The deployment of information technology in clinical laboratories and its impact on professional roles

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New information technology is deployed in hospital clinical laboratories to increase both the quality and efficiency of laboratory operations. Although total laboratory expenses may rise as a result of technology deployment, the average cost per test may decline. S-curves can be used to illustrate the effects of new information technology—such as a laboratory information system (LIS)—on the useful output and use of resources in laboratories. Major changes are now occurring as a result of the deployment of information technology, most notably in the area of automated information management. The role of laboratory professionals must be modified in response to this new information environment. The generation of information within clinical laboratories should be considered as the beginning—not the end—of the responsibility of laboratory professionals.

Companies and managers, countries and their peoples, face an increasing task of self-renewal—increasing because the pace of technologic change continues to increase. We must all become better innovators as a result— inventing new products and reinventing our own skills and jobs as well.

—Robert H. Waterman, Jr. (1)

The developed world is in the process of a major shift to the post-industrial information era. Starkweather describes four major characteristics of this new era: an orientation toward services rather than the manufacturing of goods, information overload, uncertainty about the future, and the interconnection of processes and events (2). With specific references to changes occurring in health care because of this shift, Starkweather stresses the urgent need to actively manage information, rather than information systems, because of a high degree of uncertainty about the future information needs of health-care professionals and the mounting problem of information overload.

Although most eras seem uncertain and replete with problems for people living at the time, we agree with the general thrust of Starkweather’s comments and his view that health-care professionals need to take a more active role in managing information rather than systems. Our goal in this article is to describe the relevance of his call for

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better information management in health care, with a special emphasis on hospital clinical laboratories.

We will first discuss the inevitability of the deployment of information technology in hospital laboratories, which is driven by increasing pressures for improved quality and efficiency. We will then examine the relationship between new information technology and post-analytic information management, as well as the need for laboratory professionals to develop skills relating to information technology. Finally, we will explore some of the consequences if laboratory professionals fail to adequately incorporate information management into their professional roles.

Technological discontinuities and the S-curve

Beginning about 1975, microprocessors began to appear in hospital laboratories, incorporated primarily into three types of devices: the laboratory information system (LIS), personal computers, and automated analyzers. This shift from the pre-microprocessor to the post-microprocessor era within clinical laboratories can be referred to as a technological discontinuity—a radical break with preexisting technology (3). Although such technological discontinuities are infrequent, they profoundly affect the nature of work because of the quality gains that can be achieved as a result of the switch and the changes in work rules required.

Drawing on the work of Foster, we use a series of S-curves in Figure 1 to illustrate two concepts relating to the deployment of new technology—the relationship between useful output and use of resources in clinical laboratories and the relationship between groups of S-curves and a technological discontinuity (1). Useful output is shown on the vertical axis and resource utilization on the horizontal. We define useful output as the creation of information that increases the quality of health-care products.

Each S-curve in Figure 1 represents a different mix of information technology that could be implemented within a hospital laboratory during a given period of time. A group of S-curves, which we refer to as a family, represents different combinations of information technology deployed in different hospitals. As laboratory personnel use their current technology more intensively, the laboratory will move upward along its particular S-curve, increasing the useful output of the laboratory.

By way of contrast, the deployment of a new information technology device, such as an LIS, provides the opportunity to jump to a new S-curve. If poorly managed, such a jump has the potential to temporarily impair some of the operations of the laboratory. For example, a jump from point A to point B or from point C to point D involves a reduction of useful output calibrated on the vertical axis. Although the laboratory expects to move along its new S-curve quickly and recover its lost output, this initial impairment is highly undesirable. If implementation of the new technology is carefully managed, the laboratory may be able to move directly to point B' or D'—or even higher. (continued on p. 90)
Post-analytic information management

About 15 years have passed since the appearance of microprocessors in the laboratory environment, and much of the uncertainty regarding the use of information technology in the hospital laboratory has now subsided. It is rare that a clinical laboratory, particularly in a large hospital, has not adopted some form of new information technology. In other words, the deployment of devices such as an LIS or a microcomputer has become inevitable because of quality and efficiency imperatives. Therefore, all clinical laboratories can be placed on one of the S-curves within the post-microprocessor family. However, the specific curve along which a particular laboratory is traveling will be determined by the extent and skill with which the new technology has been adopted, mastered, and integrated with other health-care products and systems.

