Final Progress Report

Title of Project:	Improved Patient Safety with Information Technology
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Dates of Project:	09/30/2001 through 09/29/2005
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Improved Patient Safety Progress Report

Structured Abstract:

Purpose: To identify and reduce "indicators" of errors in ambulatory patient care using a clinical information system, the Regenstrief Medical Record System.

Scope: To improve asthma, CHF, and lipid management in 18 primary care practices that are part of a practice-based research network (ResNet).

Methods: Data were extracted regularly and analyzed by a clinical focus team, including a specialty physician, general internist, and nurse, using root cause and multidimensional exploratory data analysis methods to identify changes in the delivery system that could potentially reduce the "indicators." We implemented physician reimbursement changes (bonus calculation based on some of the selected indicators) and implemented a multimodal feedback process to clinicians, including periodic paper summary reports and feedback to the physician through a real-time, integrated physician order entry system.

Results: During the project's duration, we implemented two different randomized trials, conducted a survey study, published an article in JAMIA; successfully negotiated multiple organizational changes to IUMG-PC to decrease errors; and greatly expanded access to pharmacy data within the practices. We have preliminary evidence that organizational changes and academic detailing have significantly decreased errors in these practices, but we continue to analyze our results to date.

Keywords: Adverse drug events, Medical Records Systems, Computerized Ambulatory Care Information Systems, Adverse Drug Reaction Reporting Systems, Ambulatory care, Medication errors, Medical errors, Quality of health care

A. Purpose (Objectives of Study)

The overall objectives for this project were to detect errors of omission and commission for selected conditions using information systems and (using the same information system) reduce the errors.

The specific aims were outlined in the original proposal. They included:

1) Identify "indicators" of errors of omission and commission in patients using a primary care practice based research network's clinical information system, in effect creating a mandatory reporting system.

2) Analyze the "indicators" using root cause analysis and multidimensional exploratory data analysis techniques.

3) Measure the effectiveness of two specific changes in the delivery system in a cross over design randomized controlled trial. The first intervention consists of providing

individualized summaries of “indicators” to physicians and supplementing that feedback with “academic detailing.” The second intervention consists of providing patient specific feedback to the physician at the time they are caring for patients using a clinical decision support system (CDSS) integrated with the physician order entry (POE) system they already use.

4) Expand the conditions we are focusing on and transition the processes developed to the IUMG-PC quality improvement team.

Scope (Background, Context, Settings, Participants, Incidence, Prevalence)

When the Institute of Medicine (IOM) released its report, "To Err is Human," in November 1999, the public response was striking. The report estimated more than a million injuries and nearly 100,000 deaths attributable to medical errors annually. The IOM report made four major points: 1) the extent of harm that results from medical errors is great; 2) errors result from systems failures, not people failures; 3) achieving acceptable levels of patient safety will require major systems changes; and 4) a concerted national effort is needed to improve patient safety. Healthcare organizations were called upon to work with their professionals to implement known safe practices and to set up meaningful safety programs within their institutions, including blame-free reporting and analysis of serious errors.

There are many types of errors. Research has traditionally focused on errors of commission, things we did but shouldn’t have. But errors of omission, or things we should have done but didn’t, may be equally important and difficult to measure. Clinical practice guidelines represent one standard against by which we can assess clinical practice to decide if an error of omission has occurred. Clinical practice guidelines describe an acceptable standard of care in situations when there has been substantial variation among clinicians.

Various methods have been utilized to decrease errors of both commission and omission in healthcare systems, including “academic detailing” and physician-directed computer reminders. “Academic detailing” is the practice of delivering carefully crafted messages to clinicians in an attempt to change their behavior, with reductions in inappropriate prescriptions of 12 percent to 49 percent noted in prior studies. In turn, as several reviews have shown, reminders change clinician behavior to improve delivery of chronic, acute, and preventive medical care. We sought close collaboration with Indiana University Medical Group-Primary Care (IUMG-PC) to (1) assess baseline error rates and (2) employ both academic detailing and computer reminders to decrease both types of errors.

IUMG-PC is composed of 18 community health centers in Indianapolis that utilize the Regenstrief Medical Record System (RMRS). The RMRS represents the permanent clinical data repository for IUMG-PC, capturing both clinical and operational data for its patients.

The Medical Gopher component of the RMRS includes functions (G-CARE) to analyze patients' clinical data and generate suggested orders, which may indicate errors of omission or commission. We have well-established tools, including CARE, Fast Retrieval, and Report, for retrieving and organizing these data.

Methods (Study Design, Data Sources/Collection, Interventions, Measures, Limitations)

Our efforts were focused on implementing two different randomized trials, a survey study, an article published in JAMIA, organizational changes to IUMG-PC to decrease errors, and an expanded ability to detect patient medical noncompliance by increasing access to pharmacy data.

1. Physician survey and randomized crossover trial to determine the effects of periodic summary feedback with academic detailing and computer-based physician reminders on "errors" of omission and commission.

We successfully completed our physician survey, established key indicators for the target conditions, constructed our academic detailing, and computerized reminder interventions, but, for patient safety reasons explained below, we have had to temporarily suspend proceeding with our randomized trial of academic detailing and computerized physician reminders.

