

Barriers to Implementing Wrong Site Surgery Guidelines: A Cognitive Work Analysis

Michelle L. Rogers, Richard I. Cook, Robert Bower, Mark Molloy, and Marta L. Render

Abstract—In 1998, the Joint Commission on Accreditation of Healthcare Organizations identified important contributors to surgical site misidentification in the operating room (OR), including communication breakdown between surgical team members and the patient, availability of pertinent information, failure of OR policies and procedures, incomplete patient assessment, and distraction. Prior to this, the American Academy of Orthopedic Surgeons (AAOS) among others, developed guidelines intended to reduce the likelihood of misidentification in surgical procedures. We hypothesized these guidelines were inconsistently implemented because of the failure to account for the dynamic complex OR environment. Over 40 h of direct observation of the entire care process (from initial consultation through post-operative care) were conducted at two hospitals. Our analysis identified critical process elements that impact the outpatient surgical process of identification. Time pressure, crosschecking, uncooperative communication culture, complexity in the work process, attention/distraction, and documentation concerns make guidelines that rely on verification of the site complicated and vulnerable to error. Suggestions for improvements in processes are made.

Index Terms—Collaborative work, human factors, medical decision-making, surgery.

I. INTRODUCTION

IN 1998, the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) reported that the numbers of wrong-site surgeries were on the rise despite several high-profile cases and the national attention being paid to medical errors [1]. In that year, close to 20 wrong-site surgeries were reported. By December 2002, more than 60 wrong-site surgeries had been reported. In a review of their root cause analyses reports, JCAHO identified six common factors that contributed to wrong-site surgeries: 1) emergency cases; 2) unusual patient characteristics; 3) intense time pressure; 4) operating room (OR) characteristics; 5) involvement of multiple surgeons, or 6) multiple procedures during a single OR visit, with the majority of

cases involving a breakdown in communication [2]. In this interval, wrong-site surgeries also increased in the percent of errors reported, from approximately 8% of all errors in 1998 to more than 15% of the total in 2002 [2]. In light of these findings, a national alert was issued to rally the medical community. JCAHO reviewed its root cause analyses reports and identified contributors to adverse events resulting in wrong-site surgery. The top seven contributors were: 1) communication, 2) orientation/training; 3) patient assessment; 4) availability of information; 5) procedural compliance; 6) OR hierarchy among team members; and 7) distraction.

Several agencies [3]–[5] including the American Association of Orthopedic Surgeons (AAOS), the American College of Surgeons, the Joint Commission on Accreditation of Healthcare Organizations (JCAHO), Association of OR Nurses (AORN), Veterans Health Administration (VA), and the VA National Center for Patient Safety proposed “best practices” guidelines to prevent misidentification during surgery following the lead of their Canadian counterparts [6]. Among these guidelines, only the VA tested and iteratively refined their guidelines at ten hospitals before mandating a guideline to ensure correct surgery [5]. All of the published guidelines include one or more of the following:

- 1) marking the surgical site;
- 2) involving the patient in the marking of the site;
- 3) using a verification checklist;
- 4) verifying the site by obtaining oral verification from the patient and/or family member and from each member of the surgical team in the OR;
- 5) monitoring compliance with these procedures;
- 6) incorporating “time outs” to assure the correct patient, procedure and site using active rather than passive communication.

Despite “best practice” recommendations, a survey by the AAOS following their marketing campaign in the 1990s to “mark the site” found that only 40% of orthopedic surgeons initial or mark their operative sites [7]. In fact, little empiric evidence addresses the efficacy, the cost or the unexpected consequences in implementing these new “best practices” in the OR [8]. Examining how the “best practice” recommendations interact with workflow processes closes a critical gap in the knowledge base regarding effective interventions to reduce the risk of wrong-site surgery. To examine the interaction, we used a human factors engineering approach of observation and interviews to characterize care processes, artifacts (or tools), and team interactions that promoted (facilitators) or hindered (barriers) correct identification in successful surgical procedures [9]–[11].

Manuscript received March 31, 2004; revised June 4, 2004 and July 27, 2004. This paper was recommended by the guest editors of this special issue.

M. L. Rogers and M. L. Render are with the Getting at Patient Safety (GAPS) Center, Department of Veteran Affairs, Cincinnati, OH 45220 USA and the Division of Pulmonary and Critical Care, College of Medicine, University of Cincinnati, Cincinnati, OH 45221 USA (e-mail: michelle.rogers@med.va.gov; marta.render@med.va.gov).

