Evaluating the Impact of an Ambulatory Computerized Provider Order Entry System on Outcomes in a Community-based, Multispecialty Health System

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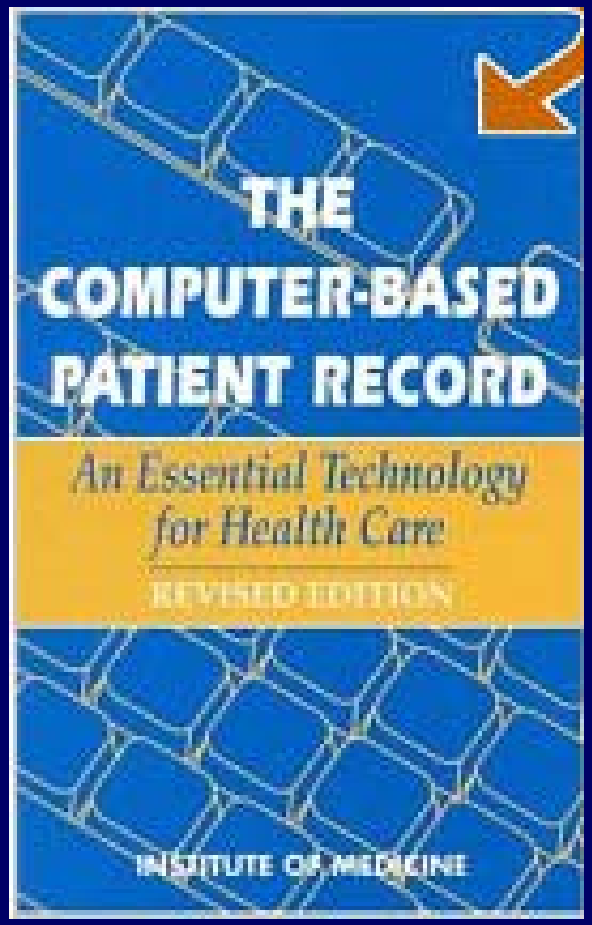
1997 Institute of Medicine Report Electronic Health Records (EHRs)



- **Improve quality and safety**
- **Enhance the productivity of health care professionals; reduce administrative costs**
- **Support clinical and health services research**
- **Ensure patient data confidentiality at all times**
- **Accommodate future developments**

CPOE systems*: A core component of EHRs

Basic

Computer entry of prescription information

- **Drug, dosage form, route**
- **Directions**
- **Quantity**
- **Patient name**
- **Date**
- **Prescriber's signature**
- **Duplicate therapy**
- **Allergies**
- **Drug-drug interactions**
- **Formulary checking**

Advanced

Drug-disease interactions
Laboratory checking
Dose calculators
Medication selection aids
Preventive monitoring

***CPOE=Computerized provider order entry**
CDS = Clinical Decision Support

Kuperman. JAMIA 2007;14:29-40

2004 Congressional Mandate

Agency for Healthcare Research and Quality

Health Information Technology Grant

5 UC1 HS 015319-03 (Sullivan)

Mentored Clinical Scientist Training Grant:

K08 HS 014739-02A2 (Devine)

Our Partnership:

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The Everett Clinic
For the whole you.

Conceptual Model of the Systems Approach to Improving Outcomes (adapted from Reason and Leape)

Description of Human Error

Cognitive Theory
1.Schematic control mode – unconscious processing; automatic reactions
2.Attentional control mode – conscious processing; used for problem solving

Model of Human Performance and Causes of Human Error
1.Skills-based performance – unconscious processing
errors are called "slips"

2.Rules-based performance – conscious processing; based on stored rules
errors are called "mistakes"

3.Knowledge –based performance – synthetic thought; used for novel situations
errors are called "mistakes"

Caused by psychological factors (interruptions, stress, environmental or emotional states)

Lessons Learned
1.Errors result from well-known, "normal" mechanisms that are complex but understandable
2.Distractions are a common cause of error
3.Human error cannot be eliminated

Description of Systems Failures
Root Causes of Systems Failures

1.Design Failures
Process design failures
Task design failures
Equipment design failures

2.Organizational and Environmental Failures
Psychological precursors
Inadequate team building
Training failures

Solutions to Reduce Organizational and Environmental Failures

1.Modify psychological precursors
2.Focus on Team building
3.Improve Training Programs

Solutions to Reduce Design Failures

Build in:
1.Redudancy
2.Simplification
3.Constraints (forcing functions)
4.Standardization
5.Information access
6.Buffering against errors

Outcomes
1. Wider acceptance of new systems
2. Greater efficiency with the use of new systems

Outcomes
Reduction in errors and adverse events

Framework for Improving Outcomes through the Implementation of a CPOE System

Systems Failures

Human Error

Prescribers and other health care professionals trained to "not err"

Human error must be expected

Solutions to Reduce Organizational and Environmental Failures = Implement e-prescribing Systems
1.Modify psychological precursors
2.Focus on Team building
3.Improve Training Programs

Solution to Reduce Design Failures = Implement e-prescribing Systems
Build in:
1.Redudancy
2.Simplification
3.Constraints (forcing functions)
4.Standardization
5.Information access
6.Buffering against errors

Improved Outcomes

Stud Aim #2: Neutral time-efficiencies
Study Aim #3: Acceptance and adoption

Improved Outcomes

Study Aim #1: Reduction in medication errors and adverse drug events

Reason, 1990; Leape, JAMA 1994;272:1351-7

Three Aims; Three Studies (1)

- Aim (Study) #1 – Medication Error Study
  - Aim 1a: Evaluate the impact of the CPOE system on medication errors, comparing pre- to post-
    - Aim 1a1: the distribution of errors
    - Aim 1a2: epidemiology of error characteristics
    - Aim 1a3: the distribution of error severity
  - Aim 1b: Link errors to subsequent adverse drug events (ADEs)

Three Aims; Three Studies (2)

- Aim (Study) #2 – Time-Motion Study
  - Evaluate the impact of the CPOE system on time-intensity of prescribing, and on work tasks
    - Time spent handwriting *versus* e-prescribing
    - Time spent e-prescribing using an interim hardware configuration (phase 1) *versus* the final hardware configuration (phase 2)
    - Time spent on work tasks
    - Time spent on overall activity types

Three Aims; Three Studies (3)

Aim (Study) #3 – Focus Group Study

- Explore and describe end-users' perceptions of and experiences with the CPOE system
- Map results to the information technology adoption model

The Everett Clinic

- Physician owned and managed multi-specialty integrated health-system with a 79-year history
- 14 locations; 60 clinics – ambulatory oncology and behavioral health
- Ancillary services - laboratory, radiology
- 225 physician-owners / 1,250+ employees
- 225,000 patients; 610,000 ambulatory visits annually
- 4 on-site pharmacies; 2.7 million prescriptions annually
- Admit to single hospital in local market
- Core values
  - We do what is right for each patient
  - We provide an enriching and supportive workplace
  - Our team focuses on value: service, quality and cost