Specifically, we:

- Assembled literature on heart failure, asthma, lipid management, chronic disease management, and guidelines implementation using clinical decision support systems

- Held regular (bi-weekly) expert panel meetings

- Participated in conference calls

- Analyzed indicators of errors or adverse events, including: (1) ER visits; (2) hospital admissions; (3) missed medication opportunities (not on an indicated med); (4) failed intermediate outcomes – e.g., high blood pressures in patients with CHF; (5) urgent ambulatory visits; (6) laboratory abnormalities; (7) undiagnosed/unrecognized (not on problem list or treated but supported by clinical data; and (8) pharmacist interventions.

- Established key indicators for heart failure, asthma management, lipid management based on both the medical literature and retrievals using the Regenstrief Medical Record System.

- Analyzed these indicators using root cause analysis and multidimensional exploratory data analysis techniques

- Obtained IRB approval for the physician survey and randomized crossover trial

- ResNet research assistants (RAs) based in the physician's practices approached physicians to participate in the study. Consenting physicians completed a four-page survey.

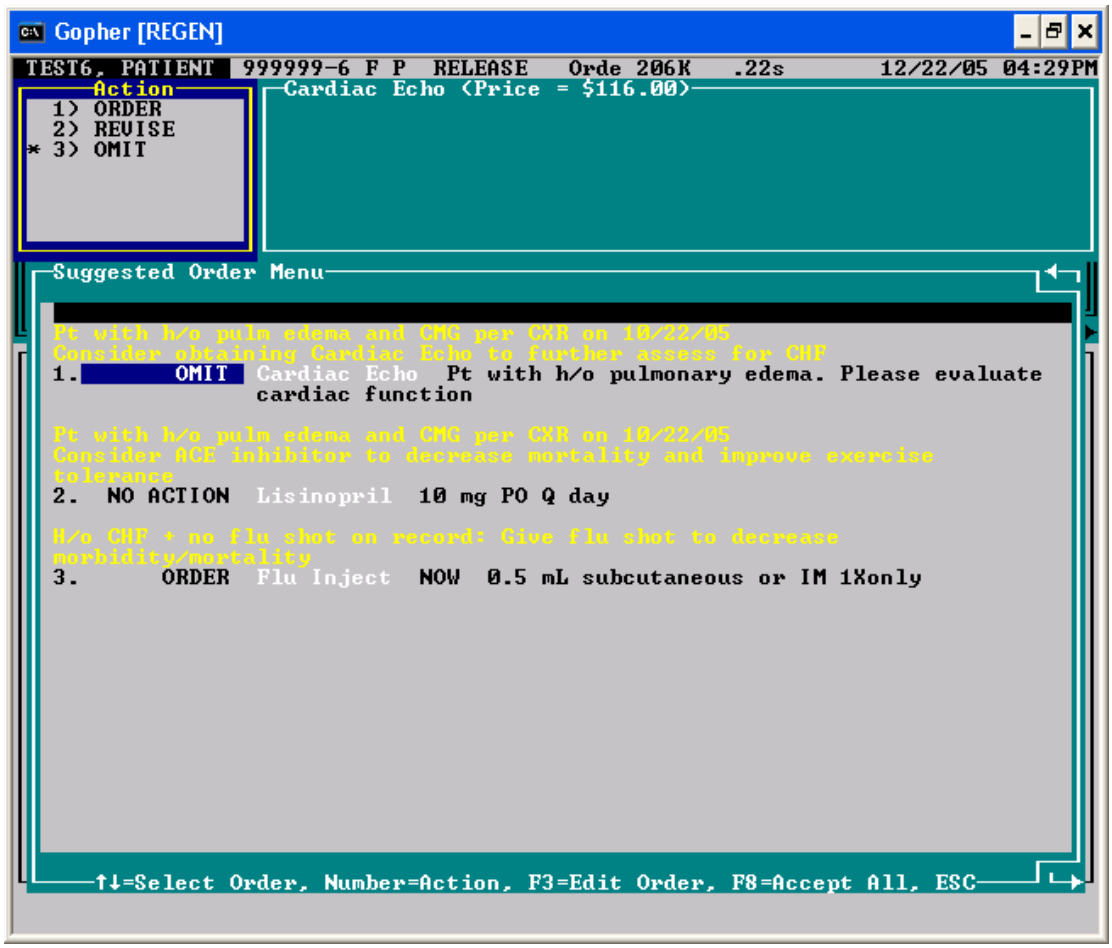
- Enrolled and conducted a survey of 85 doctors regarding their knowledge, attitudes, and beliefs about clinical practice guidelines.

- Modified Medical Gopher for study logging and intervention

- Presented findings in a poster at AHRQ Patient Safety Annual Meeting

- Developed the "academic detailing" intervention using Microsoft Access, involving a monthly reports of physicians' compliance with selected guidelines compared to their (anonymous) peers

- Created decision logic in G-Care corresponding to heart failure, asthma, and lipid management reminders (Figure immediately below depicts an example of physician-directed computer reminders)



Unfortunately, as mentioned, we recently have had to temporarily suspend this randomized trial for patient safety reasons. A few months ago, users complained of receiving intermittent reminders that were clearly wrong – e.g., reminders intended for the elderly but for patients who were much younger. (Notably, such problems with reminders have never previously been reported within our system.)