R. I. Cook is with the Cognitive Technologies Laboratory, University of Chicago, Chicago, IL 60637 USA (e-mail: ri-cook@uchicago.edu).

R. Bower and M. Molloy are with the Department of Veteran Affairs, Cincinnati Medical Center, Cincinnati, OH 45220 USA (e-mail: Robert.Bower@med.va.gov; Mark.Molloy@med.va.gov).

Digital Object Identifier 10.1109/TSMCA.2004.836805

TABLE I
CHARACTERISTICS OF FACILITIES

	Moderate-Sized Facility Metropolitan Federal Facility	Large Facility Metropolitan University Teaching Facility
Type		
Patients	Adult	Adult, Pediatric
# inpatient beds	155	315
# outpatient visits	298,134	372,731
Outpatient Care		
<i>Electronic Medical Record</i>	Yes	Yes
<i>OPC Surgical Coordinator*</i>	Yes	Yes
<i>Exam rooms</i>	12 (surgical only)	90 (OPC)
<i>Electronic Radiology</i>	Yes	Yes
<i>Laboratory /Radiology Services</i>	Yes	Yes
Operating Room		
<i># OR rooms used</i>	4/6	5
<i>Average number of cases / day</i>	5	5
<i>OR operating hours</i>	7 AM - 3 PM	7AM - 5 PM
<i># MD Staff</i>	30	600 MD
<i># RN staff</i>	25	1000
<i>Anesthesiologists</i>	1	3-5
<i>Anesthetists</i>	4	2-3
Teaching Hospital	Yes	Yes
Surgical Referral Center	Yes	Yes

II. METHODS

A. Setting

One researcher observed actual surgical cases (verbal consent obtained) and operative processes at two outpatient surgical facilities, a large metropolitan university teaching service, and a moderate-sized federal facility. Characteristics of the sites are summarized in Table I. A description of each facility follows.

The moderate-sized medical center provides inpatient (patients residing in the hospital) and outpatient (nonresident patients at the hospital) health services and is a major teaching hospital for a local college of medicine as well as over 30 other professional, allied health (e.g., physical therapy, medical assisting, radiologic technology), and nursing schools. Annually, over 1000 students receive training at this facility. A surgical outpatient office coordinates initial diagnostic and treatment services serving as a tertiary (i.e., specialized) surgical referral center for other federal medical facilities in the region. This central contact point coordinates surgical evaluation and care for patients, such as laboratory testing for surgery in the preadmission testing area. Four of six operating suites are used primarily between 7:00 AM and 3:00 PM with an average of five surgical cases per suite, per day. Approximately 30 staff, including: registered nurses (RN); licensed practical nurses (LPNs); surgical technicians; housekeepers; residents; and attending physicians, work in the OR at varying times. There is one full-time staff anesthesiologist with several certified nurse anesthetists. Post-operatively, patients are cared for in the postanesthesia care unit (PACU).

The larger university facility is a state-of-the-art ambulatory-care (available to outpatients) facility with the full spectrum of preventive, diagnostic, and treatment functions. It is home to nearly the entire adult primary and specialty clinics, pediatric specialty clinics, and outpatient diagnostic and treatment facilities of this hospital system. This facility houses 315 exam

rooms, 90 rooms for outpatient procedures and five ORs for ambulatory surgery. Care is provided by more than 600 attending physicians (most are full-time university faculty members), 620 residents and fellows, and 1000 nurses. Physician offices are conveniently located next to related diagnostic and treatment services, enabling patients to receive care for all related medical conditions within the same area of the building. Lab testing services are available on several floors. The OR suite is composed of five rooms for ambulatory surgery and averages five surgical cases per day per room with a limited number performed after 3:00 PM. There are several full-time staff anesthesiologists with few certified nurse anesthetists.

B. Observations and Semi Structured Interviews

From October 2001 to February 2002, the research team used a hybrid methodology combining field observation of the entire surgical process and semistructured interviews at the two hospitals described above. For each observation period, one observer completed standardized data templates within two days of each data collection to minimize data loss and transferred handwritten detailed observational data to electronic notes and then to standard activity protocol formats. A total of 40 h of observation was completed. The patient was followed throughout the procedure process. The observer selected consecutive cases for observation from the clinic schedule, which were: 1) presented at the weekly presurgical briefing and 2) planned to have a surgical procedure with a lateral condition (e.g., lateral defined as "of/or relating to the side"). Ten surgeons and one anesthesiologist were observed during five preoperative briefing meetings regarding 70 cases at the moderate-sized hospital. At the presurgical briefing the resident and attending physicians reviewed the schedule for the upcoming week. In this conference, surgical personnel vigilant to the misidentification risk, identified the level of risk associated with each procedure as an awareness strategy.

