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Multiscale analysis of the healthcare and public health system: Organizing for achieving both effectiveness and efficiency

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Despite expansion of medical knowledge and technology, the healthcare system as a whole is under performing in terms of quality of care and number of medical errors. Complex systems concepts can be used to examine the healthcare and public health system and to provide direct insight into the organizational and behavioral changes needed to accelerate quality improvement. Using such concepts, one can trace the origins of quality and medical error problems in the system to a mismatch between the large, simple financial flows and the complex treatment of individual patients by individual doctors. Implementing cost controls through standards setting and resource allocation leads to poor quality of care and resistance to quality improvement efforts. The solution to this problem requires two parallel, but linked systems with distinct organizational forms: (a) a high efficiency system that performs relatively simple repetitive tasks such as diagnostic screening tests, inoculations, and generic healthcare, and (b) a high complexity system that treats the complex medical problems of individual patients. Making this change in structure will better match the healthcare system to the large financial flows and the complex tasks it performs.

Introduction

Rapid improvement in the quality of care has become a high priority for the healthcare system. Despite the expansion of medical knowledge, the use of increasingly sophisticated technology, and the high level of physician training, measures of the quality of care, return on investment [1] and the incidence of medical errors [2] depict a severely under performing system. This is the first of four articles that addresses the healthcare system using recent fundamental advances in complex systems research.[3] The central analytic tool that will be used in these papers is Multiscale Analysis [4,5], which identifies the functional effectiveness of a system by comparing the set of actions a system can perform at different scales with the same analysis of its tasks. In the above definition, scale is used to refer to the redundancy, coherence or coordination of a task. Large scale tasks involve multiple individuals working as a coordinated unit, or multiple individuals performing the same task. In contrast, small scale tasks require the attention of a single individual performing a unique task. To contrast two extreme possibilities, a system containing many individuals can be organized to perform a large number of small scale tasks, or a single large scale task. There are tradeoffs that can be achieved in the nature of tasks and the organization of a system, which can be characterized by the "complexity profile" of a system: the complexity of possible actions as a function of scale that specifies the number of distinct tasks that can be performed at each scale. Using this analytic tool, an understanding of the role of organizational structure in organizational effectiveness can be obtained.

The four articles in this series identify the interplay between individual and system capability for particular organizational forms and demonstrate both why and how the current difficulties in the healthcare system exist. They also provide direct recommendations as to how effectiveness can be dramatically improved, while keeping within the financial constraints of the system. These articles explain why system structure and behavior rather than individual competence or negligence should be the center of attention for quality improvement and error reduction strategies. Beyond this recognition, they provide specific strategies for such improvement efforts. The four articles address in turn:

(1) The role of the financial and organizational structure of the healthcare system in inducing resistance to efficiency improvement and ineffectiveness—pointing to the need to separate types of tasks, simple and repetitive from complex and unique, and have different organizational forms address each type of task to enable both efficiency and effectiveness.

(2) The role of complexity in the inability of existing organizational structures to reliably perform increasingly complex tasks in individual care—pointing to the need for a local team-based structure, which distributes but integrates

observation, decision making and actions so as to enable tasks that are much more complex than any one individual can perform.

(3) The ineffectiveness of prescribed protocols, planning and assignment of responsible individuals to oversee complex tasks—pointing to the need for organizational learning, superceding individual training, as a means for creating effective teams that can perform complex tasks.

(4) The limitations of technology in addressing high complexity tasks—pointing to the need for appropriate technology and the recognition of the proper place for its use in the efficient and effective healthcare and public health system.

In this, the first article in the series, we analyze the underlying causes of resistance to improvement efforts and dysfunction in the healthcare system as a whole. The culprit is the mismatch between the financial and organizational structure of the system and the tasks it is performing. A formal multiscale analysis readily reveals the incompatibility of large scale and highly complex aspects of the system. To be effective there must be a matching between the scale and complexity of the functional capabilities of the organization and the scale and complexity of the tasks to be performed. Managed care's efforts to lower costs through large scale industrial era methods of efficiency are incompatible with providing complex individualized treatment. This streamlining approach has weakened the system's ability to provide effective medical care because it is not suited for the high-complexity tasks it performs. The solution is to classify and separate tasks and particularly to separate those tasks that can be performed by an organization designed for efficiency and those tasks that can be performed by an organization designed for complexity. In the healthcare system, the tasks suited for organizational efficiency are typically associated with healthy individuals, including public health, prevention and screening., while the tasks suited for organizational complexity are typically associated with medical care of individual patients.

