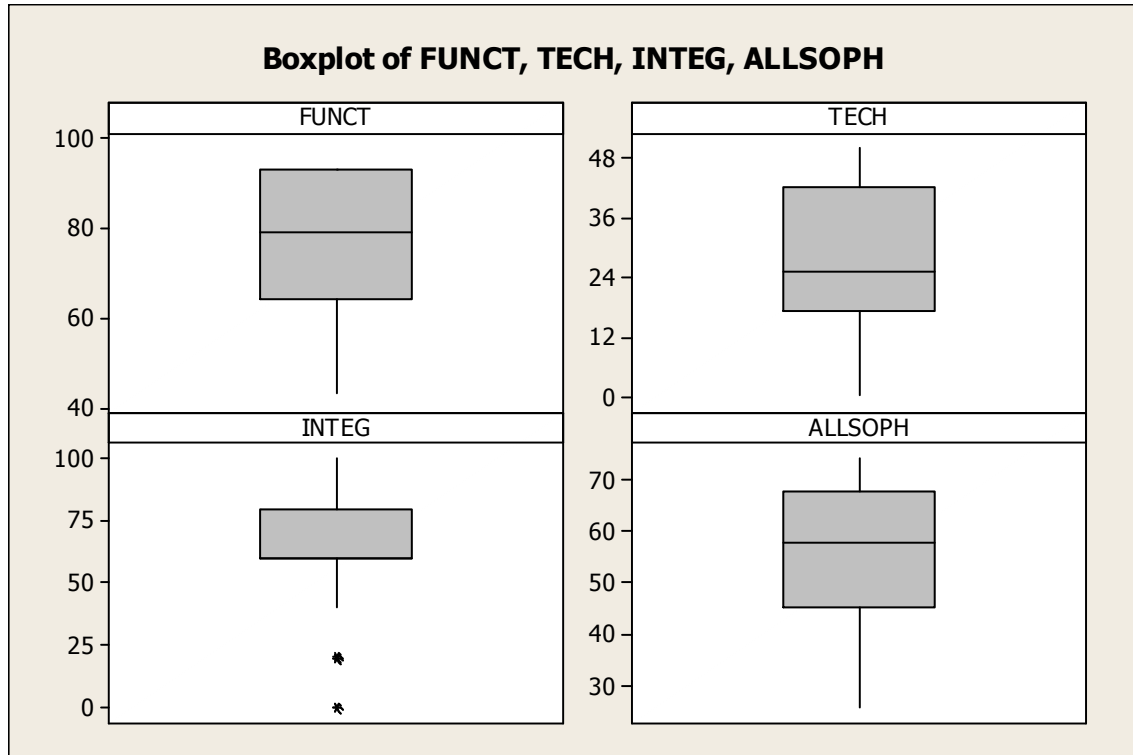

Figure 13. Boxplots for measures of IT dimensions.

Table 10 shows the score dispersion. The possible range of scores was 0 to 100.

The problem distributions of these variables added to the difficulty in evaluating the

relationships in the study. The scoring was rechecked and the outliers addressed in order

to improve normal distributions for the measures in question.

Table 10. *Descriptive Statistics for the Sophistication Scores*

Sophistication (N=175)	*M*	*SD*	Median
Functional	75.10	15.32	78
Technological	28.73	14.24	25
Integration	62.05	20.23	60
All Sophistication	55.57	12.78	58

IT Sophistication Scores by Hospital Characteristics

The IT sophistication scores were next examined by hospital characteristics used in the model: metropolitan location, academic status, and hospital size (number of beds). Two-sample t-tests were computed for all measures except for hospital size. There was a significant difference in the mean functional sophistication scores between metropolitan hospitals ($M = 77.2$, $SD = 13.6$) and non-metropolitan hospitals [$M = 68.2$, $SD = 18.5$; $t(173) = -3.40$, $p = 0.001$]. The magnitude of the difference in the means is reflected by eta squared of 0.13, which is considered a large effect size (Green, Salkind, & Akey, 2000; Nunnally & Bernstein, 1994). There were no notable findings with the other variables tested. Pearson correlation coefficients were computed between the number of beds and the sophistication measures and were not significant.

