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OM Forum

The Vital Role of Operations Analysis in Improving Healthcare Delivery

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There is now a broad consensus among healthcare professionals that the U.S. healthcare delivery system is woefully inefficient and needs to be radically redesigned. Healthcare costs have always been a driving force in policy and management, but quality has become equally important in driving decisions, particularly since emerging payment systems include metrics on clinical and operational performance. With the increasing use of information technology to capture financial, operational, and clinical data and to coordinate care across time and different venues, there is a growing demand for operations analysts to examine processes of care and provide much-needed insights on how to better utilize resources to improve outcomes while reducing costs. In this paper, I describe some of the essential features of the U.S. healthcare system and some critical issues that provide opportunities for operations researchers to make important contributions.

Key words: healthcare; information technology; data analysis; capacity planning; flexibility; coordination; practice variation
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Introduction

The U.S. healthcare system is in big trouble, and the situation is not much better in the rest of the world. In every developed country, healthcare costs are rising faster than GDP and quality problems such as medical errors, as well as underuse and overuse of healthcare resources, are way too prevalent. Delays for care are rampant, with patients waiting weeks for an appointment and spending many hours in emergency rooms waiting to see a physician or to be admitted and placed in an appropriate bed. There are many causes cited for this dilemma, including misaligned payment systems, high levels of uninsured or underinsured, overloaded physicians, and profit-seeking insurers. More fundamentally, there is a general consensus among those who study healthcare delivery that current systems are highly fragmented and suffer from a lack of coordination and communication and, in many cases, a lack of knowledge on how clinical and patient processes should be defined, organized, and managed to achieve cost-effective and timely access to appropriate care.

There has never been a more opportune time for people with analytical skills to provide decision-making guidance to improve the healthcare delivery system. First, this need has become apparent to policy makers, healthcare system administrators, and the general public. An aging population, epidemic proportions of chronic disease, and the additional number of Americans with healthcare coverage as a result of the 2010 Affordable Care Act (ACA) will all contribute to a significant increase in demand for healthcare services in the coming years. In addition, there is general agreement that the unrelenting growth in healthcare costs is unsustainable, particularly in light of a sluggish economy and large government deficits. This means that there is far more emphasis on the part of governments, insurers, employers, hospitals, physician practices, and even pharmaceutical and medical device companies to make healthcare delivery more cost effective. At the same time, new regulations, emerging payment models, and competitive pressures are forcing hospitals and physicians to increasingly report and demonstrate improvement with respect to quality measures.

Fortunately, the healthcare industry is finally in the throes of an information technology revolution. The 2009 HITECH Act allocated $19.2 billion to promote the adoption and meaningful use of health information technology. The goal is to achieve, by 2015, a 90% adoption rate by hospitals and physicians of interoperable electronic health records (EHRs) that are capable of communicating not only clinical information but also cost and quality measures. Building on this increased supply of data, the ACA established the Patient-Centered Outcomes Research Institute to conduct and disseminate research to expand and support "evidence-based medicine"—the use of statistically generated clinical protocols to guide medical treatment decisions.

Although the expansion of evidence-based medicine is critical to controlling costs and achieving better clinical outcomes, it is not sufficient. The delivery of healthcare itself needs to be transformed from a fragmented set of facilities managed to maximize utilization to an integrated set of clinical care processes focused on optimizing clinical and service outcomes at minimum cost. The confluence of high levels of motivation and an increasing supply of operational, financial, and patient data creates an unprecedented opportunity for operations researchers to work with healthcare providers to establish *"evidence-based healthcare"*—the use of operational research studies and methodologies to guide decisions on the design and management of high-performance *healthcare processes*.

In this paper, I will first describe some important features of the current U.S. healthcare environment and some of the changes that are rapidly occurring as a result of increasing cost pressures, recent legislation, and innovations in payment mechanisms, delivery systems, and technology. I will then briefly describe a few categories of healthcare delivery problems that present excellent opportunities for operations researchers to contribute to achieving the key goals of providing timely access, developing coordinated, patient-focused processes of care, and identifying the most cost-effective uses of healthcare resources.