C. Observations

We observed surgical care from the clinical outpatient encounter visit, immediate presurgery evaluation, to surgical care in the OR for three separate cases at the moderate sized facility. During the observations, the investigator tracked the actions of the staff, including use of memory aids, standardized forms, review of testing and written reports of testing, organization of the clinic visit, and type of staff and roles (e.g., resident, nurse, or case manager). This documentation was completed in order to create a model of the flow of information and patients from the outpatient clinic to the OR. For each observation period, one observer transferred handwritten detailed observational data, with frequent time stamping, to electronic notes and then to standard activity protocol formats. This was done within two days of each data collection to minimize data loss. The general operative process was observed at the outpatient surgical facility of the university teaching hospital. No actual cases were observed at this location.

D. Semistructured Interviews

Following the observation period, semistructured interviews were completed with members of the operating team, including surgeons. The semistructured interview data from each site visit was organized into templates documenting the nominal workflow on a typical day as well as sections for unexpected findings.

III. ANALYSIS

From the recorded observations and interviews, analysts characterized strategies, tools, defined roles, and missing information that: 1) required either site and/or patient identification information or that 2) were intended to improve accuracy of correct identification of the patient and laterality of the procedure. Each identified tool was examined for potential paths to misidentification, assistance for correct identification and for verification approaches. To increase generalizability, we only included strategies in our analysis if they were found in both OR environments. We defined “verification” when, in addition to a paper document, the worker sought some other source of identification (e.g., radiographs, patient, marked limb, etc.). We used data from the observations, artifacts, and interviews at both sites to cross validate and to increase validity from the themes.

IV. RESULTS

Most of the “best practice” guidelines are designed to be implemented in the OR; an environment, which at its worst, has intense pressure for efficiency, high risk for adverse events, life threatening medication regimens, is filled with interruptions where the patient, a critical source of information, is often sedated and unable to reliably participate in the identification confirmation. These factors further complicate the already complex task of surgical personnel to recognize the correct patient and correct sidedness (Table II). The fieldwork data reveal several points of vulnerability that are present before the surgeon begins the incision on the patient in the OR.

Only a few procedures were managed consistently between the two facilities. At the larger site, localized anesthesia administration is completed in specially designed rooms. For example, procedures that require a block of the sciatic nerve are positioned on the operating table in a certain way. At the moderate-sized facility, all local blocks are administered in the PACU before being moved to the OR.

A. Identified Barriers to the Guidelines’ Effectiveness

The wrong-site surgery guidelines can be grouped into three main strategies: 1) marking the surgical site; 2) patient and family participation; and 3) formalized verification process or cross-checking including use of a checklist, oral verification from the patient and/or family member, and from each member of the surgical team in the OR and timeouts; 4) monitoring compliance with these procedures. Several factors may create unexpected barriers to consistent implementation of these strategies: managing change (e.g., the ability to make and track changes across documents in the site), access to accurate independent confirmation of the operative site, and the traditional command structure in the OR impedes the practice of cross checking each other for accuracy.

B. Change Management

When a mistake is made in either marking the site or on the main documents that initiate the surgical process (the history and physical, the dictated note, the request to schedule surgery, and the consent), our sites did not have a consistent process to track and change all documents developed from the originals. For example, in one of the sites, the surgical schedule is posted at three locations at the end of the day to allow for the rooms to be set up in advance. One of the patients was unable to make their scheduled appointment and thus, all of the schedules had to be chanced and there was no way to tell which personnel had seen the old schedules and would see the new one. This is the type of mistake (wrong-site) that contributed to the “Willie King” case [12]. The “Willie King” case is the story of a patient whose leg was amputated erroneously. The subsequent investigation identified several system errors that contributed to this medical error including: the presence of two diseased legs, paperwork that was updated but not transmitted to all personnel, and miscommunication among medical staff, among others.

