Improving Patient Safety by Reducing Medication Errors

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Abstract

Purpose: The overall goal of this program was to improve patient safety by identifying the factors that predispose to medication errors and to create a research base for the design of interventions to reduce the frequency of medication errors.
Scope: A research base was developed for designing system solutions that are amenable to intervention, including technical, cultural, and human factors, in order to reduce medication errors and their associated huge human and economic costs. The program combined investigators in multiple areas to address the theme "Improving Patient Safety through Reduction of Errors in the Medication Use Process." The program was composed of four projects and four cores, based at the University of Pennsylvania and linked to the government of the State of Pennsylvania and to the network of Centers for Education and Research in Therapeutics. Each of the four cores served the four projects in such a way as to maximize quality and efficiency simultaneously.
Methods: For individual project methods, please refer to each Project Summary.
Briefly, the four projects studied patient and system factors that are predictive of hospitalizations due to dose-related medication errors among elderly individuals taking specific high-risk drugs (warfarin, phenytoin, and digoxin), using a state-run population-based pharmaceutical benefit program: human and medical practice factors as predictors of poor adherence to warfarin therapy in an anticoagulation clinic; medication errors as causes of preventable acute renal failure in the inpatient setting, given the existence of a pharmacokinetic monitoring service; and conditions that lead to medication errors among physicians, with an emphasis on work conditions that increase stress.
The four supportive cores were the Administrative Core, responsible for coordination; Data Collection Core, responsible for all field activities; Biostatistics and Data Management Core, responsible for data entry, management, and analysis; and Dissemination Core, responsible for an extensive dissemination program as the results of the program emerge.
Results: Projects 1-4 report their results separately. Summarized here is an overview of the results of all projects and core functions.

Key Words: medication safety, medication error, medical error, patient safety

1. ***PURPOSE***

General Problem and Overall Goal

The overall goal of this program was to improve patient safety by identifying the factors that predispose to medication errors and to create a research base for the design of interventions to reduce the frequency of medication errors.

2. ***SCOPE***

Overall Long-Term Objectives of this Program

We identified variations in medication utilization practices that were associated with adverse outcomes. Then, we designed and conducted four epidemiological studies to determine the predisposing factors for these errors to aid in designing system interventions to reduce medication errors. In addition, when possible, we tried to predict those patients at highest risk of medication errors, as they are the patients for whom it is most important to intervene. Our intent was to develop a research base for designing system solutions that are amenable to intervention, including technical, cultural, and human factors, in order to reduce medication errors and their associated substantial human and economic costs.

3. *METHODS*

Specific Research Aims and Hypotheses

These long-term objectives were addressed through an integrated set of four projects, each addressing a major facet of medication errors, and four cores that support the proposed research projects. Taken together, the selected projects aimed to investigate medication errors in the entire range of places where errors can arise (i.e., diagnosis, prescribing, dispensing, administration, ingestion, monitoring, and control). The projects also aimed to target selected high-risk drugs (e.g., anticoagulants, anticonvulsants, digitalis glycosides, and nephrotoxic drugs) because of their ubiquitous use, capacity to lead to errors, difficulty in proper use (low therapeutic ratio), and/or severity of the consequences of errors. The projects further aimed to include different settings (e.g., inpatient and outpatient) and various populations (e.g., the elderly, residents of rural counties, African Americans, and others) and to examine both human psychosocial factors and technical system factors. Finally, these projects took advantage of existing systems developed and used locally and nationally to minimize medication errors (e.g., pharmacy-run anticoagulation clinics and aminoglycoside monitoring services) and aimed to evaluate the characteristics of these systems that protect against errors and those that do not so that these systems can be improved throughout the nation accordingly. The risk factors identified here remain to be translated into interventions, with evaluation of those interventions. The plan was to have implemented the interventions in the next funding cycle, if this funding mechanism had continued.

Project 1: Medication Errors Leading To Hospitalization Among The Elderly

Joshua P. Metlay, MD, PhD, Project Leader

Purpose: To identify predisposing factors for hospitalizations due to errors in medication use among community-dwelling elderly patients on warfarin, phenytoin, or digoxin.

The specific hypotheses of this proposal were:

- Uncoordinated medical and pharmaceutical care, inadequate delivery of new medication instructions, visual and cognitive impairment, and psychosocial barriers (e.g., depression, coping strategies, support) are predisposing factors for medication errors leading to hospitalization among elderly patients.
- The specific causes of errors differ across different types of drugs and between new and chronic users of drugs.
- Patient and healthcare factors can accurately predict patients at high risk of hospitalizations due to medication errors.
- The costs associated with hospitalization due to medication errors exceed the costs associated with patient safety interventions designed to prevent these hospitalizations and targeted to high-risk patients.

Scope: Medication errors are the result of practitioner, patient, and system factors that are potentially predictable and preventable. For physicians and pharmacists, important causal factors likely include inadequate education and training, inadequate time, excessive fatigue and interruptions, and limited access to patient-specific data. For patients, important predisposing factors likely include advanced age, polypharmacy, poor comprehension of medications, impaired cognition, and depression. Medication errors are an important, preventable source of morbidity and mortality among the elderly. Predicting and potentially avoiding such serious ADEs was deemed a high priority for the Pennsylvania Pharmaceutical Assistance Contract for the Elderly (PACE, a PA government organization providing comprehensive pharmaceutical benefits for low-income older adults). Warfarin, digoxin, and phenytoin are among the most common medications leading to serious, avoidable ADEs.

Methods: We conducted a prospective cohort study to identify predisposing factors and develop a prediction rule for patients at risk of hospitalization due to adverse events from errors in utilization of specific medications. The long-term goal is to prevent serious medication errors by developing interventions that are targeted at these high-risk groups. We identified three drugs for investigation (warfarin, phenytoin, and digoxin), because they are among the leading drugs causing serious dose-related ADEs. We identified both new and chronic users of drugs at the time prescriptions are filled.

At the time of enrollment in the cohort, subjects underwent a detailed baseline interview to identify key predisposing factors. The factors of interest included coordination of medical and pharmaceutical care; receipt and type of instructions for medication use; levels of visual and cognitive function; and psychosocial variables, including levels of depression and support. The outcome of interest, hospitalization due to dose-related errors in medication use, was based on clinical findings and discharge codes and confirmed by the drug or anticoagulation levels measured on admission. Outcomes were identified by regular phone contact with subjects using a screening instrument to identify all hospitalizations and exclude those that are unlikely to be medication related. Medical records from all screen-detected

hospitalizations were abstracted to confirm the nature of the hospitalization, timing in relation to drug use, and drug level at admission. Drug-specific analyses focused on identifying predisposing factors for hospitalization and developing a prediction rule to identify subjects at high risk of hospitalization due to medication errors.