Research Question Findings

Multiple linear regressions were used to test the relationships between IT sophistication and hospital outcomes. In preparation for analyses, all variables were checked for linear lack of fit and for normality of residuals. The individual IT sophistication scores were tested for interaction, which was positive; they were

regressed separately. The covariates, the internal operating factors of the hospitals, were regressed on themselves to rule out multicollinearity. The results produced R^2 values no greater than 12.5 percent, which are insignificant (Lewis-Beck, 1980). Cases in which the PSI rates had denominators less than 30 were eliminated from analyses. This is a recommended practice to avoid bias in results due to a low number of cases (U.S. Department of Health and Human Services, 2003b). Box-Cox transformations were performed on the outcome variables, except for mortality. Logarithmic transformations of the variables improved the asymmetry of the distributions. The mortality distribution improved after removing outliers.

T ratios were used to evaluate the significance of the individual coefficients and independence. The rule of thumb of absolute value of $t \geq 2$ was applied. The adjusted R^2 statistic was used to determine goodness-of-fit, accounting for any positive bias occurring from R^2. The control variables included in the model were metropolitan versus non-metropolitan location, academic (teaching) status, and hospital size (by number of medical-surgical beds).

The linear regression results for the research questions are presented in Table 11, with predictor variables down the first column and outcome variables across the first row. The model findings show t values of partial regression coefficients with significance (one-way), the direction of the relationship between IT sophistication and the outcome measure, adjusted R^2, F, and n. Asterisks denote significant findings. Variance inflation factors (VIF) for each analysis were calculated, testing for multicollinearity or correlation among predictors. VIF results ranged from 1.0

Table 11. *Linear Regression Results*

	Outcome Measure								
Predictor	Hospital mortality	Ln PSI 2	Ln PSI 4	Ln PSI 8	Ln PSI 9	Ln PSI 11	Ln PSI 12	Ln Revenue by day	Ln Revenue by admit
IT Sophisticat (allsoph)	2.09*	0.55	1.66	0.74	0.94	0.04	1.02	0.80	0.56
Constant	0.0270	-6.63	-2.18	-6.49	-5.95	-5.43	-4.90	10.6	9.19
Metro status	3.35**	4.09**	2.33*	1.33	1.13	0.54	0.69	7.16**	1.51
Acad status	0.14	0.35	0.22	2.55*	1.71	0.33	0.74	1.48	1.75
Bed Size	2.79*	0.72	2.41*	4.61**	0.01	0.30	2.29*	12.19**	3.32**
IT Coeff	-	+	-	-	-	+	-	+	-
R^2 (%)	9.2	11.6	7.8	27.3	0.8	0.0	1.8	63.1	11.1
F	5.26*	5.05**	4.38*	6.54**	1.26	0.12	1.69	75.26**	6.43**
n	165	119	156	55	132	114	150	170	170
Functional sophistication	0.95	1.36	1.27	2.24*	0.24	0.95	0.40	3.06*	2.25*
Constant	0.0254	-5.83	-2.65	-5.70	-6.29	-4.98	-5.00	9.97	8.93
Metro status	3.48**	3.95**	2.03*	1.64	0.95	0.59	0.60	6.67**	1.03
Acad status	0.15	0.25	0.17	2.62*	1.72	0.33	0.77	1.58	1.83
Bed Size	2.87*	0.57	2.31*	4.74**	0.11	0.42	2.31*	11.71**	2.97*
IT Coeff	-	-	+	-	+	-	-	+	+
R^2 (%)	7.8	12.8	7.0	32.7	0.0	0.0	1.0	64.3	13.3
F	4.50*	5.48**	3.96**	8.17**	0.95	0.34	1.37	78.09**	7.56**
n	162	118	152	55	130	114	148	167	167
Technical sophistication	1.35	0.23	0.49	1.37	0.03	1.36	1.69	0.93	0.13
Constant	0.0236	-6.40	-2.38	-6.46	-6.17	-5.18	-5.23	10.7	9.15
Metro status	3.42**	4.05**	2.21*	1.39	1.20	0.59	0.86	7.18**	1.47
Acad status	0.18	0.32	0.23	2.64*	1.71	0.26	0.66	1.52	1.75
Bed Size	2.98*	0.72	2.50*	4.71**	0.03	0.32	2.20*	12.03**	3.34**
IT Coeff	-	-	-	-	+	-	+	+	-
R^2 (%)	7.8	11.5	6.3	29	0.1	0.0	2.9	63.1	10.9
F	4.56*	4.98**	3.69*	7.02**	1.03	0.58	2.16	75.42	6.34**
n	165	119	156	55	132	114	150	170	170
Integration information sophistication	0.60	1.79	0.08	2.43*	2.07*	0.34	1.22	3.70**	0.51
Constant	0.0231	-6.00	-2.40	-5.92	-5.84	-5.66	-5.26	10.2	9.12
Metro status	3.19*	3.93**	2.07*	1.42	0.96	0.06	0.69	7.32**	1.35
Acad status	0.25	0.08	0.22	2.98*	1.30	0.40	0.55	2.08*	1.80
Bed Size	2.87*	0.65	2.46*	5.42**	0.20	0.44	2.19*	12.20**	3.27**
IT Coeff	-	-	-	-	-	+	+	+	+
R^2 (%)	6.2	13.7	5.8	33.7	2.8	0.0	1.8	65.7	10.8
F	3.74*	5.79**	3.42*	8.50**	1.96	0.12	1.70	82.90**	6.19**
n	162	117	153	55	129	112	148	167	167