The following sections review in brief: 1) key relevant aspects of the structure of the healthcare system, 2) the reasons that this structure leads to instability and ineffectiveness, 3) concepts of multiscale analysis, which provides a formal approach to this conclusion, and 4) description of a systematic approach to changing the structure of the system for improved efficiency and effectiveness.

The structure of the healthcare system

The development of health insurance and the trend towards managed care have affected the structure of the healthcare system in significant ways, separating the flow of money from the interaction between physician and patient. Today, most individuals do

not directly pay their physician or other practitioner in full for their services. Payments from patients to doctors, “co-pays,” do not cover the cost of medical services. Instead, employers (or, less often, individuals) make regular payments to their insurance companies, other health plans, or Medicare—payments that are not directly dependent upon the actual services provided during that time period. Practically speaking the payment is often an electronic bank transfer once a month. Part of the money may be deducted from employee salaries, while the other part comes directly from the company. Either way, the payment amounts are decided upon in advance and are the same from month to month, until rate changes take place, typically on a yearly basis. With respect to the nature of the actual medical care provided, this sum is essentially featureless: large scale and simple, having no information encoded into it about the complex medical services it will eventually fund.

The insurance company or managed care organization divides this large scale flow of money into smaller financial flows to the different healthcare providers in its system. Sometimes they go directly for specific services, payments for treatments to specific physicians. Other times they are paid as intermediate sized payments to healthcare organizations, which are then allocated as compensation for individual practitioners, or as funding for procedures, supplies, and other medical costs.

The diagram in Figure 1 represents the flow of information, services, treatments, and money in the existing healthcare system. Information and medical treatment are exchanged in the transactions between physicians and patients, whereas the flow of money is largely from employers to healthcare insurers and thence to healthcare provider systems and individual practitioners. The difficulties in imposing efficiency and improving quality of care have their origins in the structure of these flows. An analogy, which helps explain why this type of system is ineffective, is to the phenomenon of fluid turbulence.

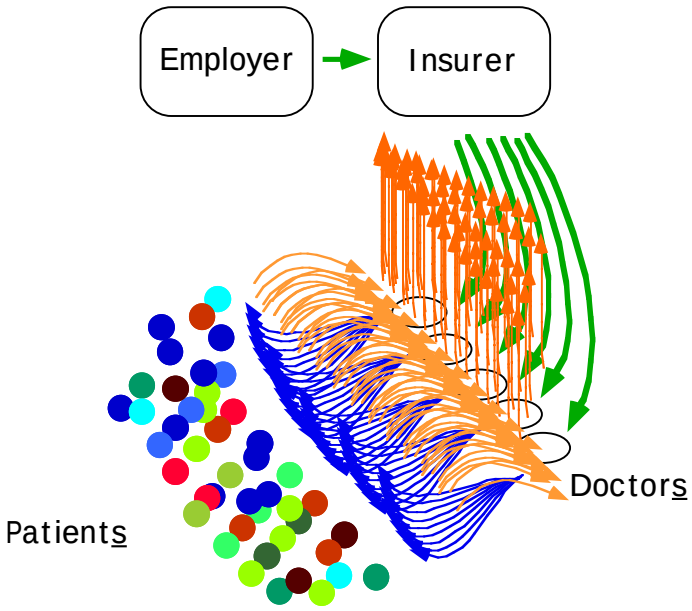

Figure 1: The structure of the healthcare system today. Financial flows are shown in green, information flows in brown, treatment in blue.

Turbulence

Turbulence occurs when a simple coherent flow is broken up into many smaller flows. It can be observed in the swirls and eddies in a fast-flowing river, or in the way the coherent column of smoke rises from a camp fire. Although one can identify situations where turbulence will occur, it's very difficult to predict the resulting motions, which are irregular and change rapidly over time.