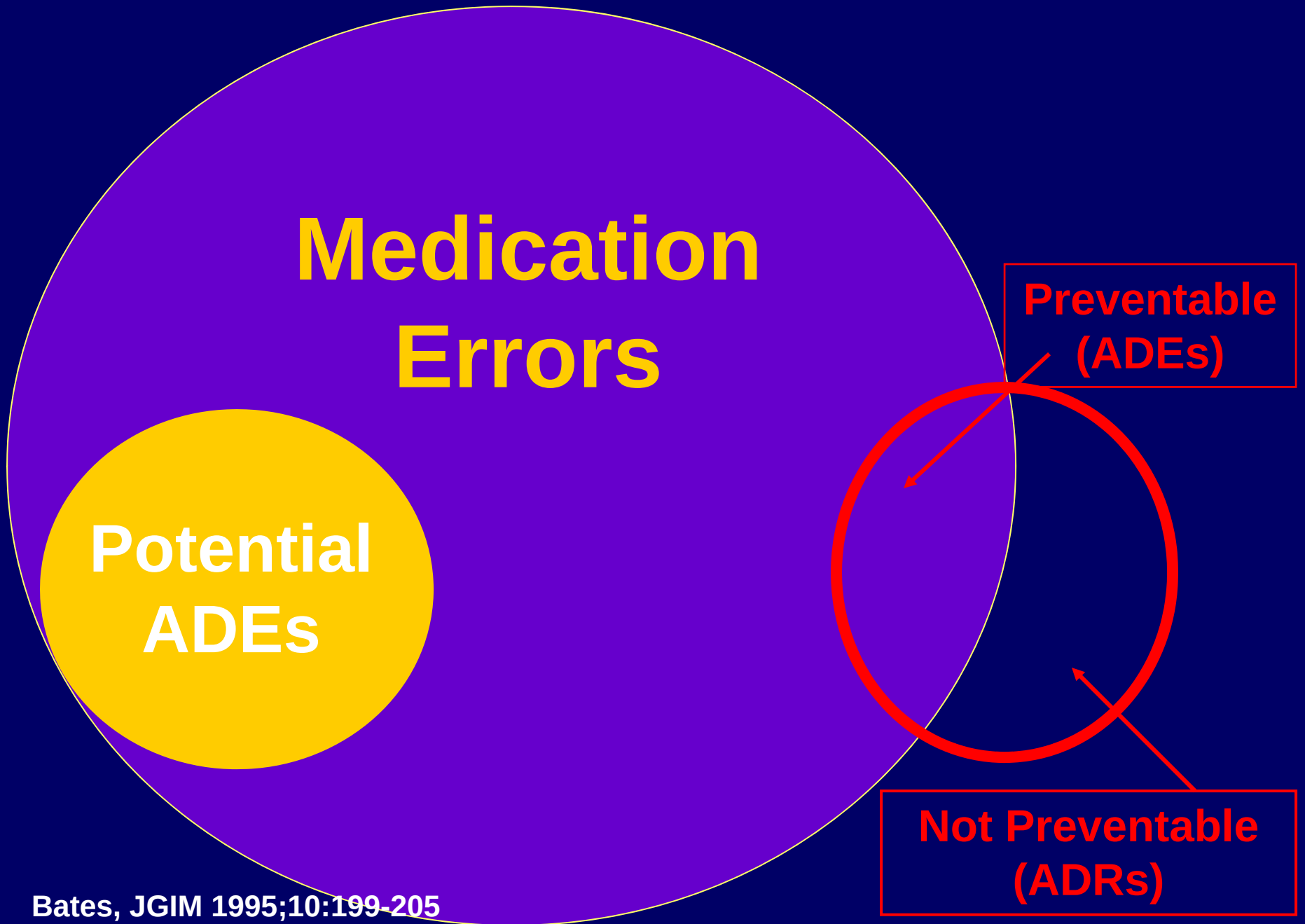
The Everett Clinic's CPOE Software

- Clinitech® - Information Technology subsidiary
- Internal development of EHR began in 1995
  - chart notes, labs and imaging reports
- CPOE implemented in 2003 – limited to medications
- Utilizes a commercial drug database
- Features of the CPOE system (basic) – medications only
  - ability to write new prescriptions (output: fax/print)
  - ability to refill prescriptions
  - optimizes ideal choice of medication
  - automatically generates medication list as prescriptions are written
  - calculates pediatric antibiotic dosing by weight
- Builds patient drug database, improving disease management

Study #1: Medication Error Study: Hypotheses

- Aim 1a: Evaluate the impact of the CPOE system on medication errors, comparing pre- to post-
  - 1a1: 50% reduction in the distribution (frequency) of errors
  - 1a2: Types of errors will change
    - Reduction in errors most logically impacted by a basic CPOE system
  - 1a3: Reduction in errors of all severity levels

- Aim 1b: Link errors to ADEs
  - Exploratory analysis



Bates, JGIM 1995;10:199-205

Background (1) - History

- Drug complications constitute 19% of total adverse events[1]
- Medication errors occur in 5.3% of inpatient orders; 7.5% of these can result in an adverse drug event[2]
- CPOE with CDS alerts resulted in a 55%[3] and 81%[4] reduction in medication errors
- 44,000 – 98,000 deaths per year occur as result of medical errors in hospitals[5]
- IOM - *Preventing Medication Errors, 2006*

[1]Leape, NEJM 1991;324:377-84; [2]Bates, JGIM 1995;10:199-205;
[3]Bates, JAMA 1998;280:1311-16; [4]Bates, JAMIA 1999;6:313-21;
[5]Institute of Medicine. 1999

Background (2) – State of the Field

- Systematic reviews[1-6] investigating the impact of CPOE/ CDS systems on medication safety:
  - inpatient setting, academic medical centers
  - "homegrown" systems
  - Wide variety in design, quality and results
  - Few focus on ADEs; some focus on CDS alerts
- Great potential for errors in the ambulatory setting
  - One (academic, major institution, "homegrown")[7]
  - 4 primary care practices – 2 handwritten, 2 CPOE
  - 1,879 prescriptions
  - 7.6% contained an error; 43% were potential ADEs; 3 errors caused ADEs
  - CDS could have prevented 95% of potential ADEs

[1]Kaushal, Arch Intern Med 2003; [2]Garg JAMA 2005; [3]Eslami JAMIA 2007; [4]Shamnliyan HSR 2008; [5]Wolfstadt JGIM 2008; [6]Ammenwerth JAMIA 2008; [7]Gandhi, JGIM 2005

Methods (1)

- Quasi-experimental, pre,- post- design
- Retrospective review of 5,000 prescriptions in each of two time frames (2 reviewers)
- Filled at one of three onsite pharmacies
- Weighted sampling
- Variables:
  - Primary outcome: error – yes/no
  - Secondary outcomes: characteristics (13) and severity (3-levels)
  - Primary independent variable: CPOE – yes/no
  - Data sources: prescriptions, EHR, laboratory values
  - Covariates: patient age & gender, prescriber specialty, therapeutic drug class, season, weeks since 1st Rx written
  - Interaction terms: CPOE and each covariate
- Approved by the UW Human Subjects Committee

Methods (2) –Analyses

- Unadjusted – two-sample test of proportion for each outcome
- **Hierarchical data** – prescription, prescriber, geographic site
- **Distribution & characteristics** – binary outcomes
  - GEE with alternating logistic regression (ALR)[1]
  - Clustered on prescriber and geographic site
  - α for geographic site NS, so included as fixed effect
  - First order GEE, clustering on prescriber
  - Weight variable to reflect clinic prescribing patterns
  - Created best fitting model, retaining variables (or groups) with $p<0.05$
- **Error severity**
  - Collapsed 6-levels to 3
  - Generalized linear & latent mixed effects model (GLLAMM)[2]
  - Multinomial logit link; same covariates

[1]Carey. Biometrika 1993;80:517-26; [2]Rabe-Hesketh & Skrondal 2008

Results (1)

Table 1.1: Characteristics of Patients and Prescriptions

	Pre-CPOE N=5,016	Post-CPOE N=5,153
Patient age (≥ 65 years)	597 (11.9%)	729 (14.2%)§
Female	2,887 (57.6%)	3,086 (59.9%)*
Prescriber specialty		
Internal Medicine	1,843 (36.7%)	2,347 (45.6%)§
Family Practice	1,255 (25.0%)	1,296 (25.2%)
Pediatrics	492 (9.8%)	407 (7.9%)‡
Walk-in Clinic	475 (9.5%)	345 (6.7%)§
Specialty	836 (16.7%)	646 (12.5%)§
All others	115 (2.3%)	112 (2.2%)
Therapeutic drug class		
Antibiotics	1,180 (23.5%)	746 (14.5%)§
Antidepressants	257 (5.1%)	296 (5.7%)
Central Nervous System Agents	402 (8.0%)	568 (11.0%)§
Hormones	278 (5.5%)	370 (7.2%)§
Schedule II-V	1,004 (20.0%)	960 (18.6%)
All others	1,895 (37.8%)	2,213 (43.0%)§
Geographic site		
Clinic site A	1,420 (28.3%)	1,691 (32.8%)§
Clinic site B	1,741 (34.7%)	2,053 (39.8%)§
Clinic site C	1,450 (28.9%)	1,087 (21.1%)§
All other clinic sites	405 (8.1%)	322 (6.3%)§

CPOE = computerized provider order entry

*p<0.05; †p<0.01; ‡p<0.005; §p<0.001 when compared to pre-CPOE

Results (2)

Table 1.2: Impact of the CPOE system on medication errors

	Pre-CPOE N (%)	Post-CPOE N (%)	Difference N (%); 95% CI for Difference (Unadjusted)	Odds Ratio 95% CI (Adjusted)*,
Total number of prescriptions reviewed	5,016 (49.3%)	5,153 (50.7%)	-	-
Total number of prescriptions with one or more errors	911 (18.2%)	423 (8.2%)	488 ((10.0%) (8.7%, 11.3%)‖	0.30 (0.23, 0.40)‖
Total number of errors	1,012	440	-	-
Number of errors per prescription				
One	811	405	-	-
Two	85	16		
Three	9	1		
Four	1	0		
Mean number of errors per prescription	1.09	1.04	-	-