Data were collected from each of four sources: baseline and follow-up telephone interviews, inpatient medical records, PACE claims records, and PHC4 data. These four sources were used to provide necessary information on study eligibility (PACE and baseline interview), predisposing factors (baseline interview), drug exposures (PACE and interviews), hospitalizations (follow-up interviews and medical records), and costs (PHC4). The specific areas covered by the baseline telephone interview included demographic variables, home living situation, visual impairment, cognitive impairment, coexisting clinical illnesses, receipt of new medication instructions, monitoring systems from clinical and pharmaceutical providers, psychosocial parameters (including measures of depression [CES-D] and interpersonal support [ISEL-6]), and sources of medical care and pharmaceutical services. Photocopies of discharge summaries and laboratory results for all screen-positive hospitalizations were requested from hospitals for each hospitalization; then, the key elements (discharge diagnosis, presenting signs and symptoms, timing of illness, and serum drug or anticoagulation levels) were abstracted by trained nurses using standardized forms.

Pharmacy claims data were available for all study subjects for the duration of the study. For each subject, we obtained the following data elements for each pharmacy claim processed during the study period: subject identifier, date of claim, drug name, American Hospital Formulary Service (AHFS) drug class, national drug code (NDC), drug dose, number dispensed, expected days supply, pharmacy identifier, and physician identifier.

Hospitalizations were coded as to the probability that the admission was related to a dose-related error in drug utilization, based on the discharge diagnosis and presenting signs and symptoms. We had all hospitalizations evaluated by two study investigators assigning a probability that the hospitalization is due to an error in medication use, with a third reviewer for all disputes, as has been done previously. The reliability of this review process was assessed with kappa statistics. Only the initial hospitalization due to a medication error was included.

Each of the drug cohorts was analyzed separately. Cumulative incidences of hospitalizations due to medication errors were calculated using Poisson regression, using person-months of drug exposure as an offset. Independent predisposing factors were identified with multivariate analysis, accounting for clustering of observations within subjects.

Medical costs were estimated based on PHC4 data for each hospitalization. We used cost-to-charge ratios estimated from the Medicare Hospital Cost Report to map hospital charges into an estimate of medical costs.

Results:

Medication Safety among Older Adults: Home-based Health Practices

We interviewed 4,955 PACE members. Thirty-two percent of the sample reported that they had not received any specific instructions about their medications. Thirty-five percent reported they received instructions from their primary care provider, and 46% indicated that they received them from a pharmacist. Fifty-four percent indicated that they used a pill box

for organizing their medications. Older adults prescribed warfarin were more likely to report receiving instructions compared with adults prescribed digoxin or phenytoin.

A substantial proportion of older adults on high-risk medications do not recall receiving instructions for the use of their medications and do not take advantage of existing systems for organizing medication regimens. Improved patient education and delivery of medication organization systems are immediate opportunities to potentially reduce the risk of medication errors among the elderly.

Identifying Rare ADEs with Diagnostic E-codes

We conducted a cross-sectional evaluation assessing the diagnostic test characteristics of ICD-9 E-codes compared to a reference standard of medical record review. This study was nested within a prospective cohort of elders using warfarin, digoxin, or phenytoin, as identified in the Pharmaceutical Assistance Contract for the Elderly (PACE) benefit program.

We identified 4,803 subjects contributing 11,409 person-years of exposure to at least one of three drug groups. Subjects experienced 8,756 hospitalizations, of which 304 were deemed, by expert review, due to an adverse event of warfarin, digoxin, or phenytoin. We determined the sensitivity, specificity, and positive and negative predictive values for drug-specific E-codes, and these results should help investigators dealing with rare events via medical record review.

Risk Factors for Warfarin ADEs

We performed a prospective cohort study of adults within a state-run program that provides drug benefits for older adults with low income. Eligible subjects filled new or refill prescriptions for warfarin at the time of enrollment. Hospitalizations were identified through a statewide hospitalization registry. Discharge summaries of hospitalizations for possible warfarin-related bleeding events were reviewed by trained abstractors and clinical experts. Incidence rate ratios (IRR) were estimated based on person-months of exposure using Poisson regression models.

From March 2002 through May 2003, we enrolled a total of 2,346 adults on warfarin. Over a 2-year follow-up period, there were 126 hospitalizations due to warfarin-related bleeding (4.6 hospitalizations per 100 person-years of exposure). Useful results can be used to recommend change in medical processes that could reduce hospitalizations for warfarin toxicity and/or lead to an intervention trial to determine if the recommendations coming from this study will decrease hospitalizations.

Risk Factors for Digoxin ADEs

Discharge summaries of possible digoxin-related ADEs were reviewed by trained abstractors, with probable episodes confirmed by a panel of clinical experts. Unadjusted and adjusted incidence rate ratios (IRR) were calculated based on person-months of exposure using Poisson regression models, adjusting for within-subject repeated measures. From March 2002 through May 2003, we enrolled a total of 2,030 adults on digoxin. Over a 2-year follow-up period, we observed a total of 34 hospitalizations due to digoxin toxicity, equivalent to 8.4 hospitalizations per 1,000 person-years of exposure. Results of this study suggest interventions that could decrease the risk of hospitalization for digoxin toxicity.

Results Dissemination

In September 2005, the Dissemination Core targeted high-level pharmacist-managers with information based on Project 1, which investigated medication-taking practices in

community-dwelling older adults. About 60 attendees of the GlaxoSmithKline Executive Management Program for Pharmacy Leaders attended the session, given by Dr. Metlay and Dr. Cohen. This dissemination effort was successful in giving information to a critical audience in a position to effect change in their organizations and communities. It also received high grades in participants' evaluation of the value of the session. The core also developed an Issue Brief, based on results being published from Project 1, on outcomes associated with patient medication practices. To avoid jeopardizing publication in academic journals, the release of the brief is being timed to coincide with articles now pending publication.

Publications

Metlay JP, Hennessy S, Localio AR, Han X, Yang W, Cohen A, Leonard CE, Haynes K, Kimmel SE, Feldman HI, Strom BL. Patient reported receipt of medication instructions for warfarin is associated with reduced risk of serious bleeding events. Arch Intern Med. Under Review.