In the healthcare system, we have an analogous situation. The large scale financial flows that drive the system eventually have to be allocated as small payments to individual doctors treating individual patients for individual problems. The transition from the large- to the fine-scale is turbulent for financial flows just as it is for fluid motion. The idea that turbulence is the analogy to what is going on in the healthcare system will not come as a surprise to those who work in it, as they have experienced the turmoil over the past 20-30 years. The unpredictable rapid changes have not been in the relationships between doctors and patients, or in the relationships between employers and insurers (though sometimes they feel involved, at least as interested spectators)--the main changes have been between the insurers and the physicians. The growth of managed care, physician cooperatives, reporting and billing systems, and hospital mergers, are all part of the interface between the insurers and physicians. These changes in organizational

structure and particularly the aggregation of medical services into healthcare providers are a response to the flows that are disaggregating from large scale to fine scale.

What does this turbulence look like in human terms? The problem of large flows connected to highly complex flows is abstract, but the reality is quite easy to recognize. Eventually the issue is related to the problem of controlling the flow, specifically: Who is making the decisions that control the flow of money in this system? Since the early 1970s and increasingly since then, an effort has been made to control the flow at the large scale end. Companies and insurers, frequently with the intervention of state and federal government organizations, negotiate the rate of flow of the money from employers to insurers. They decide on changes in the rate from one year to the next. Ultimately, how these rate changes affect the system impacts the character of the behavior and organization of the system.

Consider the effects of a simple action like changing the flow at the source, by increasing (or decreasing, though practically speaking the former is more likely) the amount by a certain percentage (e.g. 3%). This kind of increase in spending is typically done on an annual basis. The amount of increase reflects a decision about how much should be spent on health care. How does the healthcare industry implement this decision? At the opposite end of this flow, individual doctors treat individual patients with specific highly specialized care based upon high complexity choices, whose ultimate decisions are based upon years of training and experience. The costs of individual treatments range widely – from tens of dollars to millions of dollars. The consequence of this increase (so much and no more) must manifest itself in the decisions individual doctors make regarding the care of individual patients. They must decide what amount of time and attention to devote to a particular patient, as well as what medical tests and treatments to perform. Ultimately these decisions must be based upon tradeoffs in health and care that compare diverse treatments. Physicians faced with restrictions on expensive procedures and treatments, or incentives to lower their own expenses, would have to make judgments about whether the amount of time and effort devoted to a particular appointment or individual, or a particular diagnostic test or therapy is “worth it,” where “worth it” refers not only to the likelihood of a successful outcome but also to the cost-effectiveness of the decision to pursue it. Since this kind of judgment includes considerable uncertainties and it is largely incompatible with their training to treat disease, different organizations—and individual physicians—would make this judgment in different ways, resulting in extremely unstable and variable quality of care overall.

What can those who want to control costs do? It is clearly impossible for those who "manage care" to make decisions about care changes on an individual by individual basis in a way that will altogether correspond to the change in total flow specified from year to year. The only thing they can do is stipulate overall policies that act across the board. These policies typically restrict the set of options that are available for patients or

physicians. Patients are restricted to certain physicians, hospitals or other care providers. Physicians are restricted in what diagnostic tests or medications they can provide. The amount of time spent in hospitals might be limited, or incentives to reduce the amount of time or attention to individual cases may be implemented. It is not surprising that limiting the options that a patient or physician can choose will have a negative impact on the quality of care that could be provided. It is a fundamental truth that using across the board rules to try to control a highly complex system that is making careful (highly complex) decisions is not a good idea.

The ineffectiveness of these strategies has been documented in some systematic discussions and studies. [4] From early efforts, such as the Nixon administration's wage and price controls in the early 1970s, through drug formularies or limits on diagnostic tests, cost control measures have at best produced ambiguous results. Studies have raised questions regarding the underlying assumptions of these approaches, that is that such actions can actually save costs even when implemented according to plan; and in fact studies have demonstrated that indirect effects may ultimately lead to increased costs.[5] A more general analysis based upon an understanding of the functional behaviors of complex systems does not require a direct understanding of specific mechanisms in order to arrive at the same conclusion.