Some Important Features of the U.S. Healthcare System

Most healthcare in the United States is financed by employer-sponsored health plans or government programs such as Medicare and Medicaid. Regardless of who the payer is, the basic payment mechanisms are the same. For inpatient hospital care, the major payment mechanism is the DRG (diagnostic resource group) system. This system classifies clinical diagnoses into broad groups based on similar average resource use, i.e., bed days, procedures performed, nursing intensity, etc. A hospital gets paid for each patient, based on the DRG category of his or her illness, regardless of actual resource use, giving hospitals an incentive to reduce hospital length of stay (LOS) and increase admissions. In addition, certain DRGs are quite profitable for hospitals, whereas others are not, providing hospitals with an incentive to build more capacity in the most profitable areas, e.g., cardiac care and orthopedic surgery, and limiting capacity in others. Similarly, most physicians, who are generally paid separately from hospitals, are compensated on a fee-for-service (FFS) basis, essentially getting paid for every patient visit and every procedure. Therefore, for both hospitals and physicians, there is a significant financial incentive to encourage the use of healthcare services. On the other hand, there is generally little or no compensation for providing counseling on lifestyle changes that could help prevent an illness or mitigate its severity, or for communicating with patients by phone or email to remind them of the need to take their medications or schedule a follow-up visit, or coordinating care with other providers. Nor have there been, until very recently, any financial penalties associated with poor quality. In fact, quality measures are still very scarce. To help address these problems, the ACA established the Center for Medicare and Medicaid Innovation, which will examine new ways of delivering healthcare and paying healthcare providers that can save money for Medicare and Medicaid while improving the quality of care. Some of these will be discussed later in this paper.

Despite impressive gains in medical knowledge and technology, the practice of medicine is still as much art as it is science. Although some of this is due to inadequate dissemination and adoption of empirically verified best practices, much of it is due a lack of evidence on what works best for what types of patients under what types of circumstances for many categories of illness. As a result of this, and exacerbated by financial incentives, there is enormous practice variation in rates for hospitalization, surgical procedures, imaging, and use of specialized care facilities for almost every major category of medical problem, even when controlling for relevant clinical and demographic characteristics. For example, among the 306 U.S. Hospital Referral Regions in 2002–2003, the incidence of joint replacement for chronic arthritis of the hip and knee and of surgery for low-back pain varied 5.6-, 4.8-, and 5.9-fold, respectively, from the lowest to the highest region (Wennberg et al. 2007). The pattern of variation is remarkably stable over time. Furthermore, there is substantial evidence that more care does not generally correlate with better outcomes (Gifford 2010). In systems like Intermountain Healthcare, the reduction in practice variation has resulted in better clinical outcomes and lower costs (James and Savitz 2011). This is the primary motivation for the establishment of the aforementioned Patient-Centered Outcomes Research Institute.

Finally, although the care and treatment of patients often involves several facilities and healthcare providers, including primary care physicians, specialists, hospitals, imaging facilities, and laboratories, there is little or no communication or coordination among them. The result is often unavailability of medical information at the time of treatment, replication of test results, indicated protocols not being followed, prescription of contraindicated procedures or medications, etc., leading to poor clinical outcomes and unnecessary costs.

These features are at the heart of the too prevalent poor quality and wasteful expenditures plaguing the U.S. healthcare system. Although there are a handful of healthcare systems that have been able to better integrate healthcare delivery, reduce practice variation, and eliminate waste to produce lower-cost, higher-quality healthcare, most of the healthcare community is just beginning to grapple with the need to rethink and redesign their organizations, particularly in light of emerging innovations in payment models, increased reporting of quality measures, and the growing use of EHRs and other new healthcare information technologies.

What Kinds of Problems Can We Help Solve?