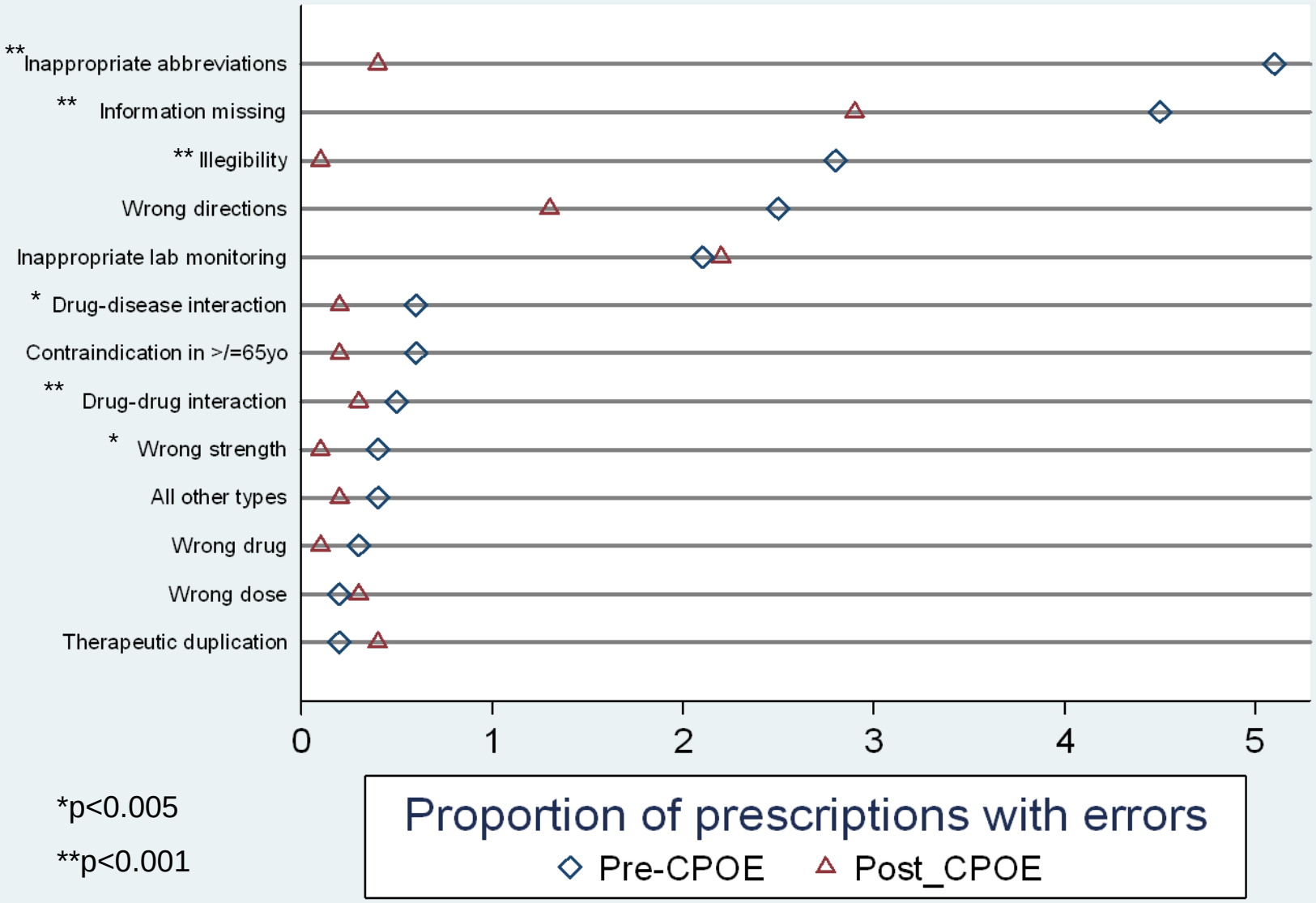
CI = confidence interval; CPOE = computerized provider order entry

†p<0.05; ‡p<0.01; §p<0.005; ‖p<0.001

*Generalized estimating equations with independent correlation; clustering at the prescriber level; prescription weighting schema applied

Adjusted model contains the following variables: Main effects: age (< ≥65), gender, antibiotics, antidepressants, central nervous system (CNS) agents, hormones, Schedule II-V agents, clinic site A, clinic site B, clinic site C; Interaction terms: CPOE*CNS agents, CPOE*hormones, CPOE*Schedule II-V, CPOE*site C

Results – Error Characteristics (3)



*p<0.005

**p<0.001

Results – Error severity (4)

Table 1.3: Effect of the CPOE system on medication errors, by severity

Error Severity	Total prescriptions Pre-CPOE N=5,016	Total prescriptions Post-CPOE N=5,153	Difference N (%); 95% CI for Difference (Unadjusted)	Odds Ratio (99.5% CI) (Adjusted)
Error Severity, by categories				
A (potential error; no ADE) N=8	7 (0.1%)	1 (<0.1%)	6 (<0.1%) (<0.1%, 0.2%)†	0.13 (0.02, 1.07)
B-D (error, no harm; potential ADE) N=1,312	895 (17.8%)	417 (8.1%)	478 (9.8%) (8.5%, 11.1%)‖	0.43 (0.38, 0.49)‖
E & F (error, reached patient-contributed to harm; preventable ADE) N=14	9 (0.2%)	5 (0.1%)	4 (<0.1%) (<-0.1, 0.2%)	0.51 (0.17, 1.53)

ADE = adverse drug event; CI = confidence interval; CPOE = computerized provider order entry
†p<0.05; ‡p<0.01; §p<0.005; ‖p<0.001
*GLLAMM with adaptive quadrature; multinomial logit model; clustering at prescriber level; no weights applied; no additional variables

- 14 / 10,169 (0.1%) of prescriptions included an error that caused harm
- 1 level “F” error (caused harm; required hospitalization); occurred pre-CPOE
- Lab monitoring (4), drug-disease interactions (3), wrong directions (3), wrong dose (2)
- No association found between errors and subsequent ADEs

Notable Findings

- 55% reduction in frequency of errors with CPOE system
  - 70% reduction in odds of an error occurring (OR: 0.3); 95% CI 0.23, 0.40)
- Reductions in most types of errors
  - Greatest reduction in errors impacted by a basic CPOE system
- Most errors do not cause harm (potential ADEs)
  - 57% reduction in odds (OR: 0.43, 95% CI; 0.38, 0.49)
  - 0.1% of errors caused harm (preventable ADEs)

Strengths and Limitations

- Large dataset
- Two independent evaluators
- Rigor of analytic methods

- Retrospective methods preclude definitive evaluation of errors that cause harm
- Capture prescribing errors only
- Limited generalizability
  - “homegrown” system
  - community setting with specific prescribing patterns
  - three pharmacies
    - weighting scheme may address this

Study #2:
Time-Motion Study

- **Aim 2.1**: Evaluate time spent (seconds) handwriting *vs.* e-prescribing (prescribers)
  - Hypothesis: The impact of e-prescribing will be time-neutral for prescribers
- **Aim 2.2**: Evaluate time spent (seconds) eprescribing, comparing phase 1 to phase 2 (prescribers)
- **Aim 2.3**: Evaluate time spent (min/hour) on work tasks, comparing phase 1 to phase 2 (prescribers & staff)
- **Aim 2.4**: Evaluate time spent (proportions) on overall activity categories, comparing phase 1 to phase 2 (prescribers & staff)

Background

Author	Year	Setting	Methods	Results
Tierney	1993	RCT of CPOE in urban hospital (n=68 teams)	Time-motion	+ 33 min/ 10 hour shift (p<0.001); less time record-keeping
Shu	2001	Pre-, post-CPOE in inpatient setting	Work-sampling	Increase from 2.1% to 9.0%; (p<0.001); less time charting; patient care time unchanged
Overhage	2001	RCT of CPOE at 11 clinics (n=34)	Time-motion	+ 0.43 min (NS); - 3.73 min
Pizziferri	2005	Pre-, post-EHR at 5 clinics (n=20)	Time-motion	- 30 secs/ patient; patient care time unchanged
Poissant	2005	Systematic review of CPOE and EHR	Several	- 28% to + 328%; 3/ 12 studies with time savings

Study Design

- Direct observation – One 4 hour time block per end-user
- All prescribers and staff whose job involves prescriptions
- With consent of prescriber and patient
- Approved by UW Human Subjects Committee

	Phase 1	Phase 2
Clinic	*CPOE System*	*CPOE System*
Silver Lake	Paper	Exam Room Desktop
Harbour Pointe	Prescriber Office Desktop	Exam Room Desktop
Snohomish	Wireless Laptop	Exam Room Desktop

Data Elements (1)[1]

Major Task Categories (12)	Individual Categories (106)
1)Computer	New Rx; Renew Rx; Fax Rx; (Drug Ref; e-mail; Lit Search; Look Up Data)
2) Writing	New Rx; Renew Rx; (Letter; Notes/Charts; Orders)
3) Phone	Rx; FAX Rx; Prior Authorization (Getting Results; Paging; Personal; Scheduling test)

Other Major Task Categories	
4) Examine/ read	8) Phone patient
5) Examine patient	9) Procedure
6) Looking for	10) Talking
7) Other	11) Talking Patient
[1]Overhage, JAMIA 2001;361-71	12) Walking

Data Elements (2)

Overall Activity Types

106 Individual categories[1]

Direct patient care	Indirect patient care – other
Indirect patient care – write	Administrative
Indirect patient care – read	Miscellaneous

[1]Overhage, JAMIA 2001;361-71

Analyses (1)

- Aim 2.1: seconds to prescribe (event)
- Linear Mixed Model
  - Outcome variable = adjusted mean difference in the number of seconds spent pre prescription-related event
  - Primary independent variable = handwritten (phase 1 or 2) *vs.* e-prescribed (phase 2)
  - Fixed effect covariates = new or refilled prescription, clinic, days exposed to software / hardware
  - Random effect = prescriber
- Aim 2.2: Same linear mixed model
  - Primary independent variable = e-prescribed (phase 1) *vs.* e-prescribed (phase 2)
- Unpaired analyses