Note. * $p < .05$; ** $p \leq .001$

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(no relation) to 1.2 (slight relation) on regression coefficients, with one exception. Slightly increased collinearity was noted for Research Question 4, regression of postoperative hip fracture, with VIF 1.7 to 1.9 for the predictors academic status and number of beds.

Research Question 1: Is there a relationship between IT sophistication of acute care hospitals and in-patient mortality?

Mortal_1=f (allsoph, mstat1, acad1, msurgbed); f (funct_1, mstat1, acad1, msurgbed); f (tech, mstat1, acad1, msurgbed); f (integ_1, mstat1, acad1, msurgbed).

A small but significant negative relationship was found between the composite IT sophistication score and in-hospital mortality. The relationships between each of the individual dimensions of IT sophistication (functional, technical and integration of information) and mortality were not significant. The metropolitan location of hospitals had a significant negative relationship with mortality, and hospital bed size had a significant positive relationship with mortality.

Research Question 2: Is there a relationship between IT sophistication of acute care hospitals and PSI 2, death in low mortality DRGs?

lnopps02 = f (allsoph, mstat1, acad1, msurgbed); f (funct_1, mstat1, acad1, msurgbed); f (tech, mstat1, acad1, msurgbed); f (integ_1, mstat1, acad1, msurgbed).

This regression was performed with the (log) of the observed rate for death in low mortality DRGs as the criterion. Neither the composite IT sophistication scores nor the dimensions of IT sophistication showed a significant relationship to death rates in

low mortality DRGs. Metropolitan status had a significant negative relationship with the criterion.

Research Question 3: Is there a relationship between IT sophistication of acute care hospitals and PSI 4, failure to rescue?

lnopps04 = f (allsoph, mstat1, acad1, msurgbed); f (funct_1, mstat1, acad1, msurgbed); f (tech, mstat1, acad1, msurgbed); f (integ_1, mstat1, acad1, msurgbed).

This regression was performed with the (log) of the observed rate for failure to rescue as the criterion. Neither the composite IT sophistication scores nor the dimensions of IT sophistication showed a significant relationship to failure to rescue. Both metropolitan location and hospital bed size had significant positive relationships with the criterion.

Research Question 4: Is there a relationship between IT sophistication of acute care hospitals and PSI 8, postoperative hip fracture?

lnopps08_1 = f (allsoph, mstat1, acad1, msurgbed); f (funct_1, mstat1, acad1, msurgbed); f (tech, mstat1, acad1, msurgbed); f (integ_1, mstat1, acad1, msurgbed).

This regression was performed with the (log) observed rate for postoperative hip fracture as the criterion. Small but significant negative relationships were present between functional sophistication and integration of information sophistication and postoperative hip fracture. This relationship of IT sophistication to postoperative hip fracture was the strongest clinical outcome relationship (adjusted $R^2 = .33$). Academic

status had a significant positive relationship with the criterion. Hospital bed size had a significant negative relationship with the criterion.

Research Question 5: Is there a relationship between IT sophistication of acute care hospitals and PSI 9, postoperative hemorrhage or hematoma?

lnopps09_01 = f (allsoph, mstat1, acad1, msurgbed); f (funct_1, mstat1, acad1, msurgbed); f (tech,mstat1, acad1, msurgbed); f (integ_1, mstat1, acad1, msurgbed).