Leonard CE, Haynes K, Localio AR, Hennessy S, Tjia J, Cohen A, Kimmel SE, Feldman HI, Metlay JP. Diagnostic E-codes for commonly-used, narrow therapeutic index medications poorly predict adverse drug events. J Clin Epidemiol. In Press.

Metlay JP, Cohen A, Polsky D, Kimmel SE, Koppel R, Hennessy S. Medication safety among older adults: home-based practice patterns. J Am Geriatr Soc. 2005;53:976-982.

Abstracts

Metlay JP, Hennessy S, Localio AR, Leonard C, Haynes K, Cohen A, Kimmel SE, Feldman HI, Strom BL. Multiple health care providers and poor medication instruction increase the risk of adverse events in older adults on warfarin. (Oral presentation at the Society of General Internal Medicine Annual Meeting. Toronto, Ontario, Canada. April 2007)

Metlay JP, Hennessy S, Localio AR, Leonard CE, Tjia J, Haynes K, Cohen A, Yuang W, Han X, Kimmel SE, Feldman HI, Strom BL. Rates of serious adverse events in older adults on high-risk medications. (Oral presentation at the AHRQ-sponsored Patient Safety and Health IT Conference. Washington, DC. June 2006)

Metlay JP, Hennessy S, Localio AR, Leonard CE, Tjia J, Cohen A, Haynes K, Kimmel SE, Feldman HI. Validity of discharge diagnoses for identifying adverse drug events. (Oral presentation at the Annual Meeting of the International Society of Pharmacoepidemiology. Nashville, TN. August 2005)

Presentations

Patient Safety Initiatives: Lessons Learned from the Penn Program for the Reduction in Medication Errors. 10/19/05 Delaware Valley Geriatrics Society October Education Meeting.

GlaxoSmithKline Executive Management Program For Pharmacy Leaders, September 23-30, 2005. Leonard Davis Institute, Philadelphia, PA.

"Improving patient safety by reducing medication errors," November 10, 2003. SOS Rx Coalition Retreat. National Consumers League. Queenstown, MD.

Key Words: patient safety, medication errors

Project 2: Medical Practice Factors as Predictors of Poor Adherence to Warfarin Therapy in an Anticoagulation Clinic Setting

Stephen Kimmel, MD, MSCE, Project Leader

Purpose: To determine the human and healthcare structural factors that lead to and predict errors with warfarin, using poor adherence as the paradigm. The **specific aims** were:

- To determine the clinical, demographic, organizational, behavioral, and psychosocial predictors of poor adherence.
- To develop a predictive index that can identify patients at high risk for medication errors before starting therapy.

The **hypotheses** were that 1) specific clinical and demographic characteristics, healthcare structure (e.g., lack of primary care physician support), pill-taking practices (e.g., polypharmacy), medical practice patterns (e.g., complex dosing regimens), and psychosocial barriers (e.g., poor cognition, passive coping strategies) predispose to poor adherence with warfarin, and 2) these factors can be used to accurately predict high-risk groups that require specialized comprehensive and systematic interventions to prevent medication errors. The ultimate goal of this research is to provide a more complete understanding of the epidemiology of patients' errors (the explanatory analysis) and to improve the prediction of which patients are at risk for these errors (the predictive analysis) in order to develop interventions that caregivers and patients can use to reduce these common medical errors.
Scope: Despite 62 years of use and extensive research, errors in the use of warfarin remain common. These errors occur because of warfarin's narrow therapeutic index. Very small deficiencies in dosing lead to under-AC with an increased risk of TE, whereas small excesses in dosing lead to over-AC with an increased risk of bleeding.

Even in specialized AC clinics that represent the best systems in place today and where all known potential etiologies of poor AC control are carefully monitored (except, as discussed below, adherence), the INR is still out of range 32% to 68% of the time, and significant warfarin-related bleeding and TE continue to occur. Despite these problems, the root causes of poor adherence with warfarin have not been rigorously studied. In addition, we and others have shown that clinicians are unable to predict adherence behavior accurately, nor do they understand ways in which their practice methods might influence adherence. As a result, improving adherence, and therefore reducing medical errors from warfarin, continues to be elusive.

Although basic demographic characteristics such as gender and race/ethnicity may explain some patterns of adherence, these factors alone are insufficient for predicting adherence. Adherence is also likely to be related to not only patient-specific factors but also medical practice factors. The interdependent elements of patient demographics, clinical characteristics (e.g., other medical illnesses), medical practices (e.g., dosing regimens prescribed, time spent with patients, availability of a primary care physician), pill-taking practices (e.g., reminder systems), and psychosocial factors most likely interact to determine adherence with warfarin.

Adherence with warfarin therapy is a paradigm for medical errors. Poor adherence can lead to potential or real failure of anticoagulation and threaten patient safety. Concerns of poor adherence are often cited as the primary reason for reluctance to use the drug. However, no study has directly and rigorously attempted to identify predictors of poor adherence with warfarin.

Methods: A 4-year prospective cohort study was performed among adult patients requiring warfarin who were treated at the HUP and Philadelphia VAMC (PVAMC) outpatient AC clinics. Patients presenting for AC were identified at the start of therapy and followed throughout their course of AC. We measured demographic, medical system, and psychosocial factors at baseline as well as medication taking behaviors and physician practice variables throughout patients' treatment. Adherence was the primary outcome, measured by Medication Event Monitoring System (MEMS®) caps. This study was an extension of an NIH-funded prospective cohort study (referred to as "the parent study") that is designed to examine the effects of genetic polymorphisms and adherence as predictors of clinical outcomes (INR levels, bleeding, and TE).

The study population included all patients at the study site initiating warfarin therapy and requiring a target INR of 2 (the lowest level recommended for any condition) to 3. These criteria are those used for the parent study. Although we excluded subjects with an upper limit of the target INR greater than 3, this represented only about 10% of subjects. Consistent with the parent study, patients were excluded if they were younger than 21 years old, were unable to provide consent, or had an abnormal INR prior to AC.

Data collected included demographics, clinical characteristics, healthcare structure, pill-taking practices, and psychosocial variables. Psychosocial tests included the following: Millon Behavioral Medicine Diagnostic, Adherence to Warfarin Questionnaire, Brief COPE, Center for Epidemiologic Studies Depression Scale, Interpersonal Support Evaluation List – 6, Life Orientation Test, Pittsburgh Sleep Quality Index, Perceived Stress Scale-10, Medical Outcomes Study Short Form -12, Cognitive Capacity Screening Exam, and the Multidimensional Health Locus of Control Scale.