Upon exploration, we found that close to 10% of patients had "buffered" CARE rules that appeared to have been calculated based on another patient's data. This was quickly identified as unacceptable and a potential patient safety issue. We immediately suspended all computer reminders that relied on buffered CARE rules.

As background, "buffering" of CARE rules refers to offline pre-calculation and storage of CARE rule results on a per-patient basis, and it is required to prevent intolerable delays for the user. Without such offline pre-calculation, we have found that it takes an approximate "extra" 8-10 seconds for a user to be able to get into the order-writing input form.

One of our programmers has since devoted substantial time to debugging this problem. It is believed to be related to one patient's data being retained in memory when the "next"

patient's CARE rules are being processed. It was believed that the programmer had found a problem in the code with initialization, but the problem persists during subsequent testing. The programmer has most recently constructed real-time logging capabilities that are anticipated to better trap the circumstances under which the erroneous CARE rules are calculated.

We anticipate that we will be able to proceed with this randomized trial in the near future, pending evidence that the above issue has been fully resolved.

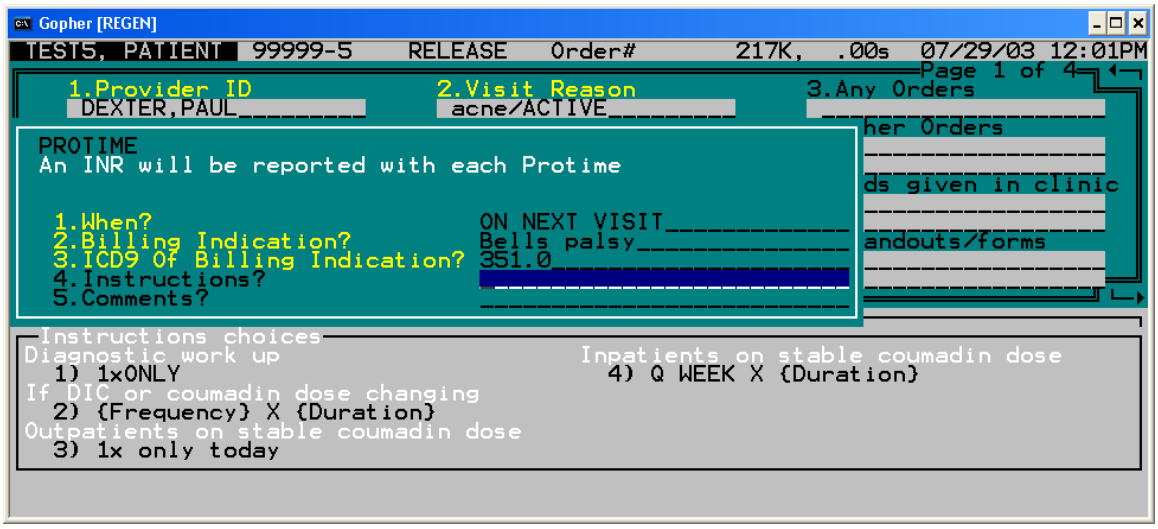
2. Randomized trial assessing the relationship between medical necessity documentation requirements and potential errors of omission.

During the course of the project, IUMG-PC physicians were required for billing purposes to document "medical necessity" for certain laboratory tests.

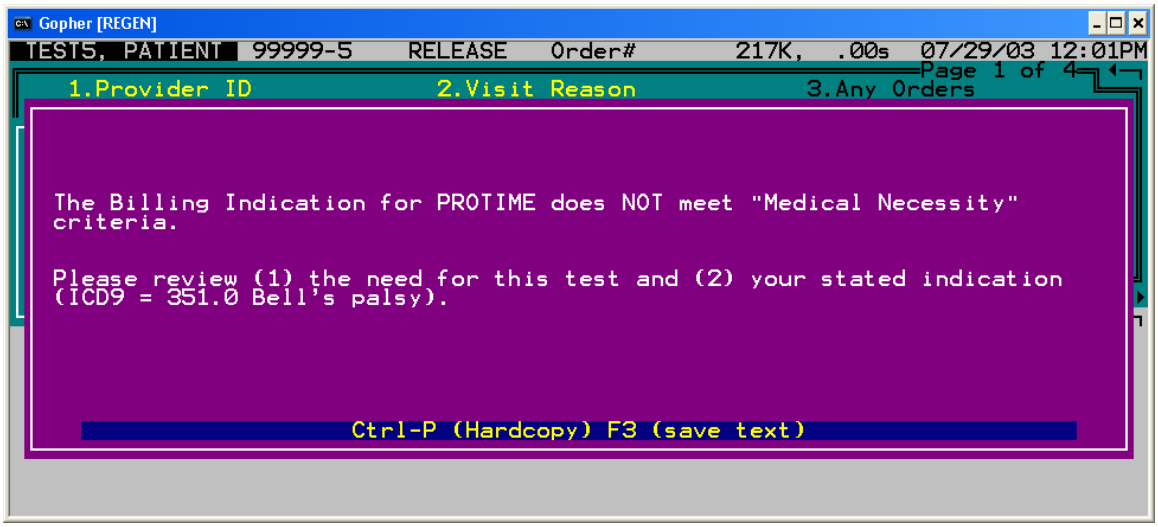
In discussions with IUMG-PC, the question arose about whether the extra work associated with physician documentation of a billing indication and its associated ICD-9 code might lead to decreased laboratory ordering rates, especially for laboratory tests related to preventive care (i.e., potential errors of omission).