This regression was performed with the (log) of the observed postoperative hemorrhage rate as the criterion. A small but significant negative relationship was present between integration of information sophistication and the criterion. No other significant relationships were identified for the sophistication measures or internal organizational factors.

Research Question 6: Is there a relationship between IT sophistication of acute care hospitals and PSI 11, postoperative respiratory failure?

lnopps11_1 = f (allsoph, mstat1, acad1, msurgbed); f (funct_1, mstat1, acad1, msurgbed); f (tech,mstat1, acad1, msurgbed); f (integ_1, mstat1, acad1, msurgbed).

The regression was performed with the (log) of the observed postoperative respiratory failure rate as the criterion. No significant relationships were identified between the IT sophistication measures or internal organization factors and postoperative respiratory failure.

Research Question 7: Is there a relationship between IT sophistication of acute

care hospitals and PSI 12, postoperative pulmonary embolus (PE) or deep vein thrombosis (DVT)?

lnopps12_1 = f (allsoph, mstat1, acad1, msurgbed); f(funct_1, mstat1, acadl, msurgbed); f (tech, mstat1, acad1, msurgbed); f (integ_1, mtat1, acad1, msurgbed).

The regression was performed with the (log) of the observed postoperative PE rate as the criterion. No significant relationships were identified between the IT sophistication predictors and postoperative PE rate. Hospital bed size had a significant positive relationship with the PE rate.

Research Question 8, part A: Is there a relationship between the sophistication of the IT infrastructure of an acute care hospital system and the hospital's financial outcome, patient revenues by day.

lnptrevbyday = f (allsoph, mstat1, acad1, msurgbed); f(funct_1, mstat1, acadl, msurgbed); f (tech, mstat1, acad1, msurgbed); f (integ_1, mtat1, acad1, msurgbed). Both revenue measures were transformed using a natural logarithm transformation. Two IT sophistication dimensions, functional and integration of information, had significant positive relationships with patient revenues by day. Both metropolitan location and hospital bed size had significant positive relationships with patient revenues by day.

Research Question 8, part B. Is there a relationship between the sophistication of the IT infrastructure of an acute care hospital system and the hospital's financial outcomes, patient revenues by admission?

lnptrevbyadmit = f (allsoph, mstat1, acad1, msurgbed); f (funct_1, mstat1, acadl, msurgbed); f (tech, mstat1, acad1, msurgbed); f (integ_1, mtat1, acad1, msurgbed).

Functional IT sophistication had a small significantly positive relationship with patient revenues by admission. Bed size was also significantly related to patient revenues by admission.

Summary of Findings

One hundred and seventy-five acute care hospitals in Texas with available IT data made up the sample for this study. The majority of the sample were non-profit hospitals (62%) located in metropolitan areas (77%). Sixteen percent (28) of the hospitals were government owned, and there were 11 academic teaching hospitals. The hospitals varied widely in the number of beds staffed ($M = 110$, $SD = 98$), admissions ($M = 10198$, $SD = 9275$) and total annual revenues generated ($M = \$134$ million, $SD = \$163$ million). Hospitals located in metropolitan locations and academic hospitals had significantly more beds, admissions, and corresponding revenues. Metropolitan location, academic status and hospital size were all positively correlated ($p < 0.002$), but no significant collinearity existed.

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Comparison of the acute care hospitals making up the study sample with non-sample hospitals showed significant differences between the two groups. Hospitals in the sample tended to be metropolitan (77%) and nonprofit (64%), with low government ownership (11%), and with an average of 245 beds. Non-sample hospitals tended to be non-metropolitan (63%), nonprofit (82%), and government owned (57%), with an average of 48 beds.

The hospital scoring for IT functional sophistication and integration of information was negatively skewed toward higher scores, with low overall scores for technology sophistication, a median of 25 for all hospitals. For metropolitan-located hospitals, the functional IT mean score was 77 ($SD = 13.6$) versus 68 for non-metropolitan locations. The differences for functional sophistication reached statistical significance ($t = -3.40$). The differences in mean scores for integration of information also approached significance for metropolitan hospitals ($p = 0.066$). Bimodal characteristics were evident in the distributions of the scores and most likely were attributable to metropolitan versus non-metropolitan location of hospitals. Seventy-seven percent of the hospitals were located in metropolitan areas. Hospital size was not correlated with the sophistication scores.