The primary outcome was adherence, measured using MEMS caps. The MEMS caps electronically record the time and day of each opening via a microprocessor in the cap. The primary measure of adherence is the "number of days with incorrect doses taken," defined as the number of days without one and only one dose taken (defined by MEMS data indicating no drug administration or more than one dose of drug taken between 3:00 a.m. and 2:59 a.m. of the next calendar day). Because warfarin is always a once-a-day drug, this reflects the number of days in which the patient took an incorrect dose.

Results: Currently, we have analyzed data from 145 patients treated with warfarin who were monitored with electronic MEMS caps. Among these participants, the mean percent of days of nonadherence was 21.8% (SD + 21.1%). Participants were six times more likely to take too few pills than to take extra pills (18.8% vs. 3.3%). Adherence changed over time, initially worsening over the first 6 months of monitoring, followed by improvement beyond 6 months. Although clinicians were statistically better than chance at correctly labeling a participant's adherence (OR=2.05, p=0.015), their estimates were often inaccurate; clinicians labeled participants "adherent" in 82.8% of visits in which patients were 20% or more nonadherent per MEMS cap. Similarly, participant self-report vastly overestimated adherence; even when participants missed 20% or more of pills per MEMS cap, they reported perfect adherence 77.9% of the time.

Among the cohort with INR data available followed for a mean of 32 weeks, 92% had at least one missed or extra bottle opening; 36% missed more than 20% of their bottle

openings; and 4% had >10% extra bottle openings. In multivariable analyses, there was a significant association between under-adherence and under-anticoagulation. For each 10% increase in missed pill bottle openings, there was a 14% increase in the odds of under-anticoagulation ($p<0.001$); participants who had >20% missed bottle openings had a greater than two-fold increase in the risk of under-anticoagulation (adjusted odds ratio 2.10; 95% CI: 1.48-2.96). Participants who had extra pill bottle openings on >10% of days had a statistically significant increase in over-anticoagulation (adjusted odds ratio 1.73; 95% CI: 1.09-2.74).

The MBMD inventory was administered to 165 participants (62% men, mean age 56 years). We compared specific scales from the MBMD inventory to several established instruments that assess similar psychological domains, including depression, stress/anxiety, substance use, cognitive dysfunction, social isolation, pessimism/optimism, physical functioning, and adjustment difficulties, in order to further validate the MBMD in this novel population. The results of these analysis are written and being sent to publishers. There is indication that the MBMD could be useful in clinical practice. Other measures showed association with adherence and are being used to create a predictive index that will be published in the future.

Our research includes several important findings that have significant implications for the care of warfarin patients. First, poor adherence is common, even among patients treated at specialized clinics in which the importance of adherence is constantly emphasized. Second, adherence declines significantly in the first several months of therapy. Third, clinicians' subjective impressions of patient adherence – even when based on the patient's INR levels or pill counts – and patients' self-reports are not reliable methods of identifying patients who are not taking their warfarin properly. Fourth, adherence significantly affects the degree of anticoagulation control, which is a strong predictor of poor outcomes. Our results suggest that patients may benefit from adherence counseling even when they claim to be taking their warfarin or the clinician feels they are doing so, particularly several months into their course of therapy. The factors associated with poor adherence suggest that interventions can be developed that include memory prompts and more comprehensive AC clinic care in order to improve adherence and reduce the substantial morbidity that results from poor AC control.

Results Dissemination

The Dissemination Core has created an issue brief for Project 2 based on risk factors for nonadherence to warfarin. To avoid jeopardizing publication in academic journals, the release of this brief is being timed to coincide with articles now pending publication.

Key Words: adherence, anticoagulation, patient safety, prospective cohort

Publications

Platt A. Psychosocial Predictors of Adherence to Warfarin. Draft paper in progress.

Cruess D. Psychological Correlates of Adherence to Warfarin: MBMD. In preparation.

Platt AB, Localio AR, Brensinger CM, Cruess DG, Christie JD, Gross R, Parker CS, Price M, Metlay JP, Cohen A, Newcomb CW, Strom BL, Laskin M, Kimmel SE. Risk Factors for Nonadherence to Warfarin: Results from the IN-RANGE Study. In preparation.

Parker CS, Chen Z, Price M., Gross R, Metlay JP, Christie JD, Brensinger CM,

Newcomb CW, Samaha FF, Kimmel SE. Adherence to Warfarin Assessed by Electronic Pill Caps, Clinician Assessment, and Patient Reports. J Gen Intern Med 2007;22:1254-9.

Platt AB, Localio AR, Christie J, Brensinger CM, Gross R, Cohen A, Price M, Metlay JP, Strom BL, Kimmel SE. Prospective Assessment of Risk Factors for Warfarin Nonadherence: The Program for the Reduction in Medical Errors (PRIME). Pharmacoepidemiology and Drug Safety 2007; 16:S46-S47.

Kimmel SE, Chen Z, Price M, Parker CS, Metlay JP, Christie JD, Brensigner CM, Newcomb CW, Samaha FF, Gross R. The Influence of Patient Adherence on Anticoagulation Control with Warfarin. Arch Intern Med 2007; 167:229-235.

Kimmel SE, Chen Z, Price M, Parker CS, Metlay JP, Christie JD, Brensinger CM, Newcomb CW, Samaha FF, Gross R. The Effects of Adherence on Anticoagulation Control with Warfarin. Pharmacoepidemiology and Drug Safety 2006; 15:S52-S53.

Simpson NS, Cruess DG, Price M, Cohen A, Christie J, Kimmel SE. Medicine Diagnostic (MBMD) among Medical Patients Prescribed Warfarin Sodium. Presented at the Agency for Healthcare Research and Quality Annual Meeting in Washington, DC, June 2006.

Parker CS, Chen Z, Gross R, Brensinger C, Newcomb C, Price M, Cohen A, Metlay JP, Kimmel SE. Patient Adherence to a Prescribed Warfarin Regimen: Preliminary Results from the In-Range Study.(Abstract), Circulation 2005;111:246.

Presentations

Platt AB, Localio AR, Christie J, Brensinger CM, Gross R, Cohen A, Price M, Metlay JP, Strom BL, Kimmel SE. Prospective Assessment of Risk Factors for Warfarin Nonadherence: The Program for the Reduction in Medical Errors (PRIME). Presented at the 23rd Int'l Conf on Pharmacoepidemiology & Therapeutic Risk Management, Quebec, Canada, August 2007.