Multiscale analysis

A formal analysis of this issue can be developed based upon Multiscale Analysis, [3] which uses a decomposition of the capability of a system according to scale. This decomposition shown for simple illustrative cases in Figure 2, describes the response capabilities of the system at each scale. Larger scales imply many individuals performing the same (or directly coupled) tasks, while finer scales imply independently acting individuals. Distinct curves illustrate the relationship between organizational forms and the tasks they can perform. The key to understanding these curves is as follows: a system in which all individuals are performing the same or coupled tasks can only perform a single act in response to an environmental demand, whether the demand is for one or many individuals to perform that act (curve (b) in Fig. 2 shows a single act at any scale up to the largest scale possible consisting of the effort of all individuals combined). This is quite different from a system where individuals are independent, and therefore, can respond individually to distinct tasks, leading to many tasks that can be performed, each one of which can only draw the attention and efforts of one individual (curve (a) in Fig. 3 shows the possibility of many different acts but all of them involving only the effort of one individual). More generally, in organizations there are various ways individuals coordinate activity and combine in groups together. This would lead to the ability to act

at different scales to differing degrees and one possible result for such a case is indicated by curve (c) in Fig. 2.

From the above discussion, it should be apparent that different types of industries should be organized in different ways. For example, mass production is a large scale task and organizations that are designed for mass production should be quite different than an organization that provides individualized care, as is generally understood to be the role of the healthcare system. Different parts of a system can also be analyzed in this way. Of particular relevance is an analysis of the financial flows of the healthcare system (larger scale) and the system of physicians that are performing the care (higher complexity at a smaller scale of action).

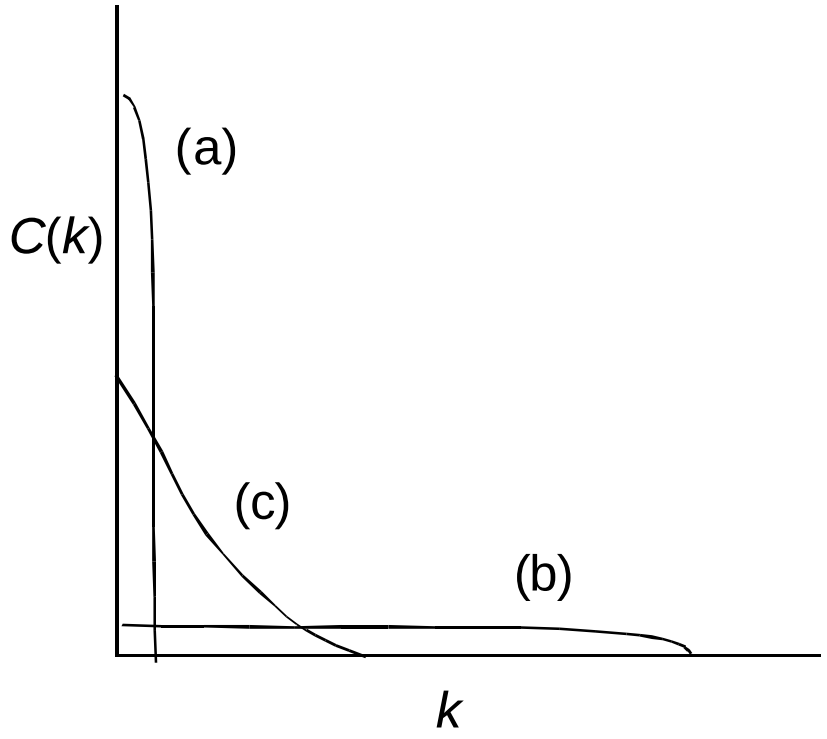

Figure 2: Schematic illustration of the complexity $C(k)$ (vertical axis) as a function of scale, k (horizontal axis, increasing to the right). A system with the highest possible fine scale complexity corresponds to a system with independent parts (curve a). When all parts act together the system has the largest scale behavior, but the same low value of complexity at all scales (curve b). Intuitively, what we call complex systems have various possible scales of behavior (curve c). The healthcare system is composed of one part (the physicians) that have a high fine scale complexity, and another part (the insurance system that is large scale. The part that connects them is highly turbulent

because of the differences between the two. This linkage also limits the effectiveness of the system when addressing either large scale or complex fine scale tasks.