We designed and completed a 6-month randomized trial involving 73 physicians to determine the effects of such documentation requirements.

For a defined set of laboratory tests (including lipid profiles, PSA, CBC, hepatic function tests, TSH), intervention physicians were required to enter a billing indication and its associated ICD-9 code (Figure immediately below depicts an example ordering window – Labels in yellow indicate fields that are "required" for completion of an order).



The entered ICD-9 code was then checked against a master list of Medicare-approved indications for those lab tests. If the entered ICD-9 code was not an approved indication for the lab test, then an alert was displayed to the physician (Figure immediately below).



3. Organizational changes to IUMG-PC to decrease errors of commission and omission.

We successfully negotiated with Senior Leadership of IU Medical Group Primary Care to include key "indicators" as essential metrics in their physician compensation plan. These target conditions were felt very consistent with their corporate priorities.

Reports of key indicators and target conditions have been subsequently run on a monthly basis and shared with the clinicians.

Graphs of performance are distributed to site directors (physician managers accountable for the practices' operations) for posting on a central bulletin for staff and physicians to review.

In addition, member-specific information is posted on an Intranet site that allows sites to go in and target patients who have not yet met a measure and benchmark themselves against other sites.

On the basis of ongoing discussions with IUMG-PC to decrease potential errors, we have also:

- Improved primary care/specialist communication by automatically notifying primary care physicians from within the Gopher order entry system when their patients are seen by subspecialists

- Implemented paging of primary caregivers at the time that their patients are hospitalized

- Implemented the means to capture "end-of-life discussion" notes, which trigger online reminders to inpatient and Emergency Department physicians when the patient presents

- Significantly enhanced the functionality and scope of Gopher order entry drug/ drug interaction checking capabilities

- Significantly supplemented Gopher order entry corollary orders – e.g., gentamicin levels when ordering gentamicin, electrolytes when ordering digoxin, "checking for patient metal" when an Abd MRI is ordered, etc.

- Implemented reminders to alert physicians when ordering radiology studies that include contrast for patients with renal insufficiency.

4. Article published in JAMIA

We gratefully acknowledged the Agency for Healthcare Research and Quality in a manuscript entitled "Physicians, Information Technology, and Health Care Systems: A Journey, Not a Destination."

A copy of our manuscript is here: https://www.ncbi.nlm.nih.gov/pmc/articles/ PMC353017/.

5. Improved ability to detect patient medical non-compliance by significantly expanded capture of IUMG-PC pharmacy data

When we started the project, a large proportion of patients (approximately 95%) had their medications dispensed by the Wishard Health Services (WHS) pharmacy, allowing us to address the important issue of appropriate medications being ordered but not filled.

As the project progressed, owing to changes in WHS pharmacy operations and Medicaid rules, more patients began to have their prescriptions filled elsewhere. As a means of accommodating to this new situation, we created interfaces to large pharmacy benefit managers (PBMs) through RxHub.

Results (Principal Findings, Outcomes, Discussion, Conclusions, Significance, Implications)

1. Physician survey and randomized crossover trial

Based on retrievals of the Regenstrief Medical Record System, we found probable errors related to the target conditions that formed the basis of key indicators. Some notable findings included:

- Recognition and monitoring
  - Only 52% of CHF patients had a prior echocardiogram
  - Only 2% of asthma patients had PFTs in past 18 months, and only 9% had ever had PFTs
- Asthma
  - 80% had controller prescribed
  - Only 45% of patients were found compliant with their controller (MPR>80%)
- CHF
  - 30% were not angiotensin blocked
  - 30% were not on any diuretic
  - 51% were not on an beta blocker (16% of those on a beta blocker are on a nonselective beta blocker)

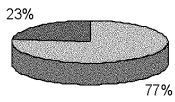
We also found considerable discrepancy among physicians in their approach to patients with target conditions. Notable findings of the physician survey that related to Knowledge, Attitudes, and Beliefs included:

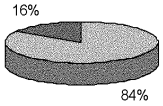
Questions	**Agreement**
In patients with CHF who are euvolemic (compensated) and on a low dose of an ACE inhibitor with systolic blood pressure of 110, diastolic blood pressure of 80, and a heart rate of 76, adding a beta blocker is the next most appropriate step.	65%
A patient whose signs and symptoms of heart failure resolve completely with diuretic treatment should be treated with an ACE inhibitor anyway.	94%
Inhaled steroids are an appropriate addition to PRN use of inhaled beta agonist for a patient with reactive airway disease who has 1 or 2 episodes per week, which resolve within an hour.	64%
Inhaled beta agonists are appropriate first-line therapy for a 50-year-old patient with a 20-pack per year smoking history who presents with symptoms of dyspnea.	46%
A diabetic patient with an HDL of 44 and an LDL of 120 should be initially treated for their hyperlipidemia with diet and exercise.	57%
Patients being treated with an HMG-CoA reductase inhibitor should have their LDL measured no more often than every year.	21%

We created the means to construct performance summaries for physicians using Microsoft Access tables. A sample of a monthly performance summary is included immediately below:

IMPROVED PATIENT SAFETY PROVIDER REPORT FOR: CARTER, JOHN

Asthma Controller Compliance





All Patients **Your Patients**

PATIENTS WHO ARE CURRENTLY NON-COMPLIANT WITH MEDICATION REFILLS

NAME	MRN	PHONE	STREET	CITY	STATE
SMITH, JOHN	1234567-1	317-999-9999	123 BEST LN	INDIANAPOLIS	IN
CLASS, VIRGIL	0789231-8	317-000-0123	456 FAIRLAND	INDIANAPOLIS	IN
ALBRIGHT, MICHAEL	0987325-5	317-213-3404	3001 N GLENDALE	INDIANAPOLIS	IN
RUTH, SARAH	0459873-0	317-902-4561	4621 KELSON RD	INDIANAPOLIS	IN
WILBUR, JIM	0123456-5	317-512-6331	PO BOX 22035	INDIANAPOLIS	IN
BENDER, MICHELLE	2222222-0	317-916-2185	318 N TREMONT	INDIANAPOLIS	IN
ALLEN, PATRICIA	1897451-3	317-217-9083	708 CASTLE	INDIANAPOLIS	IN
GRIFFITH, SIMON	3333345-6	317-209-0235	429 STANDARD DR	INDIANAPOLIS	IN
ZELLER, STEPHANIE	0000000-7	317-812-5645	2001 N TYLER AVE	INDIANAPOLIS	IN
JAMES, DARMOND	9999999-3	317-416-2154	6905 CATALINA DR	INDIANAPOLIS	IN

OPTIONS/SUGGESTIONS

1. *Call the Patient*
2. *Have Clinic Nurse Call the Patient*
3. *Wait Until the Patient's next clinic visit*
4. *Schedule a Sooner Visit to the Clinic*
5. *Send the Patient a Letter*

RESOURCES

1. *Asthma Education - Patient can be referred to asthma education coordinator Jamie Lee*
2. *Smoking Cessation - To register for this program patient needs to call 317-287-3717*

25-Feb-2003

As explained above, by necessity, we have temporarily suspended this randomized trial due to problems with CARE rule buffering.

However, we anticipate resuming the trial once the CARE rule buffering problem has been resolved.

2. Randomized trial assessing the relationship between medical necessity documentation requirements and potential errors of omission.

We completed the 6-month trial period and are now engaged in preliminary analyses.

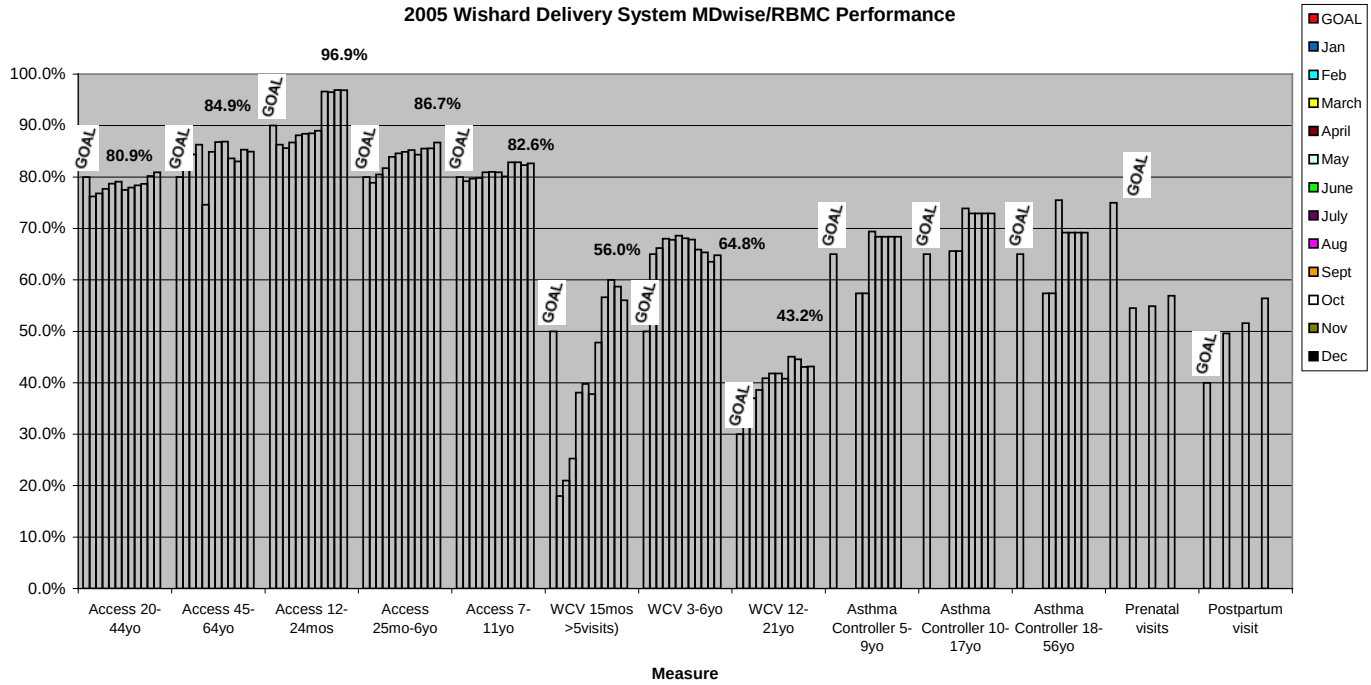
We have not detected any obvious trends in the absolute numbers of preventive care orders written by intervention and control physicians. However, we have not yet adjusted for either the number of patients seen or the physicians' baseline preventive care ordering rates.