Kimmel SE, Chen Z, Price M, Parker CS, Metlay JP, Christie JD, Brensinger CM, Newcomb CW, Samaha FF, Gross R. The Effects of Adherence on Anticoagulation Control with Warfarin. Presented at the 22nd International Conference on Pharmacoepidemiology & Therapeutic Risk Management, Lisbon, Portugal, August 2006.

Simpson NS, Cruess DG, Price M, Cohen A, Christie J, Kimmel SE. Medicine Diagnostic (MBMD) among Medical Patients Prescribed Warfarin Sodium. Presented at the Agency for Healthcare Research and Quality Annual Meeting in Washington, DC, June 2006.

Parker CS, Chen Z, Gross R, Brensinger C, Newcomb C, Price M, Cohen A, Metlay JP, Kimmel SE. Patient Adherence to a Prescribed Warfarin Regimen: Preliminary Results from the In-Range Study. Presented at the 45th Annual Conference on Cardiovascular Disease Epidemiology and Prevention in Association with the Council on Nutrition, Physical Activity, and Metabolism in Washington, DC, May 2005.

Simpson N. Adherence to Warfarin Sodium Using Electronic Pill-Cap Monitoring and the Millon Behavioral Medicine Diagnostic Inventory (Poster). Presented: Society of Behavioral Medicine, April 13-16, 2005, Boston, MA.

Project 3: Medication Errors as Causes of Preventable Acute Renal Failure in the Inpatient Setting

Harold Feldman, MD, MSCE, Project Leader

Purpose: To identify systems factors associated with the development of acute renal failure (ARF) in hospital inpatients receiving aminoglycoside antibiotics. Medication errors are frequently associated with antibiotics and were the leading cause of potential ADEs in a study among both medical and surgical patients. Nephrotoxic drugs have been identified as a major cause of ARF. Published studies have demonstrated the effectiveness of a pharmacokinetic monitoring service (PMS) in maintaining patients within an established therapeutic range, shortening patients' hospitalization and febrile periods as well as being cost effective.[21] Nonetheless, there is a dearth of controlled studies evaluating the effectiveness of a PMS in avoiding medication errors leading to serious outcomes such as ARF. Numerous drugs used in hospitalized patients are ideally monitored using blood levels, to avoid toxicity and maintain a therapeutic effect. PMSs have been developed to reduce medication errors and improve patient safety. Although experience has suggested that these services improve clinical practice, medication errors continue to occur despite them. Variations in implementation and quality of monitoring are plausible explanations for the persistence of errors despite PMS consultation. The proposed examination of monitoring of AABX will serve as a model for understanding some potential root causes of medication errors in the hospital setting. From this enhanced understanding, new systems can be developed and existing ones modified to enhance the safety of pharmaceuticals whose administration can be guided by drug levels. **Scope:** Preliminary data demonstrate a very large opportunity to reduce medication errors and adverse outcomes among patients prescribed AABX at HUP and, ultimately, nationwide. Yet, currently, *Drug Use and Effects Committee* (DUEC) ADE monitoring is missing these. Changes in systems such as DUEC and PMS to better detect ADEs and better monitor AABX are potentially important approaches to reducing errors associated with AABX as well as with other drug therapies with potent toxicities. *The Pharmacokinetic Monitoring Service (PMS) of the Hospital of the University of Pennsylvania* (PMS) at HUP, now under DUEC's oversight, was established in 1983 to provide assistance in the management of patients receiving vancomycin, chloramphenicol, or AABX. The PMS provides initial dosing assessments, blood draw recommendations, interpretation of blood drug concentrations, and dosage adjustment recommendations. Although there is broad-based acceptance of routine PMS consultation, implementation of recommendations for levels and dosing remain the responsibility of the physicians and, at times, are not heeded. The service monitors an average of 40-50 patients/day. Although pharmacokinetic monitoring of AABX is available for all patients, it is not uniformly used, and the consultation does not always begin at the start of therapy. This practice variation provides opportunity to examine the characteristics of PMS that affect its ability to reduce dosing errors of AABX that place patients at risk for ARF. **Methods:** This nested, case-control design was based on a cohort of all adults (18 years and older) receiving at least 3 consecutive days of intravenous aminoglycosides (gentamicin, tobramycin, streptomycin, or amikacin) as inpatients between January 1, 2000, and December 31, 2003. Information used to identify members of this cohort (subjects) was taken from the Hospital of the University of PA electronic ordering system (TDS). Approximately 6 million transactions were examined to identify subjects and place their clinical data into a relational database. Risk set sampling was possible, because electronic data were available for baseline factors and time in the cohort data were available for all subjects. Given the expense of

abstracting medical records, however, the primary exposure variable (discordance of recommendation and orders) was available only for those episodes to be sampled. For that reason, we selected all cases and three controls matched to cases on time in the cohort. All medication orders were identified from the hospital's computerized order entry system. We identified all orders for aminoglycosides for each subject throughout all follow-up time in the cohort. Medical records were abstracted for each day that the patient was in the cohort, as well as 1 day prior to the entry into the cohort, for all recommendations of the pharmacokinetic monitoring service (referred to as "service"). By merging the medication order data from the electronic record and the pharmacokinetic recommendations from the chart review, we were able to establish a sequence of all orders by date and time. We developed rules for comparing recommendations and orders to determine whether the two differed on the drug, dose, frequency, and total daily dose. All orders were converted into medication frequencies and dose per frequency. When combined, these produced a total daily ordered dose. If an order combined both a one time (stat or now) with a routine dose, the assumption was that the dose began at once and then recurred at the frequency applicable to the routine order. Pharmacists were categorized into four levels with increasing order of experience (pharmacist, resident, pharmacist PK veteran, and specialist).

All acute diagnoses, procedures, and service days listed in the discharge summary were retrieved and preprinted for record abstractors who were charged with finding the date on which there was first evidence of any identified diagnosis. We obtained age and gender from electronic administrative data. From the electronic discharge summary, we obtained ICD-9 codes for all diagnoses and denominated chronic diseases that might be associated with the risk of acute renal failure. Each record abstraction recorded 12 attributes of the initial service consultation, including indicators of the presence of notations on height, weight, age, gender, serum creatinine, creatinine clearance, the elimination constant, and the volume of distribution. Also collected was whether the pharmacist noted his/her name, identification number, telephone number, and time.