This discussion clarifies why recent efforts to increase efficiency have led to organizational turbulence and the current need for and difficulties with quality improvement. As the necessary treatment of individual patients has become progressively more complex and individualized, HMOs, managed care, and other health insurance solutions have been striving to make its financial structure more large scale and undifferentiated. Due to the complexity of the resulting allocation problem, unexpected "indirect" effects have resulted from these efficiency methods. Moreover, the more problems arise with quality, the greater are the efforts to regulate the actions of doctors. Uniform regulation, whether for cost containment or for quality, has the same effect on a system performing high complexity tasks-diminishing overall effectiveness. Imposing uniform care in one context may be constructive, however, in the context of complex organizations uniformity is in itself a limitation (exceptions do exist but must be understood within this framework rather than just assumed to exist). Usually, however, the resulting problems show up as indirect effects, which makes it difficult to discover their origins. It is not surprising that the institutions that serve as intermediaries e between the insurers and the doctors—the managed care industry, hospitals, and healthcare provider networks—have been undergoing dramatic changes in management structure and in patterns of delivery of care and that every change may increase rather than alleviate the difficulties and turmoil in the overall system.

The problem is that the healthcare system is expected to behave efficiently with respect to financial flows at the large scale, but to exhibit high complexity of individual patient care at the fine scale. If all patients were in roughly the same condition, requiring roughly the same treatment, an efficiency approach would be fine, as this approach works well for streamlining low-complexity procedures. However, the medical treatment of patients is an extremely high-complexity fine-scale task. One-size-fits-all does not work in this case. Applying such methods can only result in poor quality care. Although the above discussion of the current state of the healthcare system is grim, a fundamental approach to a solution to the problem does exist and will be discussed below.

Large scale health care

The resolution to this problem comes from recognizing that there are aspects of health care that *can* be treated with highly efficient processes. To apply methods of efficiency in the healthcare system, the first step is to identify which aspects of the system are repetitive and large scale. Applying efficiency to those aspects makes sense

and can save money. Applying them to the highly complex aspects is not a good idea. Efficiencies in the system can be implemented in many ways if this distinction is carefully made. Here we will focus on the largest-scale parts of the healthcare system, those that should be dealt with at a population level. Indeed, although, medical care and the treatment of disease are typically fine-scale problems, requiring complex individual attention through patient-physician interaction, these are not the only tasks that the healthcare system carries out. Which health services lend themselves to a large scale efficient approach?

The answer is generally found in preventative care and public health. The aspects of health care that can be treated in the most efficient way include: wellness services, such as nutrition programs, management of some widespread chronic problems, prenatal care, and the treatment of common minor health issues (allergies, stress, the common cold), and preventative procedures, such as inoculations and screening through diagnostic tests. Many of these services can be performed on populations as highly efficient processes, as they do not require individual decision-making by an independent complex agent (physician or other trained practitioner). They can be separated from those aspects of health care that require detailed decision-making and can be carried out using a "population-based" approach rather than through traditional one-to-one appointments.

Efficient health care/complex medical care

The approach described in this paper for enabling the healthcare system to improve its capability, is to unbind the large scale and complex tasks, so efficient and effective organizations can be formed around these distinct tasks. Specifically we argue for two very different systems: an efficient system to deal with health issues that affect entire populations (and that can be made efficient on a large scale) and a system to address the complexities of individual medical care in an effective and error-free way. By separating simple, large scale "health care" from complex, individualized "medical care", we relieve physicians of tasks that can be addressed with a much higher efficiency, enabling them to focus their attention on the complex tasks for which they are uniquely trained. Not only does this create a more cost-effective health care system but it also allows for a more effective and error-free medical system.

The high efficiency healthcare system pictured in Figure 3 would function in some ways analogously to a traditional mass production factory model. Some features of this system may seem disconcerting: it should be largely impersonal, not appointment-based, and not doctor-based. Nurses, technicians, and other non-physician practitioners can administer regular vaccinations and carry out routine diagnostic tests on large groups of people rather than through individual appointments. The purpose of the diagnostic

tests is to ensure a high level of health in the population and to identify those who will need individual medical attention with a physician. The large scale system will not handle exceptions; all individuals requiring exceptional attention would be referred to the medical system. The objective of the well-patients program will be large scale efficiency, but once a problem is identified, medical care for the sick can be highly personal and effective.