As indicated above, there is a growing consensus on the need to address large categories of cost and quality problems that can be categorized as underuse, overuse, and misuse of health resources and that are often the result of poor access, fragmentation of care, practice variation, and a lack of appropriate performance measures. There are abundant opportunities for operations researchers to address these issues and provide important insights and tools to help guide transformations of healthcare systems.

On the most macro level, there are critical policy issues involving the supply of major healthcare resources such as hospitals, beds, emergency rooms, physicians, nurses, and major imaging equipment. At the most micro level, there are decisions about the specifics of the timing, location, and nature of care for a specific patient and set of operational circumstances. In between, there are issues of process design, organization, and resource allocation. Here, I will describe three major categories of operational problems that are critical to controlling costs and improving access and clinical quality and that address the issues described above.

Identifying Capacity Needs

The major objective of the ACA is to increase the number of insured people in the United States. Specifically, it is estimated that 30 million of the approximately 50 million currently uninsured will have coverage by 2014. This projected increase, coupled with an aging population, raises serious concerns about whether there is enough capacity to deal with the associated additional demands for healthcare in the coming years. However, there is substantial disagreement about whether there is enough or too much healthcare capacity even at the present time.

A good example of this is hospitals and hospital beds. The largest category of healthcare expenditures is associated with hospital care, accounting for more than 30% of all costs (Schoenman and Chockley 2011). The need for inpatient care is likely to significantly increase with a growing, aging, and increasingly sick population. On the other hand, cost pressures and other factors have resulted in a steady decrease in the number of hospitals and hospital beds for more than 20 years (American Hospital Association 2009). There is much debate about whether a particular community or region has too many or too few hospital beds. Those who claim that there are too many beds (often government officials seeking to close hospitals to save money) point to "low" occupancy levels. Those who believe that there are too few beds point to increasing levels of overcrowded emergency departments (EDs) and more frequent ambulance diversions, i.e., times during which EDs turn away new ambulance arrivals, most often caused by a lack of inpatient beds (American Hospital Association 2010).

Like many "facts" about the healthcare system that routinely appear in the media and political discourse, these conclusions ignore some important complexities. First is the fact that hospital beds are not all identical. At the very least, hospitals have distinct units for obstetrics, psychiatric, and pediatric patients, as well as intensive-care units (ICUs) for very sick patients who require a high level of monitoring and nursing care. In addition, many hospitals have separate wards for clinical services such as cardiology, orthopedics, neurology, and oncology and/or separate medical and surgical units. Larger hospitals may have even more specialized units including dedicated ICUs for surgery, cardiology, and neurology, stroke patients and burn patients. Therefore, a hospital may have ample bed capacity in some units and insufficient beds in others, leading to long ED delays and ambulance diversions for some categories of patients, "off-placement" of patients in inappropriate units, unnecessary transfers, and premature discharges. Needed bed capacity is highly dependent upon the organization of the hospital, the mix of patient types, and the processes of care for those patient classes. Analyses must consider all of these factors to identify whether there is sufficient or inadequate capacity (Green 2003).

Even for a specialized unit, such as obstetrics, there are multiple patient types, affecting resource use and capacity needs. For example, although obstetrics beds are used almost exclusively by newly delivered mothers, the LOS varies by the type of delivery, i.e., vaginal or Caeserean section, with the latter having almost twice the average LOS as the former. In addition, for each of these categories, the delivery can be unscheduled or elective, affecting demand variability and hence the number of beds needed to provide timely access. Obstetrics patients, particularly those who are unscheduled, are, by definition, emergent

patients requiring immediate care. But what exactly does "immediate" mean and what, if any, are the clinical consequences of delays in getting a bed? In the case of obstetrics, when all beds are full, patients may be backed up into the labor and delivery areas, resulting in expectant mothers experiencing labor in hallways without monitors or adequate nursing attention. Does this result in increased risk of adverse outcomes to the mothers and/or newborns? If so, how does this impact the LOS and demand for neonatal ICUs? For this situation and most others involving delays for hospital beds and other healthcare resources, the answers to these types of questions have not yet been explored.