All variables were examined for frequency, missing values, and zero or low frequencies when cross-classified with other variables. We combined variables when patterns revealed that combinations of variables were impossible. Then daily total dose was in discordance if total ordered on that day exceeded the recommended total on that day. Second, discordance was measured in two ways: acute discordance (the primary, pre-specified measure), and chronic discordance. *Acute discordance.* For this variable, our primary measure of exposure, days of discordance, was categorized by whether the total dose was discordant on the day prior to the index date, or 2 days prior. The resulting four-level variable then became 1 = no PK service on either prior day (i.e., not yet signed on or 1 day after signoff); 2 = PK service on, but no days of discordance; 3 = discordance on at least one of the prior 2 days; and 4 = discordance on both prior days. Likewise, we created similar four-level variables for frequency and dose. The higher level of expertise of the pharmacist on either of the 2 days prior to index was used with the idea that any close supervision by a more experienced pharmacist should have been associated with lower risk of acute renal failure.

Secondary exposures of interest included (1) number of days without any recommendation, (2) total number of medication orders over the 2 days, and (3) the presence of more than one outstanding order at the end of each day (scored as 0, 1, or 2),

reflecting a higher risk of failure because of the frequency of ordering and order changes. These variables were forced into all models because of their pre-existing interest.

Potential confounders represented factors associated with increased risk of failure and possibly associated with the primary exposure variables. They included number of days (0, 1, or 2) of elevated risk associated with chronic diagnoses, acute diagnoses, or procedures. Age was included as a potential confounder for the higher risk of acute renal failure with age. Gender was a potential confounder because of differences by gender in the measurement of serum creatinine. Effect modifiers included presence of acute or chronic diagnoses and age.

All analyses preserved the matching by use of stratified failure-time analysis. The outcome of interest was the time from day zero. Each case-patient was followed until failure (the day of development of acute renal failure). Each matched control patient in turn was followed for the same number of days as the case to which he or she was matched. If the matched control eventually went on to become a case, s/he was used only for the exposure days of interest as a control. As the estimates from a survival model stratified by matched set will be the same as from a conditional logistic regression model (stratified by matched set), we chose the latter in the interests of speed in execution. SAS proc logistic was employed for these analyses. We estimated statistical power with a resulting sample of 220 matched sets of data to be 85% to detect an odds ratio of at least 1.75 for which the prevalence of exposure is approximately 20%.

Results: The final sample size of 910 was composed of 220 cases and 690 controls. We identified 2,047 courses of aminoglycosides that met the definition for inclusion in the cohort, and a subset (1,414) with available laboratory data that could be used for defining the presence of acute renal failure. By our creatinine-based definition, 278 of these courses of drugs ended in acute renal failure. These became the basis for the nested case-control study. Four-to-one matching produced 278 matched risk sets representing 1,385 risk periods taken from the 846 distinct courses of exposure to aminoglycosides. Medical records were located for 785 of the 846 episodes (94%), and 736 of these contained some evidence of pharmacokinetic service monitoring (92%) at one of the days of observation. These episodes represented 652 patients. Of the 278 courses that resulted in acute renal failure, we were able to form 266 (96%) matched sets (with at least one case and one control).

Publications: An initial paper is being put together to describe the results related to discordance as well as a secondary paper looking at discordance/concordance as outcome variables.

Presentations: None yet; we are awaiting preliminary analysis completion.

Key Words: acute renal failure, aminoglycosides, medication error, antibiotics, inpatient

Project 4: Influence of Hospital Workplace Stressors and Physician Stress on Medication Errors

Ross Koppel, PhD, Project Leader

Purpose: Hospital workplace stressors (e.g., schedules, interruptions, fatigue) and personal stress among housestaff have been repeatedly identified as significant contributors to prescribing errors. This project sought to better understand the objective sources of stress, the

personal characteristics of the housestaff, and the interplay of individual perceived stress and the objective stressors on housestaff's commission of medication errors. The project also examined the use of technology in ordering medications (e.g., CPOE and DSS), as these technologies both reduced errors and possibly facilitated errors. **The specific aims of this proposal were:**

- To determine if, and to what extent, the organization of work within a hospital (e.g., schedules, shifts, workloads, etc.) affects houseofficers' commission of medication errors.
- To determine if houseofficers' experiences of workplace stress (the cognitive, behavioral, physiological, and psychological experience of stress—called "strains") increase the risk of medication errors.
- To determine how hospital workplace stressors interact with houseofficers' strains to influence the risk of medication errors.
- To determine how hospital workplace stressors and strains interact with houseofficers' baseline psychological profiles to influence the risk of medication errors.

Scope: To determine if, and to what extent, the organization of work within a hospital creates workplace stressors that result in medication errors. The comparatively small amount of previous research on the role of healthcare workplace stressors on medication errors was remarkable because of the inherent nature of a job that employs potentially dangerous drugs and procedures and has responsibility for human health outcomes. A large part of the recent research has focused primarily on computerized prescribing (CPOE) and decision support systems (DSS). Both systems offer promise of notable error reduction, although there is considerable evidence of overpromise and underperformance. Therefore, despite the optimism that dominates conference proceedings, vendor claims, and large parts of the scientific literature, the number of such program applications actually in use and contributing to the quality of patient care is remarkably modest. The diffusion of HIT among medical practices has advanced at a snail's pace, with CPOE or Electronic Health Records (EHR) implementations found in only about 10% of US hospitals and with EHRs found only in about 12% of US physician's offices. Moreover, a growing literature documents disappointing results following implementation of a variety of HIT applications—a conversation this project contributed to via a series of articles and presentations.

Prescribing errors are the major source of medical errors and largest proportion of medication errors, causing ill effects in 1% of inpatients. Prescribing errors, however, are among the most preventable and are therefore a focus of patient safety interventions. Identifying prescribing errors, unfortunately, is itself fraught with inaccuracies. Each method of detection and reporting is subject to systematic bias.

Setting: The Hospital of the University of Pennsylvania, Philadelphia, PA

Participants: Housestaff at the Hospital of the University of Pennsylvania and those who rotate into the hospital who may spend some of their residencies at nearby hospitals that are part of the University of Pennsylvania Healthcare System. Approximately 700 physicians were in residence; about 60% were appropriate for this study. Others were senior fellows, researchers, or in-services who do not write prescriptions. Other participants in the study (people interviewed) included hospital leaders, senior medical officers, pharmacy department leaders, and IT leaders.