C. Site-Marking

Several aspects of the work process complicate implementation of site marking: 1) impermanence of the mark on the site; 2) difficulty changing the mark if made incorrectly or making the changes visible; 3) salience of the site (the ability to distinguish on inspection which organ requires surgical treatment); and 4) multiple surgeons. In addition, the common practice of marking the site in the OR eliminates the contribution of an important participant, the patient, since s/he is often already sedated. First, if the site is marked, the utility of the marking is only significant if the mark is permanent. When done too far in advance of the surgery, the mark may be removed in every day activities. Unfortunately, should the mark be too permanent (e.g., tattoo), inability to clearly remove an incorrectly placed

TABLE II
POINTS OF CONTACT IN THE SURGICAL PROCESS, VULNERABILITIES IDENTIFIED, AND PUBLISHED GUIDELINES

Guideline(s): [For pre-operative verification]	
Consent form must include:	
<ul style="list-style-type: none"> • Patient's full name • Procedure site, including laterality if applicable • Name of procedure • Reason for procedure 	
Process	Process Vulnerability
A. CLINIC/CONSULT <ul style="list-style-type: none"> - During visit, medical history, physical and consent form is completed (procedure set by facility) by clinician - All forms reviewed with clinician and patient before patient signature is obtained. - A request for surgery and/or the scheduling of the procedure is made by the clinician or administrative personnel. This is usually an additional action (e.g. form or screen in the EMR). 	<ul style="list-style-type: none"> • Wrong-site listed on consult request • X-ray absent, mislabeled or misread • Site for operation documented on the History & Physical incorrectly identified • Consent completed incorrectly • Dictation records lateral body parts incorrectly • No formal cross checks • Incomplete or inaccurate OR request (no lateral body part documented) <p>If an error is found, there are 6 artifacts that must be changed: Consult request, OR request, consent form, H&P, dictated notes & X-ray.</p>
B. PRE-ADMISSION TESTING (PAT) <ul style="list-style-type: none"> - Patients receive any testing that must take place before the procedure. - Verification of the correct person, procedure, and site should occur. 	<p><i>Examples of what happens if a mistake is not discovered</i></p> <ul style="list-style-type: none"> • If anesthesia department finds the error in documentation, there is no systematic dissemination of correction • If lateral body parts are both diseased, tests will not detect error
C. DAY BEFORE SURGERY <ul style="list-style-type: none"> - Surgery schedule is distributed and/or posted 	<p><i>Examples of what happens if a mistake is not discovered</i></p> <ul style="list-style-type: none"> • Schedule distributed with incorrect site • Changed schedule is not tracked • No systematic method to identify correction on schedule
Guideline(s): (Can be implemented days - hours before surgery)	
1. <i>Marking of the site:</i> A physician or other privileged provider who is a member of the operating team must mark the operative site. Do NOT mark non-operative site.	
2. <i>Patient Identification:</i>	
OR staff shall ask the patient to state (NOT confirm)	
<ul style="list-style-type: none"> • Their full name • Full SSN or date of birth • Site for the procedure 	
Responses are to be checked against the marked site, ID band, consent form or other documents	
Process	Process Vulnerability
D. DAY OF SURGERY PACU/Pre-Anesthesia <ul style="list-style-type: none"> - Patient arrives a certain amount of time before the procedure to be prepared - Most marking occurs at this point by the nurse or anesthesiologist (this role is assigned hospital wide) with a permanent marker in the operating room before the surgeon arrives. 	<p><i>Examples of what happens if a mistake is not discovered</i></p> <ul style="list-style-type: none"> • Schedule posted with incorrect site • Delay in patient arrival causes time pressure on start time • Attending physician does not always see the patient before they are anesthetized. • Incorrect Intravenous(IV) drug line placement
Guideline(s): [For operative verification]	
1. "TIME-OUT": within the OR, when the patient is present and prior to beginning procedure, OR staff must verbally confirm:	
<ul style="list-style-type: none"> • Correct patient • Marking of the correct site • Procedure to be performed • Correct patient position • Availability of the correct implant 	
2. Confirm with imaging data	
Process	Process Vulnerability
OPERATING ROOM <ul style="list-style-type: none"> - Anesthesia is begun - "Time-out" taken to verify procedure, site, patient, positioning, equipment 	<p><i>Examples of what happens if a mistake is not discovered</i></p> <ul style="list-style-type: none"> • Patient positioned on the operating table based on incorrect site information • Patient is marked after anesthesia (unable to confirm correct site) • Surgeon is not the one who completed the consultation • Imaging data missing, misread or mislabeled or doesn't exist.

mark introduces more opportunities for error. Second, the risk of an incorrectly placed mark increases when there is no visible sign of the disease or when both sides appear equally involved. The “best practice” guidelines seem to assume the saliency of the site is to be very high (i.e., easily identifiable). However, if the surgical site is internal or both organs are diseased, the guidelines lose some effectiveness in helping the surgical team to identify where to perform the procedure. Finally, multiple surgeons seeing the same patient, increase the complexity of site marking since there will need to be additional communication, possibly different cognitive models and different work habits.