Analyses (2)

- Aim 2.3
- Unit of analysis = major task category
- Outcome variable
  - Mean number minutes / hour on each task
  - Summed for each subject, by task
  - Weighted by total number of minutes observed
  - Average of all subjects, by task
- Grouping variable
  - phase 1 or phase 2
- Unpaired t-tests
- Stratified by professional type & clinic

Aim 2.4: Overall activity types

- Two sample tests of proportions, by activity

Results (1)

Table 2.1: Characteristics of Prescribers and Staff, and Time Observed

	Silver Lake		Harbour Pointe		Snohomish	
	Phase 1 Observations	Phase 2 Observations	Phase 1 Observations	Phase 2 Observations	Phase 1 Observations	Phase 2 Observations
Prescribers						
Consented (%)	8/10 (80%)	13/14 (93%)	11/15 (73%)	16/16 (100%)	8/8 (100%)	9/9 (100%)
Specialty						
Internal medicine	2	4	3	4	2	3
Family practice	3	4	4	6	4	4
Pediatrics	1	1	4	5	1	1
Walk-in clinic	2	4	0	1	1	1
Mean hours observed	3.9	3.8	3.8	3.8	3.9	3.9
Mean number of minutes unable to observe	19.8	13.9	12.7	34.7	7.7	4.9
Staff (Nurses and Medical Assistants						
Consented (%)	11/17 (65%)	10/19 (53%)	21/25 (84%)	20/24 (83%)	10/11 (91%)	9/11 (82%)
Mean hours observed	3.5	3.8	3.7	3.7	3.8	3.7
Mean number of minutes unable to observe	1.0	2.3	1.9	1.2	0.5	1.4

Total: 146 observations /179 possible times (82%); 45% (65 obs.) prescribers, 29% (43) nurses, 26% (38 medical assistants; 47% (69 obs) in phase 1, 53% (77) in phase 2;
Paired: 96 observations; 52% (50 obs.) prescribers, 21% (20) nurses, 27% (26) medical assistants

Results – seconds to prescribe (2)

Table 2.1: Time spent hand-writing and e-Prescribing for Prescribers

	Mean seconds per prescription event (number of prescriptions)		Mean seconds per prescription event Adjusted difference; unpaired analysis (99.5% CI)
	Handwritten (Phases 1 and 2 combined)	**E-prescribed on desktops in examination rooms (Phase 2)**	
All Sites – all prescriptions†	47 (132)	69 (312)	22 (1,43)*
All sites – new prescriptions ††	47 (111)	75 (181)	18 (-5,42)
All sites – renewed prescriptions ††	46 (21)	60 (131)	41 (-5,87)
	E-prescribed (Phase 1)	**E-prescribed on desktops in examination rooms (Phase 2)**	
Harbour Pointe – all prescriptions⊕	44 (79)	70 (147)	24 (8,39)**
Harbour Pointe – new prescriptions	45 (37)	74 (84)	29 (6, 53)**
Harbour Pointe – renewed prescriptions	42 (42)	63 (63)	19 (-3, 41)
Snohomish – all prescriptions⊕	73 (59)	73 (69)	3 (-18, 24)
Snohomish – new prescriptions	75 (43)	83 (38)	8, (-20, 35)
Snohomish – renewed prescriptions	68 (16)	61 (31)	-4, (-37,30)

CI = confidence interval

*p<0.005; **p<0.001

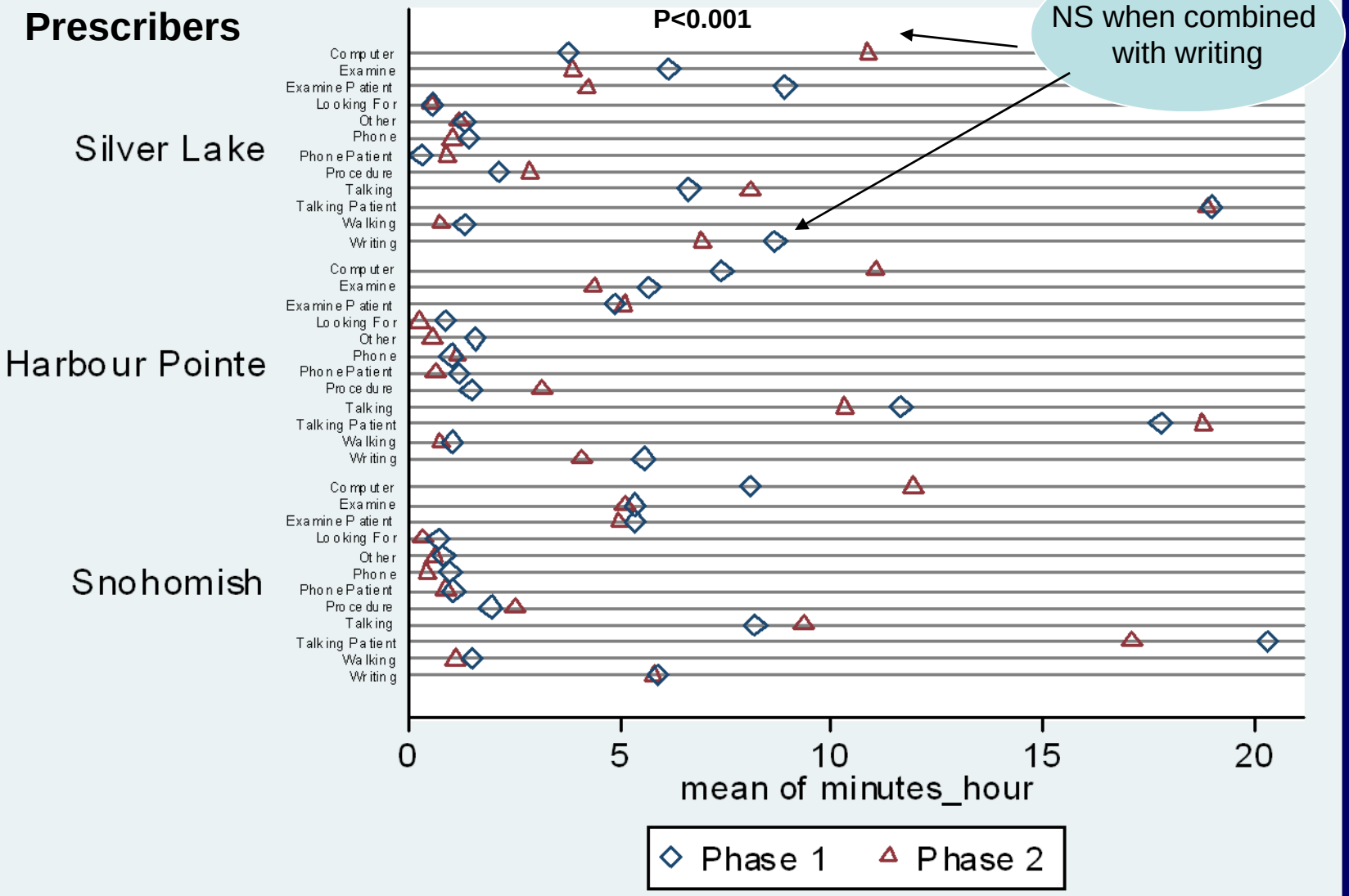
Linear mixed effects models – random effect = prescriber

†fixed effects = clinic, new/renewed prescription, days exposed to computer hardware, days exposed to e-prescribing software