Methods: We employed multiple methods to measure stressors, strains, psychological background, and errors or perceptions of errors. Once each year, we measured houseofficers' baseline psychological profiles. The questionnaire on housestaffs' stressors, strains, and perceived errors was administered from September to June – at housestaff meetings, at training sessions, and at individual meetings.

On a continuous basis, we collected objective data from the hospital administration on houseofficers' call schedule, workload (e.g., patients/physician, medication orders/day), and PIP data on interventions (see institutional letters of support). At the start of each academic year, interns and residents were administered a basic psychological profile, the DASS 21.The DASS is a set of three self-report scales designed to measure the negative emotional states of depression, anxiety, and stress. The objective workplace stressor data were obtained from the hospital administration and from physician-specific information linked to each medication order. These include rotation (medicine, surgery, ICU, etc.), number of patients for whom orders were written, number of other physicians writing for each patient in a given time period, and patient load (number of patients per house officer). In addition to perceived errors and observed errors, we have also determined (see below) that 67% of orders canceled within 45 minutes is suboptimal. We use these three measures as our indications of error/near misses.

Results

Twenty-two Ways in which Computerized Physician Order Entry Systems Enhance as well as Reduce Medication Errors

We performed a qualitative and quantitative study of housestaff interaction with a popular CPOE system. We surveyed housestaff (N = 261; 88% of CPOE users); conducted five focus groups and 32 intensive one-on-one interviews with housestaff, information technology leaders, pharmacy leaders, attending physicians, and nurses; shadowed housestaff and nurses; and observed them using CPOE.

We found that a widely used CPOE system facilitated 24 types of medication errors. Examples of these errors include fragmented CPOE displays that prevent a coherent view of patients' medications; pharmacy inventory displays mistaken for dosage guidelines; antibiotic renewal notices placed on paper charts rather than in the CPOE system; separation of functions that facilitate double dosing and incompatible orders; and inflexible ordering formats that lead to lost orders. Three quarters of the housestaff reported observing each of these errors, indicating that they occur weekly or more often.

As CPOE systems are implemented, clinicians and hospitals must attend to errors they cause, in addition to errors they prevent. It is critical, also, to incorporate plans for continuous revisions and quality improvement.

Follow-up Study on CPOE and Medication Errors

A direct comparison of error-risks associated with old vs. new CPOEs as well as examination of housestaffs' assessments of CPOE over time: 463 housestaff completed 742 surveys over 1 to 3 years—85% of the target population responded. The newer system (SCM) eliminated three medication prescribing error risks, of the previously identified 22 errors risks, and reduced the likelihood of seven others. However, nine error risks remained unchanged, three were addressed but offsetting error risks emerged, two *error-reducing* functions were eliminated, and six new error risks were introduced. Overall, housestaff

preferred the new CPOE system over its predecessor. The new CPOE remedied some of its predecessor's error risks, but several remain, and new ones were introduced. Technological solutions to medication errors are still emerging and are mitigated by hospitals' organizational/workflow realities. Proactive and responsive evaluations remain critical.

Quantifying Medication Errors via Computerized Provider Order Entry Systems and Rapidly Discontinued Medication Orders

Using computerized provider order entry systems to determine rapidly discontinued prescription orders–in which the physician stops the order within 2 hours: Can we find an expedient proxy for prescribing errors? Results of this study are currently out for submission and will help pinpoint medication orders with a very high probability of error. Such a proxy may also serve as a screening and teaching mechanism for physicians in training.

Principal Findings and Implications

We found two separate sources of stress and sources of error. Although a clear and strong relationship exists between them, we often see that these relationships are nuanced and provide useful insights about medication errors. The relationship between psychological characteristics stressors and errors is also very promising. Not all findings have yet been analyzed or submitted for publication. We will continue to publish results as they become available; results will include a study that looks at errors committed before and after the 80-hour rule. Also to be examined is the role of hospital workplace stressors in relation to medication prescribing errors. Specifically, we will examine a range of stressors but focus on errors made shortly before residents leave the hospital. Another will concentrate on errors associated with cross-covers. Other papers address the role of personality characteristics in affecting response to stressors, the timing and order of rotations, the importance of interactions with other staff, and the role of personal support—all on medication errors.

The results of this project, we hope, will inform such interventions in hospitals and other healthcare settings with similar stressors. Our work on CPOE and other forms of IT has influenced hospital policy within HUP. A review session with leaders of medicine and IT sought to incorporate changes based on our work. Moreover, a new computer system was installed, and we have continued to study that in relation to housestaff and medication errors. We have continued to provide feedback to the hospital and to the professional groups (e.g., hospital administrators, the HIT professionals, academic groups, and medical educators).

Via our widely publicized articles, presentations, newspaper reports, radio reports, and webcasts, we have reached a worldwide audience. We receive monthly notices from medical leaders and medical information officers about their uses of our work. Recently, for example, we were informed by the head of the Siberian hospital system (38 hospitals) that they used our writings to guide their arrangements of work processes and healthcare information technology.

The Dissemination Core targeted health professionals in management positions with whom to share results. To reach this important audience, the core developed curricular content for the LDI/Wharton's existing executive education program. This content was based on the results of Project 4, which described errors facilitated by a hospital CPOE system. In September 2004, the core designed and implemented a session within the GlaxoSmithKline Executive Management Program for Pharmacy Leaders. This program recruits licensed pharmacists who are leaders in hospitals and in managed care, retail, and community

pharmacies. About 40 pharmacists participated in this 7-day intensive management program held at Penn. Subsequently, the core produced an "Issue Brief" based on Dr. Koppel's work in March 2005. This brief was mailed to more than 4,000 clinicians, policymakers, and industry leaders. It was distributed during an LDI seminar with National Health Information Technology Coordinator David Brailer, and it drew a large regional audience. The brief was also posted in pdf format on the web and mailed electronically to more than 1,000 clinician executives across the country. Another brief is being written and will be distributed based on the research on "stealth dosing" and updated CPOE systems. To avoid jeopardizing publication in academic journals, the release of this brief is being timed to coincide with articles now pending publication.

Key Words: work stressors, CPOE, medication ordering, medication error, housestaff

Publications

Harrison M, Koppel R, and Bar-Lev S. Unintended consequences of information technologies in health care - an interactive sociotechnical analysis. *Journal of the American Medical Informatics Association*. 2007 Sep-Oct;14(5):542-549.