Digging deeper, obstetrics patient mix exhibits a large degree of practice variation. For example, although the national average rate of induced births is about 25%, up from 9.5% in 1990, in New York City this varies from 0% to 70% across individual hospitals and is more prevalent in academic medical centers than publicly financed hospitals. This wide degree of variation appears to reflect differences in physician and patient preferences more than medical necessity (Mann et al. 2006). Because induced deliveries are often performed before the recommended 39 weeks of gestation and lead to a higher rate of Caesarean sections, this practice variation has operational effects not only on the obstetrics unit but also on surgical facilities and neonatal ICUs.

This example illustrates the complexity involved in identifying "good" capacity levels and the need for models that use both clinical and operational data to understand the impact and interaction of patient characteristics, practice variation, congestion levels, and clinical outcomes. It also illustrates the need to consider the entire process of care and the impact of clinical practice patterns on access, costs, and clinical outcomes across interrelated facilities.

The complexity involved in identifying "good" bed capacity levels is even better illustrated in the case of ICUs. The capacity and management of ICUs is critical to cost and quality outcomes because they are the costliest units in the hospital and they serve the sickest and most complex patients. Unlike obstetrics units, but like many other clinical areas of the hospital, there are no generally accepted standards regarding the type of patient who should be admitted to an ICU. Although there may be subcategories of patients for whom the likelihood of death or irreparable harm is clearly higher if they are not treated in an ICU, for a large fraction of patients, the benefits of being in an ICU have not been established. As a consequence, the admission of a patient to an ICU is often the result of individual physician judgment as well as the congestion level in the ICU. That is, when there are beds available, it is more likely that lower acuity patients will be admitted and, when the ICU is completely full, some patients may be discharged early to make room for newly arrived, sicker patients (Kc and Terwiesch 2009). To complicate matters further, studies have indicated that readmission rates to the ICU are higher when the LOS of the initial stay is shortened due to congestion, and that the subsequent LOS is longer, thus exacerbating congestion levels further. In addition, delays in admission to an ICU bed may affect ICU LOS and clinical outcomes (Chan et al. 2011).

These examples make it clear that operational factors such as capacity, LOS, congestion, and delays are not only highly related to one another, but they are also tightly linked to clinical practice patterns and clinical outcomes. Therefore, to achieve the goals of reducing practice variation and readmission rates, two goals of the ACA and other recent regulations, it is imperative to develop operations research models informed by clinical data to help understand these relationships and provide guidance for admissions and discharge policies for patients. Although I have used the example of ICUs to illustrate the types of research needed, the challenge of identifying appropriate capacity levels in conjunction with identifying admissions and discharge policies that will be most cost effective exists for other parts of the hospital and other health facilities as well.

Another important debate about healthcare capacity is focused on primary care physicians (PCPs). There is general consensus that there is already a shortage of PCPs, particularly in some parts of the country. Patients without a PCP increasingly have difficulty in finding such a physician, and delays for appointments are often long. Much of the increased use of EDs is attributed to difficulties of patients in obtaining access to a PCP (Bodenheimer and Pham 2010). There is substantial disagreement about the size of future shortages, particularly given the newly insured population who will be seeking PCPs starting in 2015. Estimates of shortages range from 35,000 to over 45,000 by 2025 due to a growing and aging population (Colwell et al. 2008), with thousands more by 2020 due to the increased insurance coverage provided by the ACA (Hofer et al. 2011). Some of these estimates are based on careful analyses of the demand side, e.g., the growth in PCP visits due to changing demographics and the increase in the number of insured people. They all make the assumption that needed supply is a linear function of demand and generally use ratios of patients per PCP ranging from 1,500 to 3,000. What they neglect to do is factor in any measure of timely access. As any operations researcher knows, a physician practice is a stochastic service system because most demands for care are randomly generated. In addition, other factors, such as how many