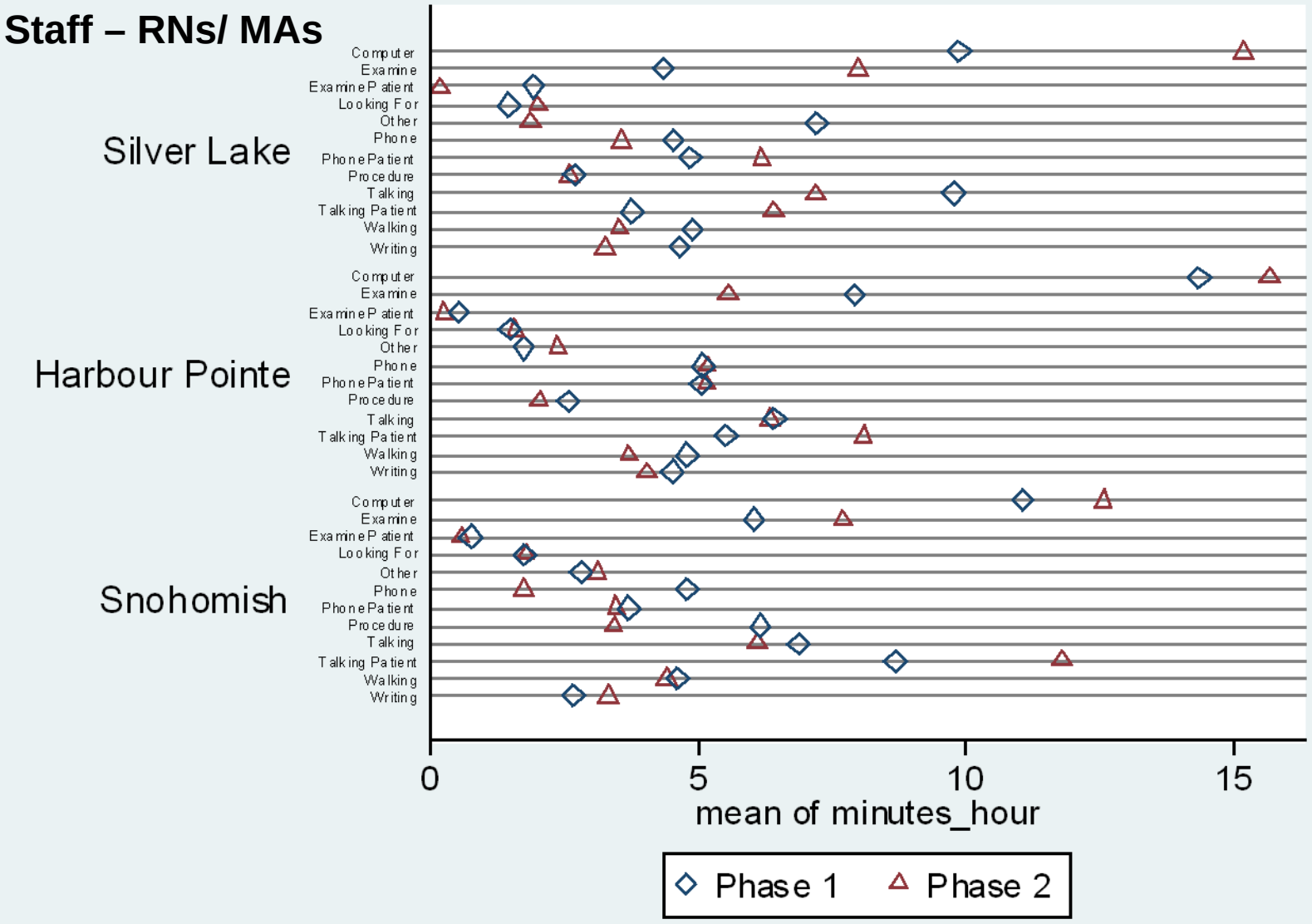
††fixed effects = clinic, days exposed to computer hardware, days exposed to e-prescribing software

⊕fixed effects = clinic, new/renewed prescription

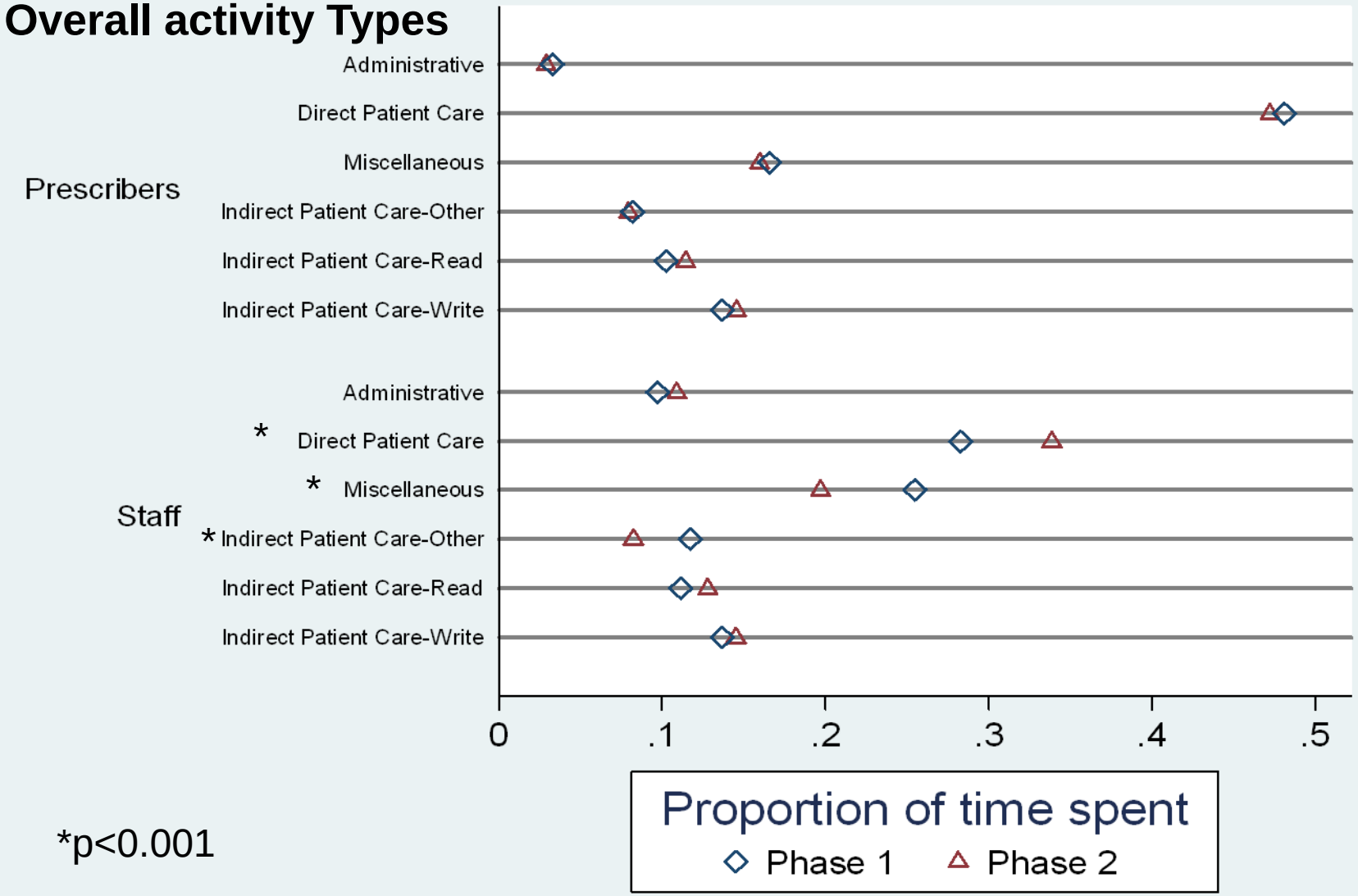
Results-min/hr on tasks(3)



Results-min/hr on tasks(4)



Results-Overall Activities (5)



*p<0.001

Notable Findings

- E-prescribing took 22 secs/ prescription longer than handwriting
  - 18 seconds per patient
- E-prescribing in phase 2 took 22 secs/ prescription longer than in phase 1
  - Computers in exam rooms – at point of care
- Prescribers spend most time talking to patient; little time prescribing
- Staff spend more time computing & talking
- Time spent in direct patient care
  - unchanged for prescribers
  - Increased for staff (corresponding decrease in miscellaneous tasks)

Strengths and Limitations

- Time-motion methods – gold standard
- Includes staff
- Reflects pre-, post-implementation of 3 configurations

- Hawthorne effect[1]
- limited to specific time periods during the day
- limited to primary care clinics
- limited ability to accurately capture simultaneously occurring tasks
- did not capture total amount of time worked per day; unable to determine impact on workload

[1]Hawthorne effect. http://www.nwlink.com/~donclark/hrd/history/hawthorne.html

Study #3:
Focus Group Study

- Aim 3.1: Explore and describe end-users' perceptions of and experiences with the CPOE system
  - Hypothesis: perceptions will be generally favorable
- Aim 3.2: Map results to the information technology acceptance model (ITAM)[1]

[1]Dixon. Int J Med Inform 1999;56:117-23

Background

- Many barriers to EHR adoption[1-4]:
  - overall prescriber resistance due to perceived time-intensity and lost productivity
- EHRs can:
  - facilitate medication errors[5]
  - cause alert fatigue[6]
  - cause a revolt against implementation[7]
- Successful implementation[8]
  - Leadership, motivation, attention to workflow, staged implementation, technical details, training, continuous improvement
- POET Group[8] – qualitative research; inpatient focused; one HMO

[1]Grossman. Health Aff 2007; [2]Doolan. Health Aff.2002; [3]Poon. Health Aff 2004; [4]Halamka. JAMIA 2006; [5]Koppel. JAMA 2005; [6]Weingart. Arch Intern Med 2003; [7]Shane. AJHP 2003; [8]Ash. JAMIA 2003