D. Patient–Family Involvement

Although it is vital that patients are involved in the surgical identification process, environmental and individual factors can impede their participation. Cognitive problems caused by anxiety, confusion, dementia or medications, a sense of time pressure, cultural issues (e.g., a patient is a passive recipient of care), vocabulary and literacy level, the ability of the patient to hear in a noisy environment and see with or without visual aids, as well as the physical condition of the patient (e.g., some medical conditions make continuous attention to the discussion of identification or sidedness difficulty (e.g., severe pain, renal, or liver failure) may impair the successful collaboration necessary for compliance with suggested guidelines. For example, during one of the surgical procedures, the attending physician did not enter the room until the procedure was about to commence and the patient was already anesthetized.

E. Verification

Several gaps in the work process were identified during this study that make verification tasks vulnerable to failure. Interestingly, the outpatient environment is not used as a primary source to ensure verification despite its advantages that include an awake alert patient, review of and access to the radiology films themselves, nursing staff whose principal role is to schedule the surgery and collect the multiple forms, and the primary development of multiple documents that each separately list the surgical plan and site. In no case did we observe crosschecking or independent confirmation that both the consent, the schedule request matched either the note and or the radiologic report.

V. SUMMARY

Several shortcomings of the guidelines could be evaluated using techniques from the human factors knowledge base, including visibility of system status, task analysis, and cognitive work analysis. Currently, the majority of clinical information systems display data for individual practitioners and do not support distributed cooperative work. Decisions are made by multiple individuals, who participate in the surgical process based on the information that is available to them. Increasing the visibility of critical patient information and updates/changes to the system for the entire surgical team to see would assist in addressing the issues of overreliance on memory, team coordination and communication, change management and crosschecking. Access to visible information regarding the site

of surgery and consistent standardized practice of managing changes made to that data noted and highlighted in a standard way could reduce gaps and holes in the system.

An accurate match between best practices and the actual work process is key for compliance with the guideline-based practices. The current “wrong-site surgery” guidelines contain several hidden assumptions that impact the success of implementation. For instance, the guidelines that encourage the involvement of patients in the site-marking process assume that the patient is physically, cognitively, and emotionally able to correct any errors. Given the current practice, this may not be possible because of differences in work practice, e.g., not marking the site until the patient is anesthetized. Solutions that utilize the patient before their cognition is impaired could be explored. Similarly, performance on the minimal status exam might identify patients whose families could better act as a surrogate in identification confirmation when undergoing surgery.

Time pressure is probably the most studied factor in complex medical work systems. The “wholesale” model of medicine, profit being drawn from volume discounts, has had significant impacts on the surgical practice. A surgeon’s time is extremely precious, but guidelines that call for preoperative visits with the patient and “time-outs” in the OR both take time. In the usual day’s work, surgeons will not be so rushed as to compromise the marking process, but those are not the situations that usually result in unintended adverse events. System redesign must take into account the tradeoffs that are necessary when faced with such obvious goal conflicts. Research in human factors engineering demonstrates that solutions lay in less reliance on the memory of surgeons, encouraging team cooperation and technological tools that enhance physical identification.

VI. CONCLUSION

Identifying the correct site is critical when preparing for and executing a surgical procedure. This complex process involves multiple practitioners who diagnose the ailment, recognize the correct site for the procedure, secure the patient’s consent, and complete the appropriate operation safely and efficiently. Each activity requires access to information (e.g., patient chart, consent forms, imaging results or films), team collaboration (e.g., multiple providers with specific roles), and situation awareness (e.g., changes in the system, setup or patient health status) while balancing multiple tasks (e.g., multiple procedures during one visit, distractions), under continuous pressure for efficiency (e.g., surgeon time, room use).