The most pronounced effects of the deployment of information technology will involve post-analytic information management—the communication, storage, and retrieval of information after it has been created. With regard to both the pre-analytic and analytic activities of laboratories, the LIS automates preexisting activities such as communicating test orders, creating work lists, entering results, or verifying results. Therefore, the LIS does not spur a major redefinition of the role of the laboratory professional in these particular domains.

By way of contrast, consider how the deployment of an LIS in a hospital affects post-analytic information management by laboratories. Before the LIS, information generated within laboratories was reported to clinicians via hard copy reports or the telephone. These communication techniques were not particularly flexible or efficient, but they did not offer much opportunity for the misuse of the reported information. Today, information in electronic files, such as laboratory test results, can be distributed, retrieved, copied, erased, extracted, merged, purged, filtered, concatenated, overwritten, and edited. And therein lies one of the major challenges of the information era; any one of these processes can either enhance the value of the information product or inexorably alter it for better or worse.

Because there has been little opportunity or need until relatively recently for laboratory professionals to actively manage information in the laboratory database after it had been generated, it is not surprising that the professional scope of laboratory professionals must now be modified in response to the new information realities and environment. The generation of information within laboratories should be considered the beginning—not the end—of the professional responsibility of laboratory professionals.

If laboratory professionals do not aggressively assume responsibility for actively managing laboratory information, control of the database may pass—by intention or by default—to others. We do not mean to dwell unnecessarily on the real or potential competitive threats to laboratory professionals. It would be just as accurate to say that information technology deployment provides an enhanced opportunity for laboratory workers to increase the quality and efficiency of the laboratories in which they work. Stated another way, information technology deployment provides both strategic opportunities and threats. It is important to be aware of both elements of the equation.

Timing the adoption of information technology

Almost all hospital-based laboratory professionals face threats from various competitors, such as commercial reference laboratories, pathology groups in local competing hospitals, and the mainframe computer group within the hospital. Mainframe computer personnel are not competitors with regard to the actual performance of laboratory tests, but they may define their professional role as the primary information managers for a hospital. In this way, they compete with laboratory professionals with regard to information management.

The immediacy of the threat posed by competitors will not affect all laboratory professionals equally. Some pathology groups may face little competition from hospitals of comparable status in their areas or may be located in hospitals in which the mainframe computer group is slow to adopt new information technology. For such groups, there may
be little need to react immediately to the challenges of the information era. However, such a benign and forgiving environment will not last forever.

Several competitive pressures are likely to emerge in the very near future. Hospital administrators may solicit bids from commercial laboratories to reduce testing costs. Competing community hospitals may increase their occupancy rate by improving laboratory services. Mainframe computer groups may spread the costs of their systems across the entire hospital by adding clinical modules such as laboratory or radiology to the financial and administrative applications currently running on their systems. Because competitive pressures will affect laboratory professionals at different rates, some will have more time than others to assess the technological changes needed to react to the environmental changes. In time, however, all laboratory professionals will have to act or risk deemphasis of their professional role.

Laboratory professionals must trade off the costs and benefits of early and late jumps to new S-curves. The pioneer laboratories, in terms of implementing information technology, will need to cope with the problems of implementing relatively new types of equipment and systems and will undoubtedly make many mistakes. In Figure 1, pioneers may be more likely to jump to point D than to D'.

However, as a result of this experimentation, the pioneers may arrive at an understanding of successful new information technology earlier than their competitors. If the new technology allows laboratories to produce higher quality and more cost-effective information products and to operate more efficiently, the pioneers and their followers will be well positioned to take advantage of the technological changes that are occurring. Despite initial problems, they may arrive at point D' before their competitors or even jump more quickly to the next S-curve.