The research questions explored relationships between IT sophistication of acute care hospitals and hospital clinical and financial outcomes. Clinical outcomes measured were in-patient mortality and six patient safety indicators. Financial outcomes were patient revenues by number of days in reporting period (annual) and number of admissions. Covariates included in the model were metropolitan location, academic

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status (teaching or non-teaching) and hospital size, measured in number of medical-surgical beds.

For the composite measure of IT sophistication, a small but significant negative relationship (adjusted R^2 = .09) was present for in-hospital mortality, indicating that higher IT sophistication was related to lower mortality. Metropolitan location also had a negative relationship with mortality, indicating hospitals located in metropolitan areas tend to have lower mortality. Hospital size had a positive relationship with mortality, indicating that larger hospitals have higher mortality. There were no significant relationships for IT sophistication and the revenue outcomes.

Functional IT sophistication was related post-operative hip fracture, patient safety indicator PSI 8. The relationship was significant and in the negative direction, indicating a higher level of functional IT sophistication was related to lower incidence of postoperative hip fracture. Hospital size was also significant and negative, indicating that larger size was associated with lower rates of hip fracture. Academic status showed a positive relationship, indicating that teaching hospitals had higher rates of postoperative hip fracture. Functional IT sophistication was related significantly to both revenue measures, patient revenues by days and by number of admissions. Metropolitan location was significantly related to the first revenue measure, indicating metropolitan hospital location was associated with higher patient revenue by day. Hospital size was positively related to both revenue measures. Technical IT sophistication did not have a significant relationship with any of the outcome measures.

Integration of information was related to several outcome measures. Significant negative relationships were present with postoperative hip fracture and postoperative hemorrhage. This indicates that higher integration of IT information was related to lower rates of postoperative hip fracture and postoperative hemorrhage. The relationship to postoperative hip fracture was the stronger of the two, with adjusted R^2 of .34. Academic status and hospital size were, as above, also related to postoperative hip fracture rates in this regression. Integration of information was also related significantly to patient revenue by day, with a positive relationship indicating that an increase in information integration was related to higher revenues. All three covariates were significantly related to this revenue measure in the positive direction.

CHAPTER 5

SUMMARY, RECOMMENDATIONS, AND CONCLUSIONS

Summary

The purpose of this exploratory study was to test whether a relationship existed between the maturity of IT in acute care hospitals and patient care and financial outcomes. The theoretical framework proposed that the sophistication of a hospital's information systems and technology is predictive of the quality of patient care and financial outcomes. The review of literature supported the proposition that if hospitals have the information technology available to support clinicians' and managers' work processes, this should be positively related to patient care outcomes. The conceptual development of the instrument, Information Technology Sophistication in Healthcare, was based on IT structure, management, and information processing constructs originally tested in the manufacturing industry. The transition to the healthcare environment linked IT infrastructure and management to hospital operations supported by patient management systems, clinical information systems, and information networking. The ability to measure indicators of patient care quality was made possible by the development and testing of the AHRQ quality indicators validated against provider care processes. The relationships between measures of IT infrastructure and support of patient care processes and hospital care outcomes had not been tested before.

The following research questions were addressed:

1. Is there a relationship between IT sophistication of acute care hospitals and inpatient mortality?

2. Is there a relationship between IT sophistication of acute care hospitals and death in low mortality DRGs?

3. Is there a relationship between IT sophistication of acute care hospitals and failure to rescue?

4. Is there a relationship between IT sophistication of acute care hospitals and postoperative Hip fracture?

5. Is there a relationship between IT sophistication of acute care hospitals and postoperative hemorrhage or hematoma?

6. Is there a relationship between IT sophistication of acute care hospitals and postoperative respiratory failure?

7. Is there a relationship between IT sophistication of acute care hospitals and postoperative PE or DVT?

8. Is there a relationship between IT sophistication of acute care hospitals and hospital financial outcomes?

Discussion of Findings

Demographic Data

One hundred seventy-five acute care hospitals in Texas were studied. The majority of the hospitals were non-profit (62%), non-teaching hospitals located in metropolitan areas (77%). The hospitals in the sample varied by location, size, and operating characteristics. Metropolitan and academic teaching hospitals were larger, with more beds and corresponding number of admissions and revenues generated. The positive correlation between location, size and teaching status was expected and the findings are reasonable.