appointments are held in reserve for follow-up care and the impact of late cancellations and "no-shows" can significantly affect delays for appointments (Green and Savin 2008). To provide a reliable estimate of needed PCP capacity, it is necessary to use stochastic models to identify patient panel sizes that are consistent with timely access to care (Green et al. 2007). Such models can also be used to evaluate the impact of operational modifications, some of which are currently being more widely adopted, such as physician pooling, group appointments, and use of non-MD professionals such as nurse practitioners (NPs), on patient panel size per physician.

The need to estimate the required supply of physicians is, of course, not limited to PCPs. Similar studies are needed for other primary-level physicians, such as pediatricians and geriatricians, and specialists such as cardiologists, orthopedists, oncologists, etc., as well as non-MD health professionals such as nurses and NPs.

Dedicated or Flexible Resources?

As mentioned above, whereas some hospitals have a single ICU to care for all patients requiring a high level of care, in many, particularly large academic medical centers, ICUs come in many flavors, including medical, surgical, cardiac, neurological, and stroke monitoring units. Sometimes these distinctions are made because of differing nurse staffing levels, e.g., a stroke monitoring unit may have a 4-1 patient-to-nurse staffing level, whereas a neurological ICU may have a 2-1 ratio. Other reasons include specialization of the nurses and convenience for the medical residents and attending physicians. Because each ICU is generally very small, e.g., four to eight beds, there could be significant economies of scale from combining two or more ICUs. On the other hand, with the increasing emphasis on managing coordinated, patient-focused processes of care, there is an argument to be made that the benefits of having dedicated units that employ standardized protocols and use specialized staff to reduce variability in treatment and the LOS, and allow for better prediction and coordination of all units of the hospital related to a particular class of patients, could outweigh the benefits of increased flexibility.

The issue of flexible versus dedicated resources is not restricted to inpatient facilities. For example, many major imaging centers that conduct MRI, PET, and CT scans, are owned by hospitals but used for both inpatients and outpatients. Similarly, operating rooms (ORs) can be used by inpatients, outpatients, and ED patients. Although there have been some studies done on policies for allocating resource use among these classes of patients (Gerchak et al. 1996, Green et al. 2006) and the relative benefits of having, e.g., dedicated ORs for emergency patients (Wullink et al. 2007), more work is needed on when dedicated resources are more efficient and effective and how shared resources should be most effectively managed.

Designing and Managing Patient-Centered Processes of Care

Many of the provisions of the ACA deal with pilot programs to develop and test new payment and service delivery models that will result in greater coordination of care. Among these are patient-centered medical homes, Accountable Care Organizations (ACOs), and bundled payments for acute episodes of care. All of these are based on eliminating or minimizing the existing FFS incentives to increase the volume of health services, and instead encourage a greater focus on keeping patients healthy and cutting costs associated with unneeded care and errors.

A medical home is a single organizational entity that provides healthcare IT supported, comprehensive, and integrated care to a defined population of patients. There are several examples of existing medical homes, which are organized around a personal care physician who directs a team of non-MD providers including, e.g., nurse practitioners and nurses, to provide for all the health needs of the patient. This includes identifying and scheduling specialists for referrals, communicating and arranging appointments with testing facilities, providing services for home care, and facilitating transitions to and from hospitals, rehabilitation centers, and long-term care facilities (e.g., see Steele et al. 2010). Medical homes may be based on a capitation payment model, i.e., a single fixed payment per participant per year, or use an FFS system supplemented by financial bonuses based on meeting cost and/or quality targets.