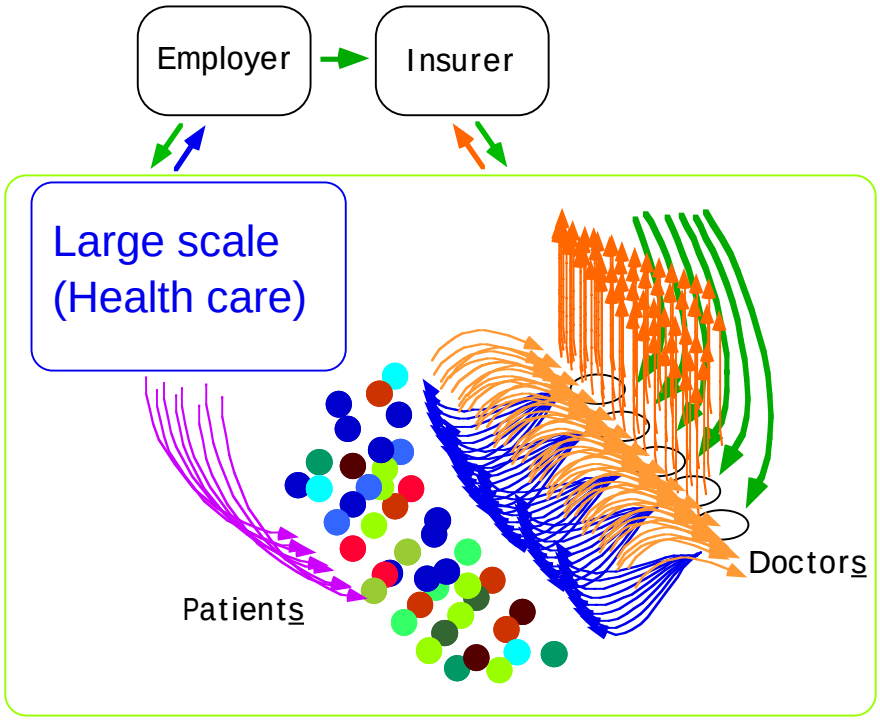

Figure 3: A proposed structure for a new healthcare system. One part is designed for efficient, population based health and wellness programs; the other part is designed for complex individualized medical care.

For example, a company could institute a mobile screening program, in which test equipment is brought to a workplace by the healthcare organization at regular intervals. Tests would be administered by technicians and results used solely for referral to a physician. An individual whose tests indicate that further actions must be taken would be advised to make an appointment with a physician in the medical system. The treatment of the individual may then require detailed and careful decisions performed by a highly trained team of physicians and other practitioners.

Employers, social organizations, community centers, and in some cases, government agencies including the Centers for Disease Control and Prevention and the Centers for Medicare and Medicaid Services, are the organizations that are naturally suited to caring about population based healthcare. It might seem surprising to some, but

good employers care, even more than individual employees about the health of their employees. Individual health is a key to productivity of the organization. Each individual has a small chance of being sick at any one time. However, a reduction in this probability can have a major impact on an employer. Even when only a small percentage of the entire population is affected, there can be a major effect or threat to overall public health, with important implications for public policy. This means that employers and government agencies may be motivated to develop, and should welcome services from organizations providing population based care that will provide them at reasonable cost.

Screening/early detection: medical and financial effectiveness

An efficient health care system addressing population based care depends to a great extent on the development of effective screening and testing; and there has been much debate regarding the effectiveness of such techniques. Some of the concerns are medically related, while others are about their financial effectiveness. It should be recognized, however, that the knowledge of how to detect medical problems and perform early treatment is being developed and will increase rapidly. Moreover, a key aspect of the financial benefit from early detection arises from the large scale and efficient application of such tests. The existing system cannot carry out these tests efficiently on large numbers of patients because it is simply not set up to do so; and this is one of the main reasons why their financial effectiveness is under question. Before we can properly evaluate which tests will be effective when applied broadly, we need to change two of our basic assumptions: 1) that the tests will be administered by the existing appointment-based medical system and 2) that technology doesn't change. Some early detection tests that have been controversial are becoming more widespread in their usage, including mammograms and various other kinds of imaging including "full body scans". More traditional screening tests that are not widely used include the stress test for susceptibility to heart attack. These and other tests, if applied widely and systematically, can help to predict the level and type of medical intervention needed to avoid a medical disaster, without having to wait for more overt symptoms to occur. When frequent screening is done, it is possible to intervene when the time is right, as opposed to responding in urgency to the first indication of symptoms.