We anticipate preparation of a manuscript based on these results in the next few months.

3. Organizational changes to IUMG-PC:

IUMG-PC now monitors performance on chronic diseases, such as asthma, lipid management, and diabetes, for several large groups of patients, including Medicaid and MPlan patients.

Each month, graphs such as the one below are distributed to the site directors for posting on a central bulletin for staff and physicians to review. In addition, member-specific information is posted on an intranet site that allows sites to go in and target patients who have not yet met a measure and benchmark themselves against other sites.



*Prenatal and post-partum measure results are derived from Mdwise remeasurement

November 29, 2005

There is strong evidence that such monitoring and feedback has significantly improved compliance rates.

For asthma in risk-based Medicaid:

- For 5-9 year olds, prescriptions for a controller increased from 58% in 2004 to 68% by the end of 2005.
- For 10-17 year olds, prescriptions for a controller increased from 60% in 2004 to 72% by the end of 2005.
- For 18-56 year olds, prescriptions for a controller increased from 68% in 2004 to 69% by the end of 2005.

For LDL<130 post cardiovascular events, IUMG-PC increased compliance from 60% in 2004 to 85% by end of 2005.

For HgbA1c< 9.5%, IUMG-PC increased compliance from 63% at the beginning of 2004 to 85.6% by the end of 2005.

4. Article published in JAMIA

Our manuscript was published in the Journal of the American Medical Informatics Association in March 2004 (found at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC353017/).

5. Improved ability to detect patient medical noncompliance by significantly expanded capture of pharmacy data.

As discussed above, we have successfully contracted with RxHub, a consortium of the largest PBMs, and Medicaid for claims data. These arrangements will allow for much more comprehensive capture of pharmacy data for IUMG-PC patients.

Because these data sources use NDC codes to describe the drugs dispensed, we have also invested in methods, data, and processes for mapping these NDC codes to clinically meaningful categories that correspond to those available from the WHS pharmacy so that we can link data across all of the sources. We have learned much from this process and have summarized that information in Appendix A.

We anticipate preparation of a manuscript that will describe our findings.

List of Publications and Products (Bibliography of Published Works and Electronic Resources from Study – use AHRQ Citation Style for Reference Lists)

McDonald CJ, Overhage JM, Mamlin BW, et al. Physicians, Information Technology, and Health Care Systems: A Journey, Not a Destination. J Am Med Inform Assoc. 2004;(11):121-4.

Overhage JM, Norton K, Amstutz K, et al. Improving patient safety in chronic diseases using electronic medical records [poster]. *Making the Health Care System Safer: AHRQ's Second Annual Patient Safety Research Conference;* 2003 March 2-4; Arlington, VA.

Appendix A: Efforts related to significantly expanded capture and linking of multiple sources of pharmacy data for IUMG-PC patients

We examined various medication databases for use to categorize NDC codes into clinically useful categories. The table below shows the matching we achieved with the three medication databases we have evaluated to date. There is a significant number of NDC codes that are not legitimate codes and don't appear in any database.

Three Knowledge Bases:

1) Multum..... 102,745 unique NDC codes

(using version obtained 2005 July 27)

Multum consists of two separate databases, which I combined:

Multum drug database contains 94,496 NDC codes; Multum Supply database contains 8,271 NDC codes

2) RxNorm..... 84,028 unique NDC codes

(using version dated 2005 June 16)

3) Thomson Micromedex Red Book..... 174,945 unique NDC codes

(using version obtained 2005 July 29)

Five Data Sources:

1) Comcotec..... 2,809 unique NDC codes

John Clifford provided me with all NDC codes used by Comcotec during the 6 months of 2004 Dec 8 through 2005 June 8. Total count of messages = 461,833

2) Clarian Pyxis formulary..... 3,292 unique NDC codes

(using version of 2005 July 6 provided by John Hook)

3) RxHub..... 7,718 unique NDC codes

Larry Lemmon provided me with 36,176 RxHub HL7 messages on 2005 August 1, with 304,855 RXD segments.

Larry says that these messages represent the last 6 months of RxHub data.

I distilled these into 7,718 unique NDC codes.

4)Wishard Inpatient Formulary..... 2,473 unique NDC codes

(emailed to me on 2005 August 9 by Karen Zendian)

5) Wishard NDC_TERM_MAP file..... 133,325 unique NDC codes

This is a file produced by John Clifford on the VAX Regenstrief Database utility on 2005 May 25.

It seems to cover all NDC codes used by the Wishard outpatient pharmacy?

Removal of Package Code

As an attempt to improve the success rate of matching, we removed the package code and then repeated the same matching technique.

Each NDC code is built up of three components:

- the 5-digit Manufacturer Component
- the 4-digit Product Component
- the 2-digit Package Component

Our hypothesis was that there may be the most variability in the Package Component;

and that the Manufacturer Component and Product Component are better standardized.

We used Perl to remove the Package Code, producing tables with 9-digit modified “NDC codes.”

