Using Cognitive Artifacts to Understand Distributed Cognition*

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Abstract - *Studies of patient safety have identified gaps in current work including the need for research about communication and information sharing among health care providers. They have also encouraged the use of decision support tools to improve human performance. Distributed cognition is the shared awareness of goals, plans, and details that no single individual grasps. Cognitive artifacts are objects such as schedules, display boards, lists, and worksheets that form part of a distributed cognition. Cognitive artifacts including the Availabilities Sheet, Master Schedule, Operating Room (OR) Graph and OR Board provide a "way in" to understand how acute care teams plan and manage the balance between care demands and staff resources. This work has import for the way that medical informatics supports the organization, management, and use of health care information through software and computing systems. Better digital cognitive artifacts will benefit team work processes, planning, communications, resource management and, by extension, patient safety.*

Keywords: cognitive artifacts, distributed cognition, patient safety, distributed planning, health care

1 Introduction

Studies of patient safety [4] have identified gaps in current patient safety research including the need for "research about communication and information sharing among health care providers..." Recent research into patient safety issues [5] strongly encourages the use of decision support tools to improve human performance.

Research into cognitive activity in surgical and critical care is challenging for a number of reasons. Care settings, patient populations and system constraints vary widely. Practitioners often suffer from poor insight into how their work is organized. Information and interaction at the sharp (operator) end is dense and complex. The researcher in this setting needs to employ viable research methods in order to understand cognition in the surgical and critical care environment. Woods and Roth's [17] cognitive engineering approach studies behavior in multidimensional actual environments in order to change behavior and improve performance. Klein's [11] naturalistic decision making (NDM) accounts for the performance of decision makers in actual settings. Hutchins' [9] ethnomethodology describes how a group forms a distributed cognition that includes artifacts to accomplish shared goals. The collective use of these methods is referred to as the "NDM approach." The surgical and critical care environment meets the criteria for a naturalistic decision setting. [16] Synchronizing the interactions among many elements within short periods means *time is pressured*. In critical care it is routine that *stakes are high*, as outcomes can have a significant effect on morbidity and mortality. The seniority that is required to manage daily activities means that *practitioners are experienced*. No individual has all of the knowledge that is necessary for coordination, and as a result *information is inadequate*. The multiple agendas that drive various staff means that team goals are *ill defined* and sometimes conflicted. All critical care activity occurs at the sharp (operator) end, which is a *rich context*. Emergencies, cancellations, unprepared or absent patients creates continually *dynamic conditions*. Demand changes, influencing patient availability, procedures to be performed. Supply changes, adding to or diminishing staff availability. The number, type and duration of procedures is continually subject to change. Emergent needs can upset plans at any moment. Because the team coordinators lack first hand knowledge of what is needed to manage the schedule, *coordination among all team members is essential*. Multiple professional skills are brought together in order to perform services, from physicians to nurses, technicians, and clerical staff. Intricately related elements including staff, facilities, equipment, procedures, patients and their families must come together at specific times in a certain state of readiness. Accomplishing this task required the coordination of many individuals and departments across various times and locations.

1.1 Distributed Cognition

Distributed cognition [9] is the shared awareness of goals, plans, and details that no single individual grasps. Through a socially distributed cognition [15], individuals cultivate a mutual awareness and an understanding that is timely, thorough and accurate in order to collectively accomplish shared goals. The complexity of acute care requires the orchestration of multiple departments including Anesthesia and Critical Care, Surgery, Nuclear Medicine, Obstetrics and Gynecology, Gastrointestinal Endoscopy,

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Interventional Radiology, Diagnostic Radiology, and Psychiatry. Such coordination relies on the development and use of artifacts.

1.2 Cognitive Artifacts

Cognitive artifacts [10] are objects such as schedules, display boards, lists, and worksheets that form part of a distributed cognition. Artifacts in the hospital organization are products of various departments that are distributed in time and location. Artifacts are used to collect and provide information and they evolve through many conditions and pass through many hands. The effort that is expended to develop and maintain and the reliance placed on these cognitive artifacts demonstrates the value that they have for the acute care team. Badram [1] outlines five strategies that acute care teams employ in order to coordinate collective activities across department, time and space: minimize articulation among collaborators, prioritizing and scheduling work and ensuring commitment to the schedule, sharing information and maintaining an overview, ensuring fair and optimal workloads and anticipating, planning and pre-handling work. The artifacts that are used to mediate this collective work "need to be shared as a way of maintaining an overview of the total activity."