Application of the guidelines in the present operative care model results in marking of the surgical site in the OR, and relying heavily on the recognition and memory of one surgeon. We found points of vulnerability in the surgical process with the greatest and easiest opportunity for recovery at the initial surgical consultation. What is also immediately evident is that clinical information systems are not robustly organized to confirm surgical sidedness early in the process; nor is there a system that informs and tracks the distribution of changes in response to incorrect information (detection and recovery are a critical element in creating safe systems). Finally, the guidelines are out of synch with existing processes, particularly in the expectation

that the surgeon will meet each patient prior to surgery to mark the site. Collectively, these data: 1) begin the evidence base for developing new robust processes for reducing hazard and injury to patients from misidentification in the OR; 2) confirm the complexity of the verification process and artifacts used to convey surgical intention; and 3) provide strong clues as to the presence of vulnerabilities present in the entire surgical process, not just within the operating suite.

This study identified the difficulties that give rise to wrong-site surgery and assessed the impact of guidelines on the processes of recognition. The surgical process is a tightly coupled complex system that includes multiple layers of interaction. There is no simple answer to this dilemma of the occurrence of wrong-site surgery. It is extremely unlikely that we can completely error-proof any process in such a dynamic environment, but we can enhance the resiliency already present in the system. This study has identified key areas of vulnerability in the guidelines' effectiveness providing a foundation for further investigation.

ACKNOWLEDGMENT

The authors thank the nurses and physicians for graciously allowing them to observe and interview them.

REFERENCES

- [1] A Follow-Up Review of Wrong Site Surgery, by Joint Commission on Accreditation of Healthcare Organizations (JCAHO). (2001). Available: http://www.jcaho.org/about+us/news+letters/sentinel+event+alert/sea_24.htm [Online]
- [2] Sentinel Event Statistics, by Joint Commission of Accreditation of Healthcare Organizations (JCAHO). (2003). Available: <http://www.jcaho.org/accredited+organizations/hospitals/sentinel+events/sentinel+event+statistics.htm> [Online]
- [3] Pre-Operative Protocols Panel—Final Report, by New York State Department of Health. (2001). Available: <http://www.health.state.ny.us/nysdoh/commish/2001/preopletter.htm#report> [Online]
- [4] Advisory Statement: Wrong-Site Surgery, by American Academy of Orthopaedic Surgeons (AAOS). (1997). Available: <http://www.aaos.org/wordhtml/papers/advistmt/wrong.htm> [Online]
- [5] Veterans Health Administration Available: http://vaww1.va.gov/anes-thesia/docs/Ensuring_Correct_Surgery.doc [Online]
- [6] Position Paper on Wrong Sided Surgery in Orthopaedics, by Canadian Orthopaedic Association (COA). (1994). Available: http://www.coa-aco.org/library_NEW/Wrong_Sided_Surgery.asp [Online]
- [7] Risk Management Foundation of the Harvard Medical Institutions (1999). Available: <http://www.rm.f.harvard.edu/publications/resource/feb1999news/article2/index.html> [Online]
- [8] Making Health Care Safer: A Critical Analysis of Patient Safety Practices, by Agency for Healthcare Research and Quality. Evidence Report/Technology Assessment no. 43; AHRQ publication 01-E058. (2001). Available: <http://www.ahrq.gov/clinic/ptsafety/index.html> [Online]
- [9] R. I. Cook and D. D. Woods, "Adapting to new technology in the operating room," *Human Factors*, vol. 38, no. 4, pp. 593–613, 1996.
- [10] K. Vicente, *Cognitive Work Analysis: Toward Safe, Productive and Healthy Computer-Based Work*. Mahwah, NJ: Erlbaum, 1999.
- [11] D. Woods, "Coping with complexity: the psychology of human behavior in complex systems," in *Tasks, Errors and Mental Models*, L. Goodstein, H. Andersen, and S. Olsen, Eds. New York: Taylor and Francis, 1988, pp. 128–148.
- [12] "Amputee recovering after wrong leg taken," *Tampa Tribune*, p. 1, Feb. 28, 1995.



Michelle L. Rogers received the B.S. degree in electrical engineering from the Georgia Institute of Technology, Atlanta, the B.S. degree through the dual-degree engineering program from Spelman College, Atlanta, GA, in 1993, and the M.S. and Ph.D. degrees in industrial engineering from the University of Wisconsin, Madison, in 2002.