Information Technology Adoption Model

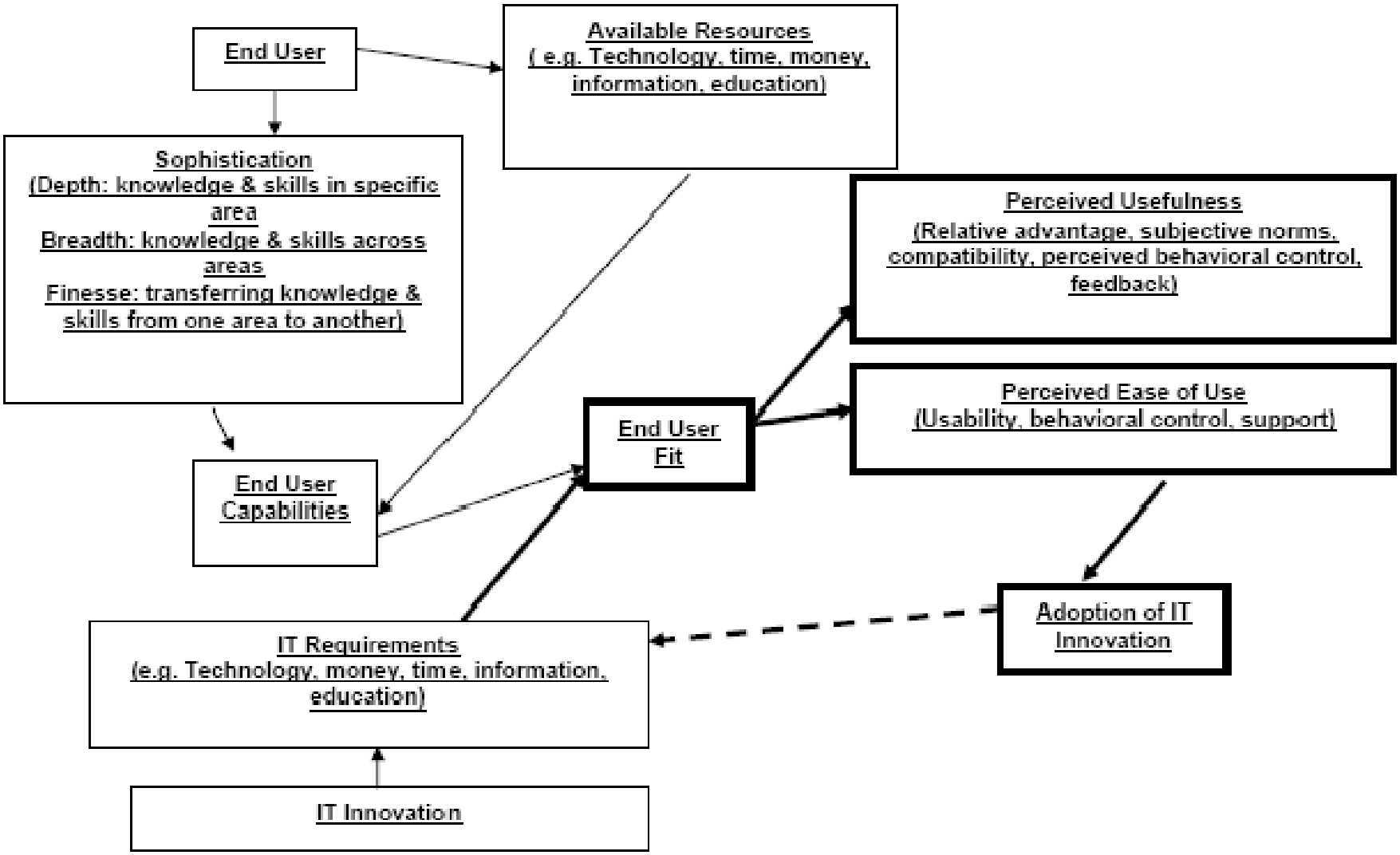


Figure 3.1: Enhanced Information Technology Adoption Model
Dixon. Int J Med Inform 1999;56:117-23

Methods (1)

- Study Design: Qualitative, focus groups; cross sectional
- Enrich / complement Studies #1 and #2
- Sampling frame: 3 primary care clinics
  - universal
  - voluntary
- Inclusion criteria: all end-users involved with the prescribing process
  - prescribers = MDs, DOs, ARNPs, PAs
  - staff = RNs, medical assistants
- 3-8 participants/group; 30 minutes/ group
- 2 groups/clinic (prescribers & staff)
- Academic investigator to facilitate focus groups

Methods (2)

- On-site consent
- Semi-structured elicitation techniques developed from review of literature (interview guide)[1]
- Content recorded on laptop, capturing comments *"verbatim"*

3 topical areas

  - expectations and impact
  - Fears
  - Barriers
  - (individual level variables)

- Approved by the UW Human Subjects Committee

[1]Miles & Huberman. *Qual Data Analysis*. Sage; 1994

Focus Group Details

	Silver Lake (Spring 2005)	Harbour Pointe (Summer 2005)	Snohomish (Summer 2006)
Participants	Prescribers (7) Staff (8)	Prescribers (6+) Staff (9)	Prescribers (3) Staff (4)
Software/ Hardware configuration	Paper; EHR-desktops	CPOE (11mos); EHR-desktops	CPOE (22 mos); EHR-laptops

2 extra focus groups: “float pool staff” and

Silver Lake staff “transition timeframe” (6 mos. post-CPOE implementation)

Data Management & Analyses (1)

- **Unit of analysis = focus group**
  - site, type of health care professional, and date
- **2 coders & epistemology**
  - 1) deductive[1]
    - (starting with a set of analytic categories)
  - phenomenological approach[1]
    - (open to new ideas, not pre-judging, just describing)
  - 2) grounded theory
- **Analysis[1-3]**
  - hermeneutic style[2] - Atlas.ti™
  - coding – open; microanalytic; constant comparison; theoretical saturation; 'check coding' comparison
  - axial coding – process of relating major categories to each other
  - Creation and comparison of themes across focus groups & end-user profession

[1]Strauss & Corbin, 1998; [2]Bradley.HSR 2007;42:1758-72; [3]Miles & Huberman, 1994

Data Management & Analyses (2)

- 8 focus groups; 70 participants; 24% prescribers
- 26 pages of transcripts
- 142 codes;
- 26 code families
- Dimensionality
  - Prescribers & staff
  - Pre- vs. Post- CPOE

Pre-CPOE	**Post-CPOE**
SL Spring	HP, Sno, Float, SL Fall (transition)
Expectations *vs.* Concerns/ fears	Benefits *vs.* Drawbacks
	Improvements needed (wish list)
	Promoters *vs.* Barriers (float pool)

Results - Themes

Clinical information (CDS features)	**Software & hardware configurations** (reliability, security, speed)
Documentation & safety (medication safety)	**Implementation, transition & improvement** (transition processes)
Organizational issues (training and support)	**Time** (time-saving, time-neutral)
Efficiency (less paper/ fewer charts)	**Overall impressions**
Patients (computers at point of care → coordination; satisfaction)	**End-user characteristics** (age, attitudes, computer experience)
Pharmacy communications (integration/ transparency)	