1.3 Coordinator Activities

Attending and resident anesthesiologists provide life support and pain management during critical health care procedures (particularly surgery). Certified Registered Nurse Anesthetists (CRNA) are specially trained registered nurses who are certified to perform anesthesia under the supervision of an attending anesthesiologist. The conduct of a single anesthetic and surgery requires synchronized and coordinated effort from every department that is involved.

A select group of more senior anesthesiologists take on additional work as anesthesia coordinators who plan and manage anesthesia staff assignments. The process of planning and managing the OR and outpatient clinic are far more complex than most outsiders appreciate. Care providers and support staff all have to appraise the published schedule, distribute resources, coordinate their efforts with those of other personnel and reassess their situation and plans in frequent cycles through the day. Cognitive artifacts are embedded throughout the process. As each procedure unfolds, the Anesthesia Coordinator (AC) and Nursing Coordinator (NC) rely on the pager or phone, and reading or writing on the master schedule or OR Board to balance resources with demand across the unit. The twenty-four OR's at Pacifica, the author's research site, handle roughly fifty to eighty procedures every day.

1.4 Planning Process

Plans for each day's procedures start a year beforehand. Figure 1 shows the time line that begins with the Department of Anesthesia and Critical Care's annual plan.

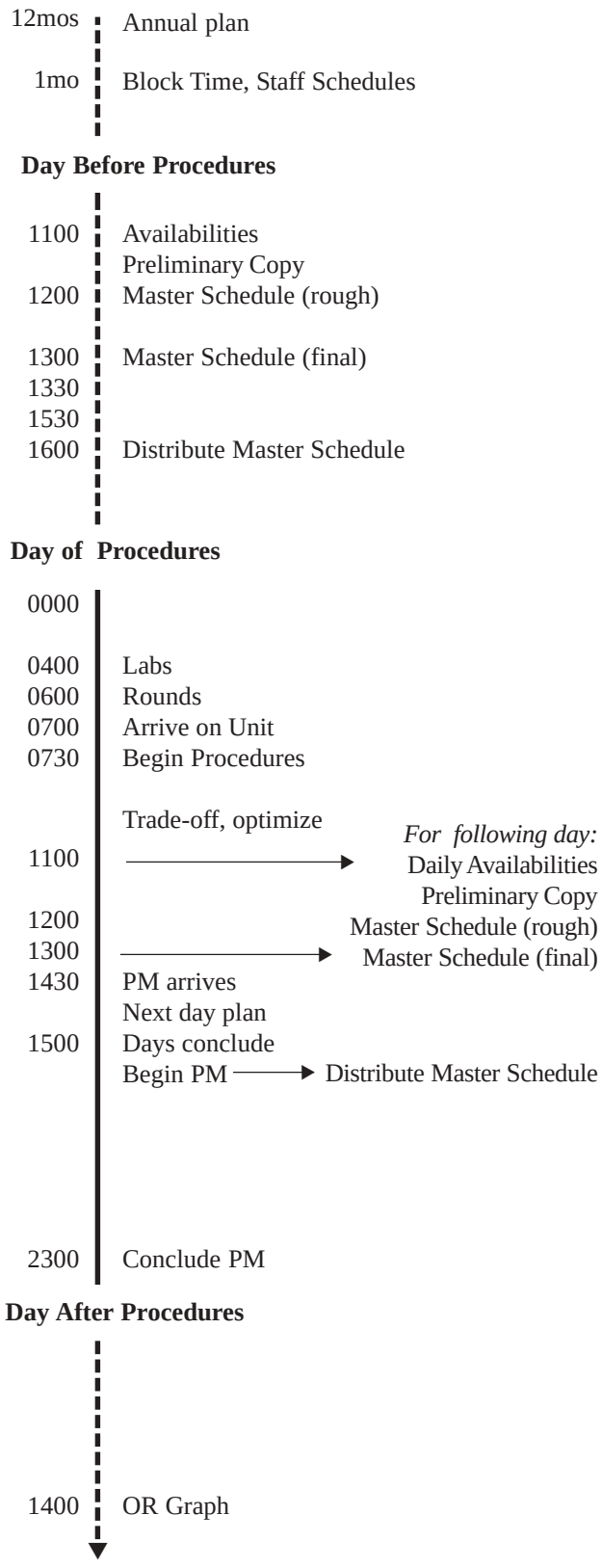

Figure 1. Schedule Time Line

The annual plan reflects long term staff issues such as leaves of absence, retirements, schooling, hiring intentions, expected numbers of residents, vacation plans. The master schedule for anesthesia assignments evolves from annual to monthly to daily schedules. The sequence to develop, execute and complete the master schedule for each day actually spans three days, as the diagram shows. The anesthesia coordinator prepares the final master schedule at around 1100 each day, starting the cycle for the next 24 hours. Production of the OR Graph the next day completes the cycle.