The comparison of the study sample hospitals with the hospitals not part of the sample, primarily due to missing IT profile data, provides information important for generalization of the study findings. Hospitals in the sample were predominantly metropolitan in location, with an average of 109 beds, as opposed to the non-sampled hospitals, with rural location and an average of 47 beds. Both were primarily non-profit, with the study sample having a better mix of non-profit and profit (64% and 36% respectively). The non-sampled hospitals were 82% nonprofit. The differences between the groups indicate that the study findings are more representative of metropolitan profit and non-profit hospitals, with an average of 100 or more beds. There may be a self-selection bias present in the sample. Metropolitan hospitals may have better IT capability than rural hospitals and also may be more likely to report IT capability.

Functional IT sophistication measured the availability and diversity of IT

systems and hardware that supported the patient care processes. The mean scores on

functional sophistication were significantly different between hospitals in metropolitan

versus non-metropolitan hospitals, and the differences in the integration of information

scores by location approached significance. Both of these scores showed bimodal

distributions and were negatively skewed, with higher scores than expected.

Metropolitan hospitals made up 77% of the sample. The differences between the

metropolitan and non-metropolitan hospitals appear to be the reason that bimodality is

present. Metropolitan hospitals were also significantly higher for bed size, number of

admissions, and revenues. Menachemi et al.'s (2006) recent paper on IT and financial

performance found similar results, although they were able to show the relationship

more directly with variables of cash flow and expenses as well as revenues. Hospitals

that performed better financially had more IT applications. That may be what is

reflected in the higher functional and integration scores for this instrument.

Technical sophistication measures the diversity of hardware devices available to

support clinical care. The technical scores were very low across all hospitals (a median

of 25 on a 100-point scale), and this was surprising in light of the higher functional and

information integration scores. The low scores may be a reflection of self-reporting, the

limited hardware range included in the dataset, or instrument inaccuracies in assessing

the information.

The study instrument had lower than expected Chronbach's alpha reliability coefficients. Reliability for the functional and technological domain items was .57, and for the integration domain was .46. The composite scoring, which includes all three domain items, had a coefficient alpha of .75. The study instrument was modeled after the Information Technology Sophistication survey developed by Pare and Sicotte (2001), an instrument developed for concurrent survey use, supplemented with interview data by the IT study investigator. The current study used retrospective, self-report data without the possibility of clarification or addition of interview data. The items used for measurement of IT application and hardware capability for the sophistication domains were also limited by the information profile data available in the retrospective data. The IT sophistication profiles created from the available data resulted in a limited profile of the three domain activities in comparison with the original instrument. The small number of items used to measure the individual components of sophistication, and the reliance on retrospective data were most likely the causes of the lower reliability coefficients. The limitations of the study instrument most likely contributed to the relatively small number of significant findings for the relationships between IT capability and care outcomes.

Regression Model Results

There were eight research questions concerning possible relationships between IT sophistication (maturity of HIT) and hospital , clinical and financial outcomes . The clinical outcomes were in-patient mortality and six patient safety indicators (PSIs).

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Small, but significant relationships were confirmed by linear regression on three of the seven clinical measures. The small coefficients of multiple determination (adjusted R^2) for two of the measures, mortality and postoperative hemorrhage rate, are not unusual for administrative data. The direction of the relationships and lack of fit values (no significance) in regression results do not indicate interaction or bias. The relationships of functional sophistication and integration of information with postoperative hip fracture indicated stronger relationships, with adjusted R^2 of .33. The findings of relationships between IT measures and any care outcome other than mortality are the first reported. The models were predictive, but it is suggested that more significant relationships might be identified with a larger sample.

The financial models both showed significant positive relationship with IT sophistication. Functional sophistication and integration of information again showed positive findings with revenues, with respectable adjusted R^2 of .64 to .66. These findings confirm Menachemi et al.'s study (2006) of positive relationships between IT availability and financial outcomes. The additional small significant relationship of functional sophistication to patient revenue per number of admissions was also present. Both of the revenue variables were log transformed, so interpretation is limited to direction. Surprisingly, the composite sophistication score did not show a positive relationship with either revenue measure.