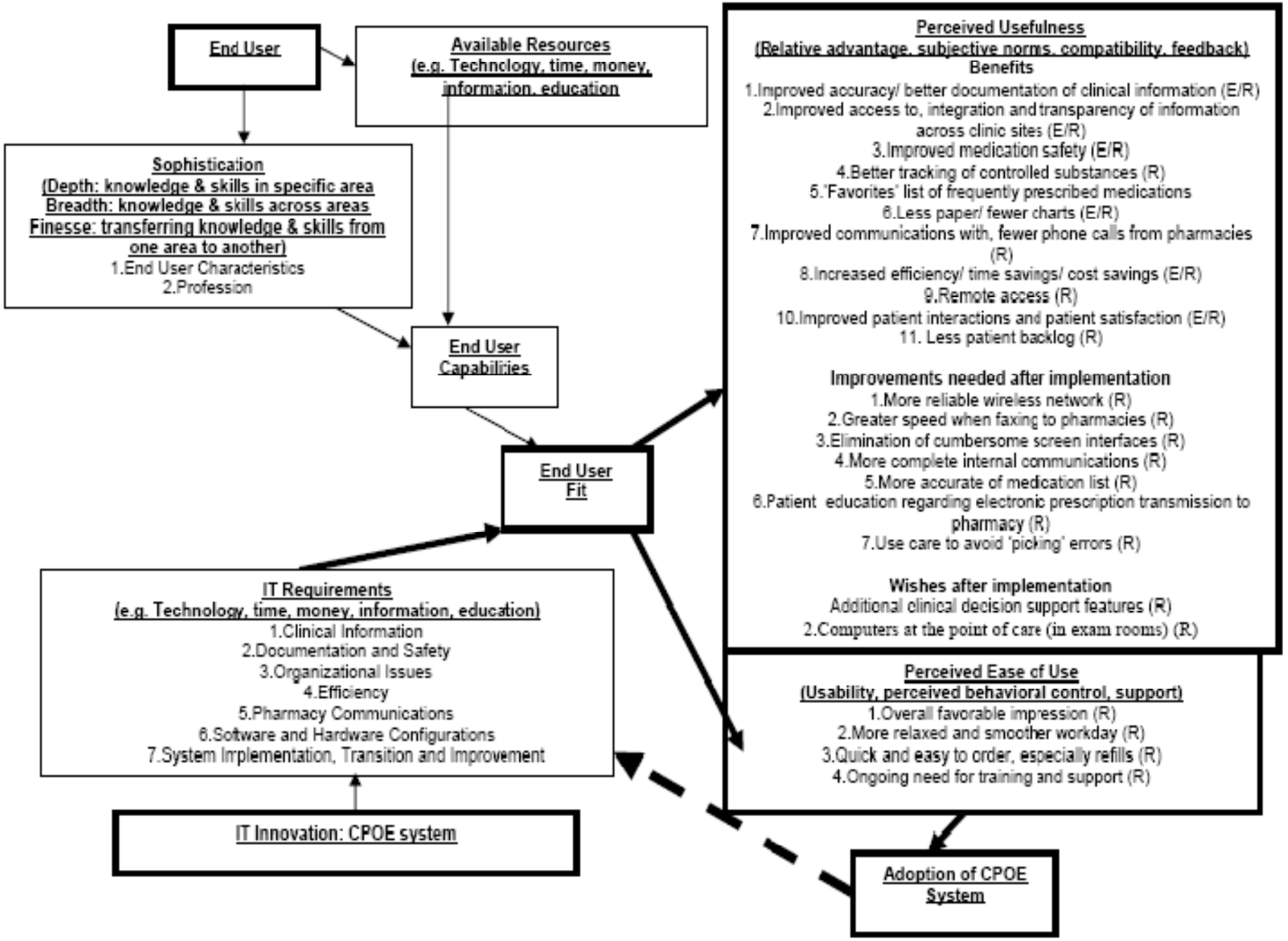


Figure 3.2: Mapping Focus Group Results to the Enhanced TIAM

Notable Findings

- Improvements in access, accuracy, documentation, integration, transparency
- Reduction in medication errors (2ndary)
- Large initial investment of time (staff)
- Staff early adopters
- Good training/ more training
- CDS alerts (prescribers); internal communications (staff)
- Workload shift to staff; but worth it
- Less paperwork; fewer charts
- Network challenges, pharmacy challenges
- Computers at point of care (care coordination)
- Remote access (care coordination)
- Time neutral (prescribers)
- Improved patient satisfaction
- Positive attitudes (or reserved, but not negative)
- Benefits realized; fears were not; favorable impressions

Strengths and Limitations

- Includes staff

- Cross-sectional data
- Primary care clinics
- Voluntary participation
  - Those with positive attitudes may have participated
- Two focus groups conducted by member of system implementation team
- Written transcripts only

Contributions to the Field

- Collection of 3 studies
- Results suggest a basic CPOE system can be successfully implemented in community-based setting, not affiliated with academic medical center
  - improved medication safety
  - time neutrality
  - favorable impact
- Lessons learned to enable successful adoption[1]

[1]Devine AHRQ Publications 2008

Contributions to the Field

- Results generalizable in many ways due to universal issues involved in CPOE adoption[1-4]
  - optimize background information databases
  - identify core functions; user-friendly screen functionality
  - proactive planning of revised workflow to ensure time-efficiency and productivity
  - address network reliability, security, integration
  - organizational, cultural and environmental issues
- Limited generalizability, but important findings
  - homegrown system
  - staged implementation
  - iterative improvements

[1]Bell, Health Affairs May 25, 2004; [2]Bell, JAMIA 2004; [3]Poon, Health Affairs 2004;

[4] Devine AHRQ Publications 2008

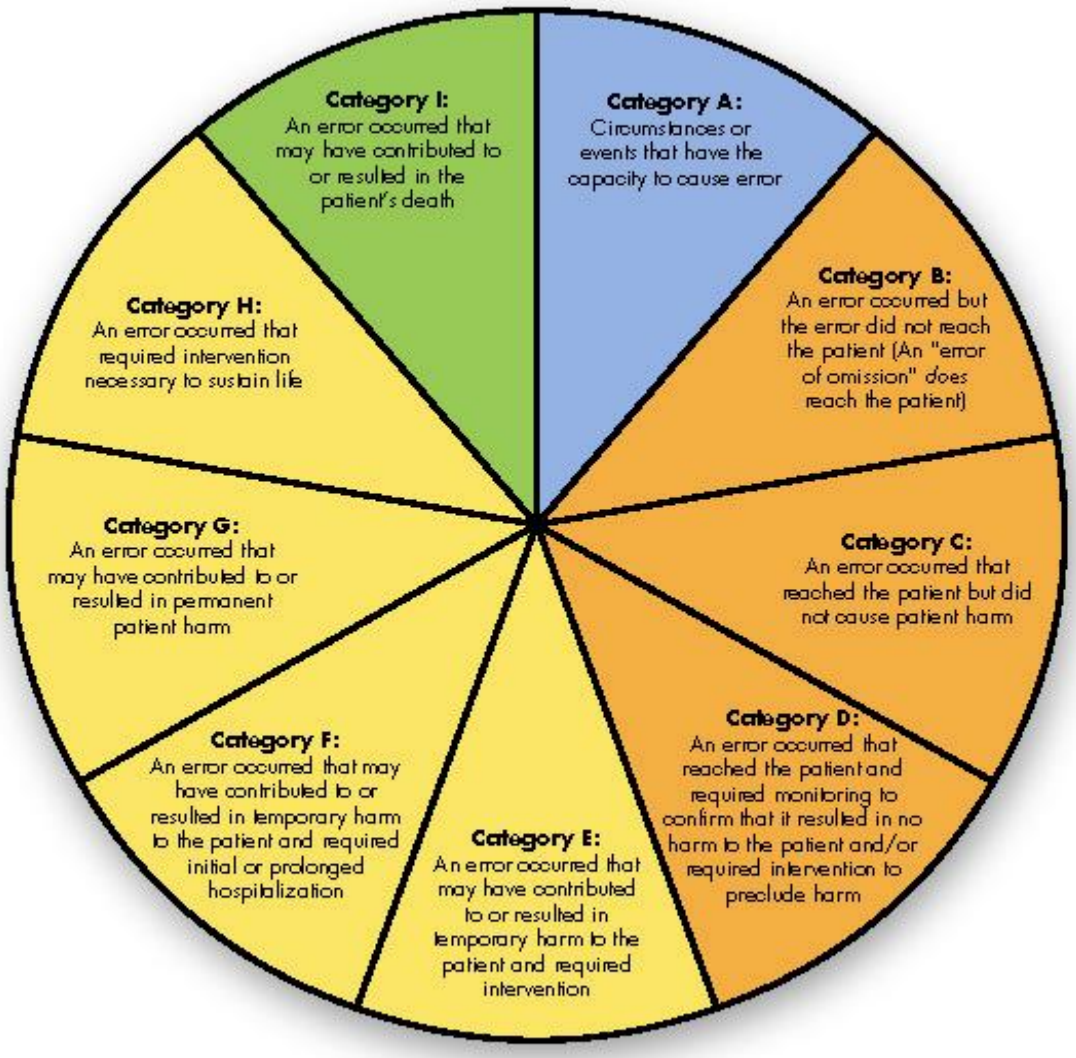
Collaborators

- **UW**
  - Dave Blough, PhD
  - Will Hollingworth, PhD
  - Diane Martin, PhD
  - Tom Payne, MD
  - Sean Sullivan, PhD
  - Peter Tarczy-Hornoch, MD
  - Ryan Hansen, PharmD; Tom Hazlet PharmD, DrPH, Emily Williams, MS, Bryan Comstock, MS
- **The Everett Clinic**
  - Al Fisk, MD, MMM
  - Nathan Lawless, ChE, RPh
  - Jennifer Wilson-Norton, RPh, MBA

Thank you!

Supporting Slides

NCC MERP Index for Categorizing Medication Errors



- No Error
- Error, No Harm
- Error, Harm
- Error, Death

Definitions

Harm
Impairment of the physical, emotional, or psychological function or structure of the body and/or pain resulting therefrom.

Monitoring
To observe or record relevant physiological or psychological signs.

Intervention
May include change in therapy or active medical/surgical treatment.

Intervention Necessary to Sustain Life
Includes cardiovascular and respiratory support (e.g., CPR, defibrillation, intubation, etc.)

PSR0306

NCCMERP Risk Assessment Index[1] and Bates' ADE Categorization Schema[2]

NCC MERP Category	Description of NCCMERP Category	Bates' ADE Category
No Error		
A	Circumstances or events that have the capacity to cause error	Rule violations
Error, no harm		
B	An error occured, but the medication did not reach the patient	Intercepted potential ADE
		Serious ADEs
C	An error occurred that reached the patient but did not cause patient harm	Non-Intercepted potential ADE
D	An error occurred that resulted in the need for increased patient monitoring but no patient harm	Non-Intercepted potential ADE
Error, harm		
E	An error occurred that resulted in the need for treatment or intervention and caused temporary patient harm	Preventable ADE
F	An error occurred that resulted in initial or prolonged hospitalization and caused temporary patient harm	Preventable ADE
G	An error occurred that resulted in permanent patient harm	Preventable ADE
H	An error occurred that resulted in a near-death event (e.g., anaphylaxis, cardiac arrest)	Preventable ADE
Error, death		
I	An error occurred that resulted in patient death	Preventable ADE

[1] National Coordinating Council on Medication Error Reporting and Prevention. http://www.nccmerp.org/medErrorCategories.html; [2] Bates, JGIM 1995;10:199-205

Two Weighting Schemas

1) proportion of prescriptions retrieved and evaluated from each of 3 on-site pharmacies reflects proportion filled at each of 3 pharmacies, during 12 month timeframe