2 Cognitive Artifacts as a Research Tool

Sociologist Herbert Blumer's [3] symbolic interactionism explains social behavior as each individual's response to the meaning that the person attaches to others' actions. In order to understand the actions of people, it is necessary to identify their world of objects, whether physical, social or abstract. Objects reflect the nature and changes that occur in the life of the group because human group life is a process in which objects are being created, affirmed, transformed and cast aside. People actively manage the dynamic characteristics of their work place by drawing on a deep knowledge of their work domain to create and use artifacts. Cognitive artifacts are physical objects that acute care team members create and use in order to manage their work environment. Studying these artifacts reveals the deep knowledge that team members have used to create them.

Two themes guide this research into acute care cognition. The first is the effort to understand the work domain as a complex, high hazard, time-pressured, interrupt-driven environment. The second is the effort to understand how acute care team members manage the domains using strategies such as anticipation, hedging and husbanding resources and making trade-offs. Artifacts reveal information about both themes. Artifacts are highly encoded representations of what matters in this domain. Artifact encoding conveys the information in a compact, efficient manner. Their content is inherently connected to what is meaningful in the domain.

Nemeth [13] demonstrates how the study of cognitive artifacts including the Availabilities Sheet, Master Schedule, OR Graph and OR Board provides a "way in" to understand how acute care teams plan and manage the balance between care demands and staff resources. Figure 2 shows how this research used artifacts to study cognition at the unit level in two directions. One direction shows how an artifact evolves into a plan and then the reality of a daily schedule. The second direction ruse the artifact as a highly encoded representation that describes the nature of this complex work domain. While the first approach shows how the artifact is created, the second approach uses the artifact to reveal the basis for its creation.

2.1 Coordinator Analysis

The first approach studied how anesthesia coordinators plan for the daily schedule in the OR unit and outpatient clinic and then manage it the following day. The author invited coordinators to write a schedule while being recorded on videotape. Four coordinators out of eight were available and agreed to participate. Three coordinators were willing to be videotaped. Summaries of the sessions included three elements: verbal transcript, annotated artifacts, and cognitive activity analyses. Categorization, classification and analysis were used to produce a formalized performance description [8] for a numberof anesthesia coordinators who wrote daily schedules. Each session analysis was formatted in three columns in order to show the simultaneous interaction between cognition and artifact.Verbatim transcripts of the coordinator's verbal protocol are shown in the left column. Cognitive artifacts that the coordinator uses during the session are shown in the center column. Diagrams that represent the system state as it evolves are shown in the right column along with comments on the major phases and incremental steps of cognitive work.

The analyses reveal the deep structure that is behind coordinator scheduling.Transcripts of their description while writing the schedule indicated the processes that coordinators employ. Analyses of the sessions show how the coordinators allocate resources to meet demand in the interest of staging how activity should occur the following day.

2.2 Artifact Analyses

Cognitive artifacts can be used to learn about the work they have been designed to support. For Hutchins [9], "cognitive artifacts are involved in a process of organizing functional skills into functional systems." This amounts to "a category of processes that produce cognitive effects by bringing functional skills into coordination with various kinds of structure." The study of a cognitive artifact yields insight into the nature of the artifact itself as well as insight into the technical work situation and intentions that the artifact represents. Focusing on artifacts provides an opportunity for researchers to identify critical features of the domain and work situation. This is because cognitive artifacts typically are used to support important, difficult activities. The work that the artifact is designed to support can also be improved by making a better artifact. Better information design or improved use of information technology (software) can make technical work more enjoyable, more efficient, and more reliable.