She is an Industrial Engineer and Health Services Researcher with the Getting at Patient Safety (GAPS) Center, Department of Veterans Affairs, Cincinnati, OH, and a Volunteer Research Assistant Professor at the University of Cincinnati, Cincinnati, OH. Since coming to the Center, she has worked on projects involving scenario-based usability testing and cognitive work analysis of the bar-coded medication administration and computerized patient-record system software for the Department of Veteran Affairs. The GAPS Center uses human factors methodologies to identify and design prototypes of software solutions in order to promote patient safety. The Center's focus is on how gaps in continuity of care are bridged by practitioners, and its goal is to create the components of a "safety culture." Her current research focuses on the impact of clinical information systems on the work processes of health care practitioners, with particular interest in the role of technology in patient safety, job design, and user-centered design.



Richard I. Cook received the B.A. degree in economics from Lawrence University, Appleton, WI, in 1975 and the M.D. degree from the University of Cincinnati, Cincinnati, OH, in 1986.

He is a Physician, Educator, and Researcher at the University of Chicago. His current research interests include the study of human error, the role of technology in human expert performance, and patient safety. He has been a faculty member in the Department of Anesthesia and Intensive Care, University of Chicago since 1994. He has been involved with the National Patient Safety Foundation since its inception and sits on the Foundation's Board. He is internationally recognized as a leading expert on medical accidents, complex system failures, and human performance at the sharp end of these systems. He has investigated a variety of problems in such diverse areas as urban mass transportation, semiconductor manufacturing, and military software systems. He is often a consultant for not-for-profit organizations, government agencies, and academic groups. His most often cited publications are "Gaps in the continuity of patient care and progress in patient safety" (*Brit. Med. J.* 320), "Operating at the sharp end: The complexity of human error" (Mahwah, NJ: Erlbaum, 1994), "Adapting to new technology in the operating room" (*Human Factors*, 1996), and the report *A Tale of Two Stories: Contrasting Views of Patient Safety* (Chicago, IL: National Patient Safety Foundation).



Robert Bower received the B.A. degree from Grinnell College, Grinnell, IA, and the M.D. degree from the College of Medicine, University of Nebraska, Omaha.

He is Chief of the Surgical Service at the Cincinnati Veterans Affairs Medical Center, Cincinnati, OH. At the College of Medicine, University of Cincinnati, Cincinnati, OH, he is a Professor of surgery and the Vice-Chair of education in the General Surgery Department.



Mark Molloy received the Diplôme Annuel from the University of Paris, Sorbonne-Paris, France, in 1979, the B.S. in chemical science from Xavier University, Cincinnati, OH, in 1980, and the M.D. degree from the School of Medicine, St. Louis University, St. Louis, MO, in 1984.

He is a Staff Surgeon at the Cincinnati Veterans Affairs Medical Center, Cincinnati, OH, and an Assistant Professor of clinical surgery at the College of Medicine, University of Cincinnati, Cincinnati, OH. His current research interests include the study of

learning curves in surgery and the use of educational tools to improve technical and cognitive surgical skills and enhance patient safety. Dr. Molloy's most frequently cited publications in these areas are: "Appendectomy: Improving Care through Quality Improvement" (*Archives of Surgery*, 1997), "Cholangiography During Laparoscopic Cholecystectomy—Cumulative Sum Analysis of an Institutional Learning Curve" (*Journal of Gastrointestinal Surgery*, 1999), and "Institutional and Individual Learning Curves for Focused Abdominal Ultrasound for Trauma" (*Annals of Surgery*, 2000).



Marta L. Render received the B.S. degree in nursing from Vanderbilt University, Nashville, TN, in 1975 and the M.D. degree from the University of Kentucky, Lexington, in 1979.

She is an Intensivist and Health Services Researcher at the Department of Veterans Affairs, Cincinnati, OH, and a Professor of medicine at the University of Cincinnati, Cincinnati, OH. She directs the Getting at Patient Safety Center, Department of Veteran Affairs, Cincinnati, OH, a group of clinicians and human factors experts who evaluate software for

potential accidents in the making, the Tools Ensuring Consumer Healthcare Safety's Research Enhancement Award Program, designed to increase health services researchers in Cincinnati, and a project to implement best practices in the operating rooms and intensive care units of ten Cincinnati hospitals. Her current research interests include human-computer interaction, particularly in the intensive care unit, team communication strategies, and benchmarking as a method to implement best practices in the intensive care unit.