2) analysis weighted to reflect clinic-wide prescribing practices

- Adjusted for prescriber specialty & therapeutic drug class
- Stratified by onsite pharmacy from which prescription retrieved
- R x C tables – proportion of scripts represented by each pair of provider specialty and drug class, within each pharmacy
- R x C table – same elements from 12 months of claims data from all clinics, all pharmacies
- Ratio – numerator = claims; denominator = study data
- Each ratio applied to each prescription in dataset

Med Error Study-Analyses (1)

- **Aim 1**: Estimate unadjusted differences in error characteristics:

  $(p_1 - p_2) / \sqrt{[p_0 (1 - p_0) (1/n_1 + 1/n_2)]}$; where $p_0 = (X_1 + X_2) / (n_1 + n_2)$

- **Aim 1**: Estimate error distribution and severity – binary outcomes
- Hierarchical data – prescription, prescriber, provider/ clinic type, geographic site
- Generalized estimating equations (GEE) with alternating logistic regression (ALR)[1]
- GEE – an extension of generalized linear models: $g(\mu_{ij}) = X'_{ij}\beta$; GEE adds the covariance component; used for first order models (mean and (co)variance)
- ALR:
  - **Step 1**: logistic regression using 1st order GEE to estimate regression coefficients (β); binomial distribution; logit link
  - **Step 2**: logistic regression of each response on others from the same cluster, using an offset to update the odds ratio parameters; estimate pairwise odds ratios for within cluster associations (α), conditional on β

[1]Carey. Biometrika 1993;80:517-26

Med Error Study–Analyses (2)

- Equation to estimate the dependence of the outcome on the covariates (β's):
- **Logit $Pr(Y_{hijk}=1|X_{hijk}) = \beta 0 + \beta 1$(e-prescribing) $+ \beta 2(cov_{hijk})$**

- Equation to estimate the pairwise odds ratios for the within cluster associations (α's) while simultaneously taking into account the β's:
- **log odds ratio $(Y_{hijk}=1) = \alpha_0 + \alpha_1 Z_{hijki'j'k'} + \alpha_2 Z_{hijki'j'k'}$**

- Pairwise odds ratios will describe the odds in favor of an error occurring for a prescription within that level, when compared to a second prescription from within that same level of association.

- The results of the algorithm should return estimates that specify the odds ratios of an error occurring, given each covariate; as well as odds ratios for within prescriber, within provider/clinic type, and within geographic site, each adjusted for the covariates.

Sample Size Calculation: Study #1

- Pilot study error rate = 28%
- Estimated error rate for this study = 25%
- 5% reduction[1] - to 24%
- 2 adult; 2 pediatric clinics
- 2-sample, 2-sided, χ^2 test; α = 0.05; 80% power
- 1,222 prescriptions/clinic
- 10,000 prescriptions

[1]Bates, JGIM 1995;10:199-205

Power Calculation Med Errors (1):

- Average # scripts/ prescriber = 120
- Use an ICC of 0.02
- Variance inflation factor (VIF) =
  1 + [(m -1) * ICC]
- VIF = 1 + (120-1)(0.02) = 3.38
- 10,169/3.38 = 3,009 scripts
- 49% pre-; 51% post =
  - 1,474 pre and 1,535 post

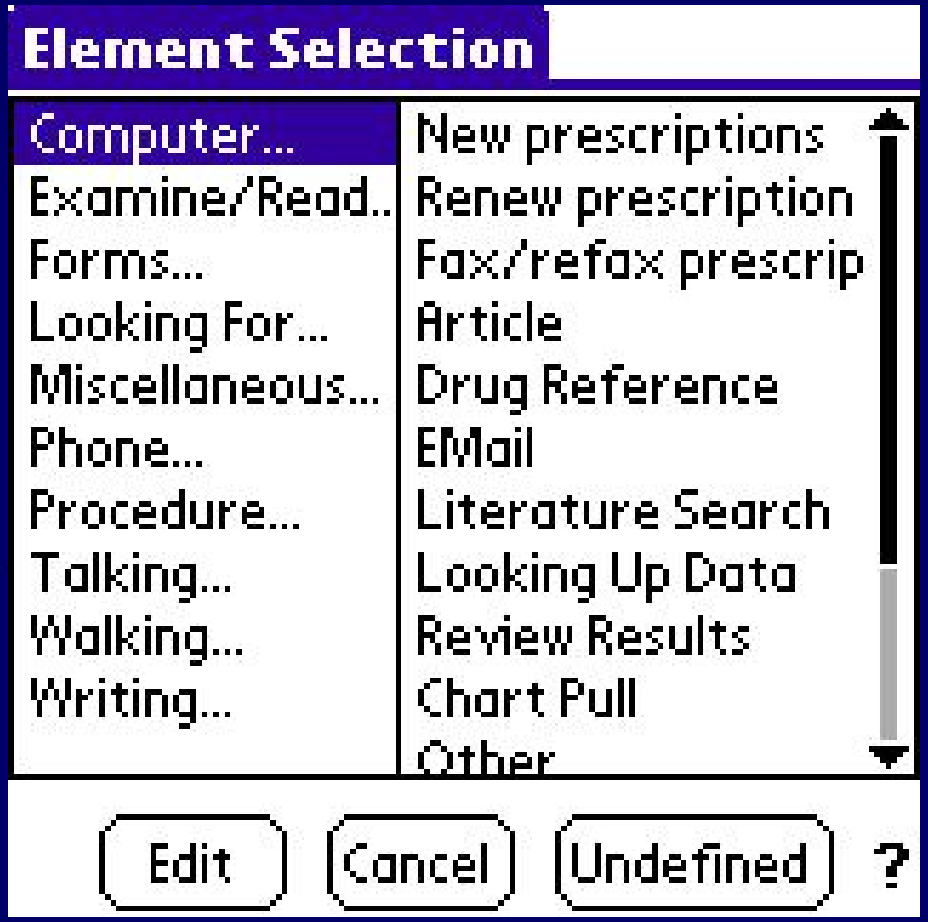
Power Calculation Med Errors (2):

- . sampsi 0.25 0.20, n1(1474) n2(1535)
- Estimated power for two-sample comparison of proportions
- Test Ho: p1 = p2, where p1 is the proportion in population 1
- and p2 is the proportion in population 2
- Assumptions:
- alpha = 0.0500 (two-sided)
- p1 = 0.2500
- p2 = 0.2000
- sample size n1 = 1474
- n2 = 1535
- n2/n1 = 1.04
- Estimated power:
- power = 0.9002

Data Collection Tool

All timing data collected with Timer Pro™

http://performance-measurement.com/



Time-Motion Analyses (2)

- Aim 2c: Linear Mixed Model

  $E(Y_{ij}|X_{ij}) = \beta 0 + \beta 1(\text{stage of e-prescribing}) + \beta 2(\text{prescriber}) + \beta 3(\text{covariate}_{ij}) + b_{0i} + \varepsilon_{ij}$

  where

  Y = adjusted mean difference in the number of seconds spent pre prescription/related event, for prescribers

  $\beta 1$ = stage of e-prescribing

  $\beta 2$ = prescriber (random effect)

  $\beta 3$ = new or refilled prescription (fixed effect)

  b_{0i} = random intercept between prescriber

  ε_{ij} = error term within clusters

  i=index for cluster/subject (prescriber)

  j=index for measurement within cluster (prescribing event)

Power Calculation-Time Motion (1)

- Aim 2c – Silver Lake site
  - 10 prescribers
  - Write 10 prescriptions / 4 hour time block
    - 50 $\pm$ 5 secs to hand-write
    - 60 $\pm$ 5 secs to e-prescribe
  - Assume
    - ICC = 0.01
  - Variance inflation factor (VIF) = 1 + [(m -1) * ICC]
  - VIF = 1 + [(10-1)0.01] = 1.09
  - 2-sided test; α = 0.05
- 95% power to detect 20% difference in time to write a prescription

Power Calculation-Time Motion (2) Updated (1)

- Number of prescribers = 25 pairs and 15 singles
- 35 prescribers
  - Write 8 prescriptions / 4 hour time block
    - 50 ± 5 secs to hand-write
    - 60 ± 5 secs to e-prescribe
  - Assume
    - ICC = 0.01
  - Variance inflation factor (VIF) = 1 + [(m -1) * ICC]
  - VIF = 1 + [(8-1)0.01] = 1.07
  - 132 handwritten + 312 e-prescribed events = 444 events
  - 444/1.07 = 415
  - 125 (30%) handwritten; 290 (70%) e-prescribed

Power Calculation-Time Motion (2) Updated (2)

- . sampsi 50 60, n1(125) n2(290) sd(5)

Estimated power for two-sample comparison of means

- Test Ho: m1 = m2, where m1 is the mean in population 1 and m2 is the mean in population 2
- Assumptions:
- alpha = 0.0500 (two-sided)
- m1 = 50
- m2 = 60
- sd1 = 5
- sd2 = 5
- sample size n1 = 125
- n2 = 290
- n2/n1 = 2.32

- Estimated power:
- power = 1.0000