Not all tests are a good idea. Still, to develop a perspective on evaluating when tests are constructive, it is helpful to compare the introduction of these tests with the introduction of new technologies in other industries, for example, the consumer electronics industry. We are now seeing the introduction of high-definition television. If we studied this technology a year or two ago, we would find that it was not cost effective and not broadly useful. The way it was introduced, however, was by starting with high

cost versions that only a few people could afford. Then gradually, as both the technology improved and the volume of production increased, it became accessible to many people and financially viable for the companies that are producing it. How did the companies know that this would work? First, they didn't know for sure. Still, they had experience with previous generations of consumer electronics. This experience told them that technology improves with time, and as adoption increases, mass production reduces costs. When we think about healthcare we don't think in the same way because the system is not designed around mass production and scientific medical studies are not allowed to suppose that we might learn more in the future about how to use the information that we gain from medical tests.

Highly efficient, rapid, and cost effective performance of tests and inoculations will lead to improved efficiency and relieve the financial pressure on the medical treatment of individual patients. There is another industrial example that provides a useful analogy. There have been studies and changes in practice in preventative care and equipment maintenance in factories that have had dramatic effect. [6] Preventative maintenance does not reduce costs immediately. Initially, there is a great deal of work to be done because problems are detected earlier and much work must be done to repair the broken equipment. However, this eventually leads to lowered overall costs as the reduced failure rates from properly maintained equipment reduce the failure rates later on. On the other hand, poor maintenance catches the system in a vicious cycle of failed equipment and overtaxed maintenance crews performing interventions in a crisis context. Studies show that this later case is where you spend more and get less in terms of equipment reliability! It is not too hard to see the analogy between this and the current situation in healthcare, where we are spending more and getting less from our healthcare system than others are. [1] Many countries using other healthcare systems focus more attention on public health than the U.S. This does not mean that they have the balance right (even more public health might be better, or more individualized care might be needed), but it suggests that we are moving in the wrong direction when we focus on cost containment and efficiency in the treatment of individual patients. Implementing preventive tests and early diagnostic techniques will initially require a greater investment, but with application of such tests on a large scale, a significant and permanent decrease in costs should follow. Better yet, we can spend the same amount of money and achieve a much higher quality of life through improved health.

The underlying message of these studies is simple and clear, however, reaching the point where organizations behave this way is not necessarily easy. Quite generally, a short- term perspective of treating just the problems that you see is ineffective over the long term. This means, however, that starting to take the long-term view will make matters worse (at least in cost and effort) in the short-term. The overall key to success is perseverance!

Conclusion

What goes by the name "health care" right now is an individualized system. Despite the fact that many of its services are largely universal, population-oriented ones, the system provides these services mainly through the traditional one-to-one physician-patient model, so that it can provide individualized medical care when problems arise. The problem is that this one system is expected to provide both financially efficient health care and complex medical care, therefore it should not be surprising that it is struggling with this dichotomy. Efforts to lower costs through managed care and other insurance and care delivery schemes must lead to ineffectiveness, which is manifested in medical errors and decreasing quality of care. A fundamental solution requires separation of complex tasks from large scale tasks. Individualized care should be entrusted to a fine-scale medical system, while a distinct system should be created for large scale and efficient heath care or wellness programs. The large scale financial structure that currently drives the healthcare system will then be matched to an efficient, population-based care delivery system, relieving much of the turbulence caused by the allocation problem. The result: a healthier population, a more focused culture of high-quality medical treatment, a relieving of pressure on our overtaxed medical practitioners, and, perhaps surprisingly, lower costs.

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