Number of unique “shaved 9-digit NDC codes” in the three knowledge bases and the five data sources:

Multum..... 56,585

RxNorm..... 40,553

Thompson..... 92,584

Comcotec..... 2,682

Clarian Pyxis..... 2,745

RxHub..... 6,073

Wishard Formulary..... 2,295

NDC_TERM_MAP..... 71,909

Then, we repeated the same analysis as before. For example:

```
SELECT Comcotec_shaved.ndc, Multum_shaved.ndc
FROM Comcotec_shaved LEFT JOIN Multum_shaved ON Comcotec_shaved.ndc = Multum_shaved.ndc
GROUP BY Comcotec_shaved.ndc, Multum_shaved.ndc
HAVING (((Multum_shaved.ndc) Is Not Null));
```

	Multum	**RxNorm**	**Thomson**
Comcotec	77.2% (2071/2682)	54.4% (1460/2682)	75.6% (2027/2682)
Clarian Pyxis	98.1% (2692/2745)	75.2% (2063/2745)	96.0% (2634/2745)
RxHub	95.1% (5776/6073)	64.2% (3900/6073)	96.5% (5858/6073)
Wishard Formulary	95.3% (2186/2295)	67.5% (1549/2295)	94.6% (2170/2295)
NDC_TERM_MAP	56.8% (40,846/71,909)	19.7% (14,157/71,909)	73.9% (53,135/71,909)

It was clear from the above analyses that each of the five data sources have NDC codes that are not recognized by any of the three knowledge bases. We defined such NDC codes as “Bad Boys.”

We picked out these “Bad Boy” NDC codes with queries such as:

```
SELECT comcotec.ndc, comcotec.description

FROM ((comcotec LEFT JOIN multum ON comcotec.ndc = multum.ndc) LEFT JOIN rxnorm ON
comcotec.ndc = rxnorm.ndc) LEFT JOIN Thompson ON comcotec.ndc = Thompson.Package_Code

GROUP BY comcotec.ndc, comcotec.description, multum.ndc, rxnorm.ndc, Thompson.Package_Code

HAVING (((multum.ndc) Is Null) AND ((rxnorm.ndc) Is Null) AND ((Thompson.Package_Code) Is Null));
```

Comcotec "Bad Boys"

Comcotec has 610 "Bad Boy" NDC codes (610 of 2809 = 21.7%) that have no matching equivalents in the three knowledge bases (Multum, RxNorm, Thomson).

However, most of these "Bad Boy" NDC codes are actually used very rarely.

- 469 of these "Bad Boys" appeared only once.
- 79 appeared only two times.
- 29 appeared only three times.

(whereas the total count of all occurences of Comcotec NDC codes is 461,833).

Many of these "Bad Boys" have suspicious numbers:

- 6 start with the digits "44444"
- 5 start with the digits "77777"
- 3 start with the digits "88888"
- 574 start with the digits "991"

It is instructive to examine the descriptive names associated with these NDC codes.

For example,

- 228 of the "Bad Boys" are cream or ointment preparations of FLUOCINONIDE
- 26 are cream or ointment preparations of TRIAMCINOLONE
- 58 are TETRACYCLINE CAPS

Clarian Pyxis "Bad Boys"

Clarian Pyxis has 392 "Bad Boy" NDC codes (392 of 3,292 = 11.9%)

Many of these have suspicious numbers:

- 12 start with the digits "00000"
- 10 start with the digits "55555"
- 11 start with the digits "66666"
- 317 start with the digits "99999"

About a third of the "Bad Boys" represent IV fluids. For example,

106 of them are IV fluid preparations starting with the word “Dextrose”

Many are numbered sequentially, as if someone at the pharmacy was creating NDC codes:

99999999112..... Dextrose 2.5% Sod Chloride 0.2% 1000mL

99999999113..... Dextrose 2.5% Sod Chloride 0.2% 250mL

99999999114..... Dextrose 2.5% Sod Chloride 0.2% 500mL

99999999115..... Dextrose 2.5% Sod Chloride 0.3% 1000mL

99999999116..... Dextrose 2.5% Sod Chloride 0.9% 1000mL

RxHub “Bad Boys”

RxHub has 168 “Bad Boy” NDC codes (168 of 7718 = 2.2%)

However, most of these “Bad Boy” NDC codes are actually used very rarely.

- 76 of these “Bad Boys” appeared only once
- 34 appeared only two times
- 21 appeared only three times

(whereas the total count of all occurences of RxHub HL7 RXD segments is 304,855).

Interestingly, 73 of the “Bad Boys” are associated with drugs from CVS. For example,

- CVS ACETAMINOPHEN 325 MG TAB..... 50428301424
- CVS ACID REDUCER TABLET..... 50428116957
- CVS ALCOHOL SWABS..... 50428130344
- CVS ALLERGY 12.5MG/5ML ELIX..... 50428316224

(a query of the FDA website for the Labeler code “50428” returns “No matching records found.”)

Wishard Inpatient Formulary “Bad Boys”

Wishard Inpatient Formulary has 167 “Bad Boy” NDC codes (167 of 2473 = 6.8%)

Many of these “Bad Boys” have suspicious numbers:

- 4 start with the digits “11111”
- 76 start with the digits “55555”
- 13 start with the digits “77777”
- 38 start with the digits “99999”

NDC_TERM_MAP “Bad Boys”

The Wishard NDC_TERM_MAP file has 30,062 “Bad Boy” NDC codes (30062 of 133325 = 22.5%)

Of these, 15,393 are associated with a blank in the “TERM” field. However, the remainder seem to have a valid name of a real medication in the “TERM” field.