The second approach studied the acute care team using observation and interview methods in order to understand how they use cognitive artifacts to manage their daily activity. The author captured subject comments and events as they occurred by writing field notes of daily activity into two pocket-size booklets. He conducted informal interviews with roughly 25 nurses and coordinators and 40 anesthesiologists/CRNA's and anesthesia coordinators during observations. He reviewed the structure and variations of roughly fifteen daily availabilities, master schedules and OR Graphs over three months. During this time the author wrote twelve case studies to synthesize the observations, comments from informal interviews and analysis. Each case study followed a similar structure:

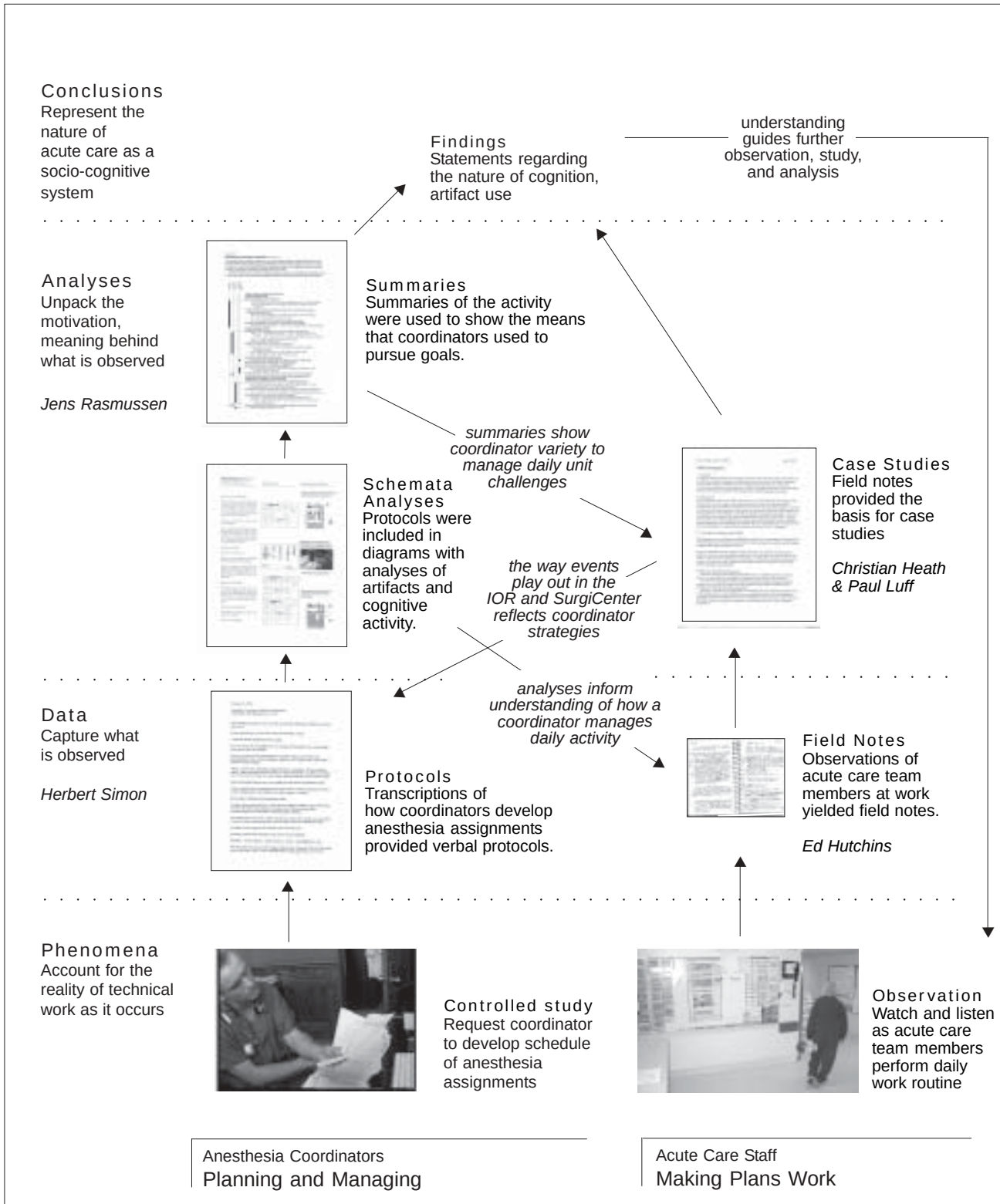

Figure 2. Methods to Research Acute Care Cognition

title, brief summary, background, sequence, and comment. The sequence section of the case study included actual behavior and quotations that occurred during observations. These data form the foundation on which conclusions about acute care cognition are based. The author "unpacked" the meaning that was embedded in observed behavior in the case study comment section. Comments showed how schedule development played out in the OR unit and outpatient clinic, reflecting coordinator strategies.

3 Issues

Scheduling fails when gaps [6] occur in the continuity of care. Loss of information, incomplete, or poor quality information can affect both schedule development and unit management. Coordinator efforts and their use of artifacts strive to maintain an accurate description of the current and the intended state of the system. The artifacts serve as a tool to bridge the boundaries of departments, laboratories and individuals that must collaborate.