Because medical homes provide a broad range of health services using a team approach, and are focused on cost-effective ways to keep a population of patients healthy rather than on responding to health problems after they appear, there are a large number of research issues concerning the type of care, the frequency of care, and the location of care, given the associated resource costs and the probabilities of clinical outcomes. For example, many hospital admissions are for medical conditions associated with chronic disease—such as poorly controlled diabetes or worsening heart failure—which can be treated in either the inpatient or the outpatient setting, but with different associated risks and costs. Even within the context of outpatient care, little is known regarding what constitutes efficient and effective care, e.g., how often chronic disease patients should be monitored and the impact on costs and clinical outcomes of physician visits versus remote monitoring or phone calls.

An ACO refers to a group of providers and suppliers of services (e.g., hospitals, physicians, and others

involved in patient care) that work together to coordinate care for the Medicare patients they serve. ACOs must care for at least 5,000 patients over three years and will be paid under normal Medicare payment formulae. If they demonstrate at least a 2% savings compared to a given baseline and meet or exceed given quality targets, they will share in those savings. There is both a one-sided risk model (shared savings only with no penalty for losses) and a two-sided risk model (shared savings and capped losses for all three years), allowing the ACO to opt for either model. ACOs are just now being developed in response to recently issued regulations. An ACO can be started by a hospital, physician practice, or a network of hospitals and/or physician practices. Because, as in a medical home, the financial incentives are aimed at keeping costs down and quality high, many of the same research questions associated with medical homes are also relevant to ACOs. In addition, because ACOs will usually consist of multiple organizations, there are additional research issues regarding coordination mechanisms and how savings and/or risks should be allocated to the various participants to best align incentives.

Both medical homes and ACOs focus on keeping populations healthy. A critical component of this is developing protocols for screening and diagnostic imaging. For example, in screening for various types of cancer, when should imaging be performed to best balance the trade-off between the total costs involved, which may include follow-up tests and procedures from inconclusive findings, versus the likelihood of finding a dangerous health problem early enough to be effectively treated? Additional complexity is introduced in considering the multitude of imaging technologies available, such as MRI, CT, mammography, and PET scans, each of which may provide different information regarding the presence or absence of a given disease with different degrees of specificity and sensitivity as well as different associated costs. Diagnostic imaging has been targeted by employers and insurers as an area of overutilization and so there is considerable interest in developing better guidelines to identify in which situations a given imaging methodology should be used. Although all of these questions involve clinical data and judgment, they all have operational and cost implications regarding resource utilization and allocation.

Bundled payments for acute episodes of care are aimed at minimizing gaps in communication and follow-up that can result in poor health outcomes and associated increased costs. For example, Geisinger ProvenCare is a bundled payment plan for coronary artery bypass graft surgery (Paulus et al. 2008), which charges a flat payment for surgery and all related care for 90 days after discharge. It is based on a set of 40 standard processes for each patient with the goal of reducing hospital LOS and readmissions. The single-episode price includes preoperative evaluation and work-up, hospital and professional fees, routine discharge care, and management of related complications occurring up to 90 days postsurgery. The ACA encourages hospitals, doctors, and postacute care providers to bundle payments plans for certain health conditions. To accomplish this, research is needed not only on identifying effective clinical protocols but also on understanding the impact of these protocols on resource utilization, e.g., hospital LOS, readmissions, postacute care facility LOS, etc., across the providers involved and the associated capacity needs. Similar to the ACO model, there are also questions as to how to distribute episode payments across hospitals, physicians, etc. to appropriately align incentives to maximize healthcare value.

Summing Up

The examples given above are but a few of the many challenges that exist and will arise as health delivery systems, payment methods, and healthcare IT continue to evolve. Managers of healthcare systems are looking for help in sorting out how they should respond in this new environment. Although there has been a focus on healthcare IT and financial incentives as the means to transform and improve healthcare delivery, there is not as much awareness on the role of operations modeling in identifying trade-offs and policies that can guide the development of high-performance healthcare processes. Hopefully, as our community becomes increasingly involved in working with healthcare managers and as we publicize our successes, operations analysts will become routine participants in improving healthcare systems.

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