The majority of the relationships between location (metropolitan versus non-metropolitan) and outcomes were significant and in the negative direction, which appears appropriate. Metropolitan hospitals have more financial resources, and that

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influence logically follows to predict lower mortality and complication rates. According to recent literature on nurse staffing and physician staffing, availability of better staffing as well as increased financial resources may be some of the factors influencing this outcome. Educational levels of nurses in metropolitan versus non-metropolitan locations may also be another factor influencing differences. Additional analysis of hospital-specific factors may provide more insight into these relationships.

The bed size relationships were negative for the postoperative hip fracture rates as well, indicating that larger hospitals may have lower rates of complications, adding to the relationships for hospital location reported earlier. The relationship of academic status relationship to postoperative hip fracture rates was positive, however, and this would indicate higher rates of complications. Again, these findings are exploratory only. The stronger relationship was with the postoperative hip fracture rates, and the direction of the relationships appear to be appropriate.

Limitations

There are several limitations to consider when reviewing the results. This is an exploratory cross-sectional study using retrospective data. The IT data were voluntarily reported and may represent self-report bias from hospitals that have better IS systems, are better-managed, or have more resources for larger systems. The sampling was limited due to the inability to match data across all three sets. Only acute care hospitals were sampled, and in comparison to the other acute care hospitals not included because of the lack of IT profiles, metropolitan hospitals with larger bed size were the best

represented. The sample characteristics may limit generalization to other healthcare settings. The sample may limit generalization, but with the closing of smaller, especially rural hospitals in 1980s and early 1990s, it is probably a true picture of setting availability for acute care.

The observed rates for the patient safety indicators were used in the regression models. Transforming the observed rates gave a better linear fit and residual normality. It may be that a case mix index needs to be included in the model, because the risk-adjusted rates could not be used. However, with the addition of the covariates, that bias may be ameliorated somewhat by capturing the influence of the patient type that frequents acute care hospitals in these settings. In other studies, primarily of financial outcomes, a case mix index is included for accurate patient risk comparisons across hospitals. It was assumed that for this exploratory study, not using an index did not cause error in the results.

Research Recommendations

Further study is anticipated for the relationship of IT sophistication to hospital outcomes as well as for description of hospital IT capacity. Instrumentation will be an important area of research, in order to develop these measures of IT capacity and understand the relationship to care outcomes. Questions about the link of IT capacity to care processes remain unanswered: is the importance of IT capacity in the provision of data to drive decisions or in its affect on communication and team work processes? The availability and use of technology can be presumed to influence

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decision making and related care outcomes. Providing more detailed data and information with more sophisticated tools may also produce educational benefits. Further study can be made of information access at the bedside and the information turnaround to determine the next care actions. There remain questions to be explored regarding the affects of technology, its availability, and its uses.

The conceptual framework outlined in this study shows promise for future research on the relationships of IT to healthcare processes and outcomes, with multiple directions to take. Research on the influence of IT in the clinical area is just beginning to show positive findings that can give some direction to resource allocation and can illustrate important relationships to care outcomes.

The use of retrospective data has inherent limitations, but it is useful for exploring and screening relationships in preparation for later, more robust studies. The study instrument was clear and easy to use, and it is expected that the measure will show more reliability with more complete IT profile data. Prior studies by the original authors of the instrument showed excellent psychometric properties.

Several new studies have been published this year using similar measures to capture IT capacity for study of healthcare benefits. Positive financial findings have been repeated and are supportive to the attempts of administrators and government policy analysts to make the best decisions on allocation of resources. Clinical findings and financial findings go hand in hand—more research in IT is needed across all areas of hospital performance in order to improve the financing, selection, and use of IT.

APPENDIX A

DEFINITIONS

1. Complication or adverse event: " 'An injury caused by medical management rather than by the underlying disease or condition of the patient' (Brennan et al., 1991). In general, adverse events prolong hospitalization, produce a disability at the time of discharge, or both" (U.S. Department of Health and Human Services, 2003b, p. 8).

2. Diagnosis code: The principal diagnosis code is the ICD-9-CM code corresponding to the condition established after study to be chiefly responsible for causing the hospitalization. The secondary codes are the ICD-9-CM diagnosis codes corresponding to additional conditions that coexisted at the time of admission, or developed subsequently, and which had an effect on the treatment received or the length of stay (U.S. Department of Health and Human Services, 2006).

3. Diagnosis related group (DRGs): A classification system that groups patients according to diagnosis, type of treatment, age, and other relevant criteria. Under the prospective payment system, hospitals are paid a set fee for treating patients in a single DRG category, regardless of the actual cost of care for the individual (U.S. Department of Health and Human Services, 2006).