Assessing whether an individual hospital laboratory is a pioneer in terms of deploying emerging information technology is relatively simple. Review the history of the laboratory with regard to the initial installation of an LIS and subsequent upgrades of the system, the use of new automated analytic instruments, and even the adoption of fax technology for transmitting hard copy reports to remote reporting sites. Another litmus test is how laboratory managers perceive the importance of emerging information technology such as the LIS and computer networks. If they are not perceived as necessary for efficient laboratory operations, the laboratory is probably working its way up an earlier, and probably outmoded, S-curve.

Conclusion

Control over information systems and power will not be awarded by default; it will go to those departments and individuals that begin to offer solutions for the problems facing hospitals (5). Laboratory professionals who view these changes as opportunities will achieve a strategic advantage over their competitors because they will begin to grapple with them earlier and to reinvent their professional roles accordingly.

The message of this article is that laboratory professionals must be more entrepreneurial. The entrepreneur, according to Drucker, “always searches for change, responds to it, and exploits it as an opportunity” (6). For laboratory professionals, the opportunity provided by computer-based information technology is to maintain and enhance their role as information managers and specialists, thereby supporting their ability to provide high quality and efficient care to patients (7,8).

REFERENCES

Careful management of the implementation process will involve greater resource utilization than an initial move to the suboptimal points B or D. The initial decrease in useful output is related to the disruption of normal laboratory work routines through the introduction of the new technology, the required training costs, and the capital investment in the new information system. Training costs are commonly underestimated when budgeting for a new LIS. The seemingly lower costs of haphazard implementation of a new system are illusory, however, because increased costs will ultimately be incurred to proceed to point B' or D' and beyond. Only after successful implementation will the laboratory begin to ascend the new S-curve and realize the sought-after quality and efficiency gains that initially prompted the deployment of new technology.

This scenario concerning the ascent of a particular S-curve assumes that the correct LIS has been chosen at the time of technology purchase. In this context, correct means that the device functions well and produces all available benefits. If an incorrect LIS has been selected, or if organizational inefficiencies within a particular laboratory degrade the anticipated performance of a correct system, output will deteriorate following system deployment. In this situation, the information technology fails to serve its intended purpose.

Following a technological discontinuity, a shift similar to a jump within an S-curve family will occur, but this shift often involves greater use of resources and a greater increase in useful output. Two families of S-curves that bridge the technological discontinuity caused by the introduction of microprocessors into hospital laboratory practice are shown in Figure 1. This discontinuity resulted in increases to quality, such as an increase in the number of tests that could be performed and more rapid turnaround time. At the same time, however, the new devices created expenses not associated with the older laboratory technology.

Quality, efficiency, and total cost of laboratory operations

The most important reasons for deploying new information technology in hospital laboratories are to increase the quality and efficiency of clinical laboratories (4). Quality is defined as enhanced effectiveness and appropriateness (i.e., achieving chosen goals and doing the right things). Efficiency considers the average cost of the useful outputs of the laboratory. The vertical axis of the graph in Figure 1—useful output—is roughly equivalent to effectiveness plus appropriateness—or quality. The slope of an individual S-curve (i.e., useful output divided by resource utilization) can be considered as a measure of efficiency.

Resource utilization, and therefore costs, may increase as new techniques and devices are introduced. This increased resource use is consistent with claims that the cost of hospital technology has risen drastically in the past three decades. A hospital may be reluctant to incur such increased costs, even with concomitant increases in useful output. Therefore, laboratories may not be able to muster the resources to jump to a new curve, even if anxious to do so. However, this capital budgeting issue is beyond the scope of this paper.