Reanalysis with the “Bad Boy” codes removed

After studying the “Bad Boy” NDC codes that do not match any of the three knowledge bases,

we used MS Access to create new tables with the “Bad Boy” codes removed.

Our hypothesis is that the “Bad Boy” NDC codes represent a locally invented code, created at a local pharmacy, and would never be matched by any national drug code database.

Therefore, if our goal is to compare these national drug code databases (Multum, RxNorm, Thomson, Medispan, First Data Bank), we might get a more accurate comparison, if we exclude any “locally invented” codes from the analysis.

We constructed the same 5 x 3 matrix as before, using these smaller tables that have the “Bad Boy” codes removed:

Comcotec..... 2,199

Clarian Pyxis..... 2,900

RxHub..... 7,550

Wishard Inpt Formulary..... 2,306

NDC_TERM_MAP..... 103,263

	Multum	RxNorm	Thomson
Comcotec	98.8% (2,173/2,199)	68.3% (1,502/2,199)	94.4% (2,075/2,199)
Clarian Pyxis	99.5% (2,886/2,900)	75.1% (2,177/2,900)	96.1% (2,786/2,900)
RxHub	97.1% (7,331/7,550)	66.4% (5,015/7,550)	98.6% (7,439/7,550)
Wishard Formulary	99.1%	67.5%	97.8%

	(2,285/2,306)	(1,557/2,306)	(2,256/2,306)
NDC_TERM_MAP	68.6% (70,860/103,263)	24.2% (25,008/103,263)	90.0% (92,861/103,263)

NDC categorization

RxNORM shows promise as a coding system for medications that we receive as NDC codes so we have turned our attention to what hierarchy we could adopt. UMLS contains NDF-RT, and that could be used; unfortunately, though, NDF-RT categorizes medications by "clinical drug" (e.g., digoxin or amoxicillin) and "strength," with the "dosage form" (e.g., injectable, oral tablet or elixir) under the strength. We have found that using "clinical drug" and "dosage form" for groupings is more relevant for e-prescribing clinical decision support. The commercially available drug terminologies allow us to construct groupings based on "clinical drug" and "dosage form" but may not offer much advantage in the NDC mapping. My current leaning is that we will use RxNORM to map from NDC codes to clinical concepts (this means we have to map RxNORM concepts to RMRS concepts).

Using the "clinical drug" digoxin as an example:

RMRS Code RMRS term RxNORM Concept
129 Digoxin Digoxin Oral Tablet
2029 Digoxin Elixir Digoxin Elixir
6735 Digoxin Inj Digoxin Injectable Solution

12135 .Digoxin Capsules Digoxin Oral Capsule
Digoxin Oral Solution

NDF-RT
The NDFRT has a "Digoxin Preparation" whose children are:
Digoxin 0.1 MG/ML
Digoxin 0.1 MG
Digoxin 0.25 MG/ML
Digoxin 0.25 MG
and other strengths also.
"Digoxin 0.25 MG/ML" has a child "Digoxin 0.25 MG/ML INJ"

"Digoxin 0.25 MG" has two children: "Digoxin 0.25MG TAB,UD" and "Digoxin 0.25MG TAB"

Thus, the NDFRT does not have a concept such as "Digoxin Tab" or "Digoxin Inj".

Multum

Multum has a relational database in which either Route or Dose Form can be used as selection criteria.

Drug_Id = d00210 (Digoxin) and Route = 2409 (Inj) select for the Main_Multum_Drug_Codes 3032 (Digoxin Inj Solution 100 mcg/mL) and 3034 (Digoxin Inj Solution 250 mcg/mL).
Drug_Id = d00210 (Digoxin) and Route = 2426 (Oral) select for the Main_Multum_Drug_Codes 3013 (Digoxin Oral Capsules 50 mcg) and 3037 (Digoxin Oral Tablets 125 mcg) and others.

Similarly, Dose Form (Solution, Elixir, Tablets, Capsules) can be used as a criteria instead of Route.

Medispan
Medispan has the GPI (Generic Product Identifier) consisting of seven pairs: the sixth pair represents dosage form.

"Tab" is represented by 03 in the sixth pair; "Inj" by 20 in the sixth pair; "Elixir" by 10 in the sixth pair; "Cap" by 01 in the sixth pair.

Therefore, Medispan can classify Digoxin into the following 4 Dosage Forms:
31 20 00 10 00 01 xx = Digoxin Caps
31 20 00 10 00 03 xx = Digoxin Tab
31 20 00 10 00 10 xx = Digoxin Elixir
31 20 00 10 00 20 xx = Digoxin Inj

Ulitmedex
Thomson's Ultimedex Code has 25 characters. Characters 19 and 20 represent the Route. Characters 21 and 22 represent the Dose Form.

For example:
AHT AHR AJ4 000 000 A63 PO A1 --- = Digoxin Oral Tablets
AHT AHR AJ4 000 000 A63 PO AE --- = Digoxin Oral Capsules
AHT AHR AJ4 000 000 A63 IV A5 --- = Digoxin IV Solution
(because "PO" is oral, "IV" is intravenous, "A1" is tablets, "AE" is capsules, "A5" is solution)