4. Functional sophistication: The proportion and diversity of processes or activities being supported by computer-based applications (e.g. vital sign recording, med admin, staff scheduling; (Guy Pare & Sicotte, 2001).

5. In-hospital mortality: number of deaths per all discharges per reporting period,

6. ICD-9CM: International Classification of Diseases, with n=9 for Revision 9

or 10 for Revision 10, with CM = Clinical Modification (U.S. Department of Health and Human Services, 2006).

7. Integration of information: degree to which computer-based applications are integrated both internally via a common database and externally via electronic communication links. Example: extent to which lab systems integrated with other computerized systems (ER, OR, nursing systems) and with external entities (other hospitals, clinics) computerized information systems (Guy Pare & Sicotte, 2001).

8. Major Diagnostic Categories (MDCs): MDCs are formed by dividing all possible principal diagnoses (from ICD-9) into 25 mutually exclusive diagnosis areas. The diagnoses in each MDC correspond to a single organ system or etiology and in general are associated with a particular medical specialty (U.S. Department of Health and Human Services, 2006).

9. Medical error: " 'The failure of a planned action to be completed as intended (i.e. error of execution) or the use of a wrong plan to achieve an aim (i.e. error of planning)' (Institute of Medicine, 2000). The definition includes errors committed by any individual, or set of individuals, working in a health care organization" (U.S. Department of Health and Human Services, 2003b, p. 8).

10. Net Patient Revenues: The estimated net realizable amounts from patients. Medicaid dispro share payments, third party payers and others for services rendered, including estimated retroactive adjustments under the reimbursement agreements with third party payers.

11. Patient safety: Avoiding accidental injury or harm to patients during provision of care. Patient safety is ensured when systems and processes of operation minimize any potential errors and include the ability to intercept them when they do occur (McKinsey Global Institute).

12. Patient Safety Indicators (PSI): "a set of measures that can be used with hospital inpatient discharge data to provide a perspective on patient safety. Specifically, PSIs screen for problems that patients experience as a result of exposure to the healthcare system and that are likely amenable to prevention by changes at the system or provider level. These are referred to as complications or adverse events. PSIs are defined on two levels: the provider level and the area level…*Provider-level indicators* provide a measure of the potentially preventable complication for patients who received their initial care and the complication of care within the same hospitalization. Provider-level indicators include only those cases where a secondary diagnosis code flags a potentially preventable complication" (U.S. Department of Health and Human Services, 2003b, p. 2).

13. Preventable adverse event: "An adverse event attributable to error is a 'preventable adverse event ' (Brennan et al., 1991). A condition for which reasonable steps may reduce (but not necessarily eliminate) the risk of that complication occurring (U.S. Department of Health and Human Services, 2003b, p. 8).

14. Quality: Quality of care is the degree to which health services achieve the desired health outcomes and care processes are consistent with current professional knowledge and standards (National Roundtable on Healthcare Quality, 1999)).

15. Quality indicators: "Screening tools for the purpose of identifying potential areas of concern regarding the quality of clinical care. For the purpose of this report, we focus on indicators that reflect the quality of care inside hospitals" (U.S. Department of Health and Human Services, 2003b, p. 9).

16. Technical sophistication: diversity of hardware devices, e.g. medical imaging, bar coding devices, data warehousing, wireless networks, PAC equipment (Guy Pare & Sicotte, 2001).

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BIOGRAPHICAL INFORMATION

Valeria Ann Hart was born in Little Rock, Arkansas on May 9, 1950, the daughter of George Theodore Hart and Chrystal Thomas Hart. She completed high school at Mount Saint Mary Academy in Little Rock and earned her Bachelor of Science in Nursing from the State College of Arkansas, Conway, Arkansas in 1972. Her Masters in Nursing, a Clinical Nurse Specialist degree, was received from the University of Arkansas for Medical Sciences, Little Rock in 1990. Clinical nursing practice included medical-surgical staff nursing, critical care in cardiovascular and pulmonary specialties, and clinical teaching. Research experiences included research coordinator for pharmaceutical and nursing research studies, and Associate Director of the Center for Nursing Research at the University of Texas in Arlington, Texas. She is currently employed as Director of Clinical Research and Data Management at Parkland Health & Hospital System, Dallas, Texas. Residence is in Arlington, Texas.