Increased costs incurred in clinical laboratories because of technology deployment may be balanced by decreased costs elsewhere in the hospital. For example, reducing the turnaround time of test result reporting may reduce the total cost of health care for patients in both inpatient and ambulatory care settings. Because Figure 1 reflects only costs incurred within clinical laboratories and does not incorporate cost reductions that might be achieved elsewhere in the hospital, it may exaggerate overall increases in resource utilization required by the adoption of new technology in laboratories. However, even within laboratories, cost reductions can be achieved when working with a mix of current and past technology. Such reductions may occur in one of two ways. Either the laboratories move backward to an earlier S-curve, or they learn to use the mix of technology of the current S-curve more efficiently.

The quality of care may diminish when efficiency gains are achieved by the elimination of diagnostically or therapeutically useful services (4). Moving back to an earlier S-curve, therefore, is likely to be inappropriate and “anti-quality.” By using existing resources more efficiently, however, laboratories can reduce total costs without impairing quality. This is represented by the backward bending portion of the curve, which is entered after the laboratory incurs the initial start-up cost and learns to use the information system.
Even if total costs incurred by a laboratory rise when a new laboratory technology is adopted, increased efficiency may still be attained when the laboratory jumps to a new S-curve. This seemingly contradictory statement follows from the definition of a gain in efficiency as a decrease in the average cost of useful output. In other words, if a new technology permits laboratories to increase useful output at a greater rate than the increase in resource utilization, the new level of useful output is more efficient than the old. In Figure 1, we depict such a reduction in average cost by raising the S-curve families above a 45° line from the origin. If, instead, the new curve largely fell below a 45° line, this would indicate that overall efficiency gains are not keeping pace with the gain in useful output.

The challenge of the top flat portion of the S-curve

The S-curves presented here represent the idea that the quality and efficiency of laboratory services will increase after adopting a new combination of information technology. However, after deploying a particular mix of information technology over a period of time, the laboratory will arrive at the "top flat" portion of an S-curve. At this point, the maximum achievable gains in terms of quality and efficiency will have been nearly wrung out for the mix of technology in current use. In other words, the absolute amount of useful output cannot be increased much further, and efficiency will begin to decline. It then becomes necessary for laboratory professionals to deploy a new mix of information technology to achieve higher quality and efficiency (i.e., to attempt to jump to a new S-curve).

Having achieved a new S-curve status, a similar process of S-curve ascent begins anew, but laboratories can now achieve a previously unattainable level of quality. This ascent of the S-curve yields a strategic advantage over competitors who may be operating on the top flat portion of the previous S-curve and for whom additional resource expenditures will not yield commensurate gains. Such competitors have reached the limits of their current technology. Therefore, more intensive use will not yield additional benefits.

Information technology and enhanced useful output

Let us expand on our depiction of the S-curves in Figure 1 as canted slightly backward—a modification of Foster's concept of S-curves that were tilted only in a forward direction. The forward-tilting S-curve assumes that increased levels of useful output will always be accompanied by increased resource utilization. Our slightly backward-tilting S-curves relax this assumption and show that upward movement of a laboratory along an S-curve can result in higher absolute levels of useful output for a given, or lower, absolute level of resource utilization.

Our representations of S-curves may be criticized because they appear to represent "something for nothing." Can both increased useful output and declining total resource expenditures occur after the installation of an LIS in a laboratory and yield simultaneous quality, efficiency, and total cost dividends? We argue that this proposition is correct. The key to this dilemma hinges on the change in realizable useful output that occurs following successful implementation of a new information technology.

Many desirable tasks that could not be undertaken before become standard operating procedures in the new environment. Before the deployment of an LIS in a laboratory, for example, delivery of patient test results to physicians in critical care units immediately following result verification was theoretically possible—but prohibitively complex and expensive to implement. The rapid retrieval of test results by physicians on demand from a long-term historical hard copy archive could be similarly described. With an LIS, however, such information retrieval and reporting services are considered routine and, in fact, are commonly used to justify the initial system purchase. Given the deployment of the correct LIS, a supportive organizational environment, and a reasonable attempt to quantify all of the system's useful work, it is eminently reasonable to expect increased useful output in relation to resource expenditures.