What does this have to do with safety? Anesthesia coordinators develop schedules that result in successful outcomes. Inability to synchronize erodes the ability of the team. Staff, tools or equipment fail to converge at the same moment in time. Patients fail to receive the care that they can, or must, receive. Team cohesion breaks down as leader credibility suffers. Care delayed is care denied.

Obstacles to the use of computers in health care have not been computers. The actual obstacle has been to understand the complex health care domain in which such systems exist. Electronic cognitive artifacts are implemented in acute care for a variety of reasons. Systems may be intended to improve billing, to extend the efficiency of a system that has been installed in other units or offices, to take advantage of recent developments in software or electronics technology, or obtain higher status by cultivating the impression of being at the leading edge of technology. None of these agendas take into account the needs of those who are at the sharp end.

Nemeth [13] describes how a recent digital version of the master schedule impedes rather than helps team members. A hard copy of the master schedule continues to be posted daily in the OR unit six months after digital system's "go live" date. That indicates the level of trust that unit members still have in the physical artifacts and have yet to develop in the electronic system. Bardram [1] and Berg [2] also describe instances in Denmark and in the United Kingdom in which physical artifacts that were supposed to be replaced by electronic system still remain in use. Failures such as this and others described by Heath and Luff [7] and Luff, Hindmarsh, and Heath [12] have resulted in a collective resistance among practitioners to the acceptance of new information technology.

It is not enough to agree that automation does not serve acute care needs. The next step is to use the preceding deep look into acute care planning and management to develop guidance for computer-based information support. Electronic versions of cognitive artifacts will need to surpass what physical artifacts provide in order to justify the costof their development and operation. That will require a deep grasp of the joint cognitive system that is acute health care

4 Findings

Information technology has much in common with analog artifacts, as they are often modeled as iconic representations of physical tools. Understanding the origin and nature of the analog artifacts relies on deep and sustained observation of the groups and activities they support in order to derive their meaning. Few information technology projects invest the necessary attention to this understanding. The result is systems that seek to leverage technological capability while being blind to the sophisticated, refined interactions that practitioners have developed to perform complex work [7].

The study of cognitive artifacts is an effective, efficient means to understand high hazard complex work domains. Through the use of the methods that are described in this paper, the author has discovered a number of insights that have implications for the development of digital cognitive artifacts. At a minimum, any cognitive artifact in this environment, whether physical or digital, must be:

Accurate—Current and valid in its representation of the system state

Efficient—Impose the least burden on users to create and use information.

Reliable—Available for use when needed.

Informative—Contain information that pertains to circumstances of interest to the team

Clear—Unambiguous and free from confusion

Malleable—Able to be manipulated by those who use them

With success in these criteria, digital cognitive artifacts can move forward to add value to acute care planning.

Prompting—Digital artifacts might survey information in the distributed cognition for gaps and inconsistencies that go unnoticed and unaccounted for. Nominating such item(s) for the schedule writer to consider would enrich and improve the cognition.

Speculation—Digital artifacts can make it possible for coordinators to speculate about possible courses of action and then choose among them. Providing multiple options for evaluation would make their consideration more thorough.

Consequences—Applying evaluation criteria to potential courses of action could make it possible to display the consequences of choices. For example, a system might show how billing could be increased or how costs could be minimized by opening one room or closing another.

Value-based decisions—Digital artifacts can be used to develop templates of schedule planning strategies. Coordinators can review and employ a template that best matches their values and preferences. Such templates can capture scheduling expertise and make it available for use by others, expanding best schedule writing practices beyond a single individual. Study of template use through time might open the way to insights about coordinator training and the development of schedule models to ease coordinator work loads.

4 Conclusions

This paper has described the nature of planning technical work in the high hazard environment of health care. It has described the use of cognitive artifacts to understand that work domain and has demonstrated the value that the method has for the development of digital cognitive artifacts.

Well-considered understanding of work domains that employ approaches must serve as the basis for the development of digital cognitive artifacts. That understanding must rely on deep understanding of those domains derived from research based on approaches such as those described in Nemeth [13] and Nemeth [14] . Without it, information systems will continue to impose an impediment to the health care providers such systems are intended to serve. With such research, digital cognitive artifacts have the potential to add value to acute health care. Improved artifacts that eventually prove trustworthy may also diminish the well-deserved resistance that practitioners currently show.

Better digital cognitive artifacts will benefit team work processes, planning, communications, and resource management. By extension, such improvements will also enhance patient safety.

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