Kaplan B, Elkin P, Gorman P, Koppel R, Sites F., Talmon J. Book Chapter: Working Conference on Virtuality and Virtualization, The International Federation for Information Processing (IFIP) Working Group 8.2 on Information Systems and Organization and 9.5 on Virtuality and Society, *Virtual Patients: Virtuality and Virtualization in Health Care*. In: Crowston K, Sieber S, Wynn E, eds. Proceedings of the IFIP WG 8.2/9.5 Conference on Virtuality and Virtualization, Portland, OR, USA, Springer. July 2007.

Koppel R. Defending computerized physician order entry from its supporters. *Journal of Managed Care.* 2006 July;12(7):369-370.

Koppel R. Commentary: What do we know about medication errors made via a CPOE system versus those made via handwritten orders? *Crit Care*. 2005 Oct 5;9(5):427-8. Epub 2005 Aug 22.

Koppel R. The invention of the risk factor: insurance companies and the creation of public health programs and modern medicine contemporary sociology. A Journal of Reviews. 2005 Sept;34(5):465-470.

Koppel R, Localio R, Cohen A, Strom B. Neither panacea nor black box: responding to three *Journal of Biomedical Informatics* papers on computerized physician order entry systems. *Journal of Biomedical Informatics.* 2005 Aug;38:267–269.

Koppel R, Metlay J, Cohen A, Abaluck B, Localio R, Kimmel S, Strom B.

Role of computerized physician order entry systems in facilitating medication errors. JAMA: Journal of the American Medical Association. 2005 March 9;293(10):1197-1203.

Koppel R. Computerized physician order entry systems: the right prescription? *Leonard Davis Institute for Health Economic Issue Brief*. 2005 March;10(5).

In Process for Publication

Davidson S, Koppel R, Heineke J, Wears R. Finding the missing link between healthcare information technology and improved healthcare outcomes: an agenda for research and action. Submission to NEJM, November 2007.

Koppel R, Cohen A, Feldman H, Leonard C, Sites F, Strom BL. Comparing medication prescribing errors with a new computerized physician order entry (CPOE) system

to those with an older CPOE system: direct and longitudinal analyses. Submission to NEJM November 2007.

Koppel R, Leonard C, Localio R, Cohen A, Strom B. Quantifying medication errors via computerized provider order entry systems and rapidly discontinued medication orders. *Journal of the American Medical Informatics Association.* Accepted for revision and resubmission.

Presentations

Koppel R. CPOE and work processes. Invited presentation to the Agency for Healthcare Quality and Research. Patient Safety Conference. Washington, DC. October 2007.

Koppel R. Hospital design research and applied sociology. Paper presented at the Association for Applied and Clinical Sociology annual meeting. Michigan. October 2007.

Koppel R. Medical vs. Sociological Findings: What are Data vs. Discussion? Paper presented at Qualitative Methods Research Network, European Sociological Association Conference. Glasgow. September 2007.

Harrison M, Koppel R. Unintended Consequences of Healthcare Information Technology: Interactive Sociotechnical Analysis. Academy of Management. Philadelphia. August 2007.

Koppel R, Sites F. The Virtual ICU: Critical Care Telemedicine System with Smart Data Analysis and Electronic Documentation. Paper presented at the IFIP8.2 "Working Conference on Virtuality and Virtualization." Portland, OR. July 2007.

Koppel R. CPOE: Facilitating Medication Errors? PA Society of Health-System Pharmacists. Harrisburg, PA. October 2006.

Koppel R. Should there be a national mandate for CPOE and EMR? Delaware Valley Meeting of the HIMSS. Philadelphia. September 2006.

Koppel R. Web-based National Lecture (with Pascale C and Karsh B-T) for the Agency for Healthcare Research and Quality. 2006.

Koppel R. "Implications of Healthcare Information Technology on Hospital Operations and Quality." Papers presented to the Health Care Round Table, Conference for Hospital Chief Medical Officers, Colorado Springs, CO (September) and Health Care Round Table, Conference for Hospital Chief Quality Officers. Austin, TX. November 2005.

Koppel R, Cohen A, Localio R, Metlay J, Kimmel S, Linkin D, Strom B. "Incorporating Ethnographic Methods in Research with Implications to National Medical Policy: Postures and Questions of Validity." Paper presented at the Conference on Ethnographic Organizational Studies of the European Sociological Association (Research Network "Qualitative Methods"). Torun, Poland. September 2005.

Koppel R. "Looking into and out of CPOE's Black Box: Monitoring its Uses, Benefits and Consequences." Paper presented at the conference on "Information Technology at the Clinical Interface," Johns Hopkins University School of Medicine. Baltimore, MD. 2005.

Koppel R. Grand Rounds, Mount Sinai Medical Center, New York City. The Controversy About Medication Errors and CPOE. 2005.

Koppel R. "CPOE and Other Health Information Technologies: Influences on Work and Patient Safety." Paper presented to the University of Wisconsin School of Medicine, Department of Industrial and Systems Engineering and The Center for Quality and Productivity Improvement. Madison, WI. 2005.

Koppel R. “The Challenges and Promise of Computerized Physician Order Entry (CPOE) Systems: Re-examination and New Data.” AHRQ Conference on Healthcare Information Technology. Agency for Healthcare Quality and Research. Washington, DC. 2005.

Koppel R, Cohen A, Strom B, Abaluck B. “Studying Physicians’ Perceptions of Medication Error: Comparing Four Research Methods.” Paper presented at the Conference on Ethnographic Organizational Studies of the European Sociological Association (Research Network “Qualitative Methods”). Murcia, Spain. 2003.

Koppel R, Localio R, Abigail C, Abaluck B, Metlay J, Strom B. “Understanding Medication Errors in the Context of Hospital Culture and Operations: Sociological and Information Systems Analyses.” Paper presented at the Annual Meeting of the Sociological Practice Association, Atlanta, GA. 2003.

Koppel R, Abaluck B, Strom B, Localio R, Cohen A. “Use of Multiple Research Methods in Applied Social Research: Studying Causes of Medication Errors.” Paper presented at the Annual Meeting of the Society for Applied Sociology. Sacramento, CA. 2002.

Koppel R, Metlay J, Strom B, Cohen A. “Organizational Ethnography and the Study of Medication Order Errors in a Hospital.” Paper presented at the Conference on Ethnographic Organizational Studies of the European Sociological Association (Research Network “Qualitative Methods”) and the Swiss Sociological Association. University of St. Gallen, Switzerland. 2002.