

A Review of Medication Reconciliation Issues and Experiences with Clinical Staff and Information Systems

P.J. Porcelli¹; L.R. Waitman²; S.H. Brown³

¹Department of Pediatrics, Wake Forest University, Winston-Salem; ²Department of Biostatistics, University of Kansas Medical Center, Kansas City, KS; ³Department of Veterans Affairs, Department of Biomedical Informatics, Vanderbilt University, Nashville, TN

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Summary

Medication reconciliation was developed to reduce medical mistakes and injuries through a process of creating and comparing a current medication list from independent patient information sources, and resolving discrepancies. The structure and clinician assignments of medication reconciliation varies between institutions, but usually includes physicians, nurses and pharmacists. The Joint Commission has recognized the value of medication reconciliation and mandated implementation in 2006; however, a variety of issues have prevented simple, easy, and universal implementation. This review references issues related to the development and the implementation of medication reconciliation including: – the need of a system or standard for accurate drug identification to create a definitive ‘gold standard’ patient medication list, – identifying stakeholders of medication reconciliation within the institution and contrasting staff interest and participation with institutional resources, – observations and opportunities of integrating medication reconciliation with the electronic patient health record, and – summarizing a series of institutions experiences developing and implementing medication reconciliation. Last, as medication reconciliation becomes a regular process within medical centers, key concepts for effective implementation are discussed.

Correspondence to:

Peter J. Porcelli, MD MS
Department of Pediatrics
Watlington Hall
Wake Forest University
Medical Center Blvd.
Winston-Salem, NC 27157
E-mail: porcelli@wfubmc.edu

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Introduction

The Institute of Medicine report “To Err Is Human” described medical errors as a significant source of patient injury [1] and prompted the medical community to develop ideas and evaluate processes to reduce medical errors and patient injuries [2]. Medication errors are a leading cause of patient injury; the 7,000 medication related deaths per year are more than all US annual workplace-injury related deaths [3]. Medication reconciliation is defined by The Joint Commission as “the process of comparing a patient’s medication orders to all of the medications that the patient has been taking ... to avoid medication errors such as omissions, duplications, dosing errors, or drug interactions and should be performed at every transition of care” [4], and was developed specifically as to reduce errors in health care. Initial descriptions of medication reconciliation were presented in 2003 by Pronovost et al. [5], but variations of reconciliation as part of history-taking have been practiced for years, from Dr. Smith quizzing his patients about medications taken at home to inclusion of a pharmacist on rounds with the medical team [6, 7] to review patient medication lists or offer advice for medication decisions [8]. In 2005 medication reconciliation was identified as a National Patient Safety Goal by The Joint Commission [9], requiring institutions to develop and implement medication reconciliation as an active process to be evaluated during regular Joint Commission on-site surveys [10].

Several factors explain why medication reconciliation in the hospital environment is a complicated, challenging task for health care providers whose patients have complex disease states and numerous medications. As healthcare institutions across the country transition to electronic patient record systems, the current state of development presents an opportune environment for institutions to implement medication reconciliation as part of their overall patient health and safety strategy [11]. This report reviews concepts and justification to implement medication reconciliation, discusses the need for accurate medication identification, summarizes institutions development and evaluation of medication reconciliation, and offers common ideas and themes for an effective program.

Background

Organizational culture and clinical factors have emerged during recent years emphasizing the need to create medication reconciliation procedures and integrate them into daily clinical workflow. These factors include increased development and sale of new and combination prescription and over-the-counter drugs: the most recent Approved Drug Products Electronic Orange Book includes over 25,320 medication listings [12]. Second, with new pharmaceuticals comes the recognition of brand and generic drug names that are similar to and confused with medications for other indications: a 68 year old man presented with increased prothrombin and partial thromboplastin times and spontaneous hemorrhagic syndrome after receiving Previscan (fluidione), a vitamin K antagonist, instead of the desired medication for benign prostatic hypertrophy, Permixon [13]. Third, there is emerging a progressively aging population taking a greater number of medications which require different, complex timing schedules: one recent description of pharmaceutical use in community dwelling older patients 77.5 ± 8.7 years of age (mean \pm 1SD) showed an average of 9.6 ± 4.1 medications per person [14]. Fourth, the growing elderly population may present with physical and intellectual impairments, some with significant degrees of dementia [15]. Corsonello et al. described drug adherence during hospital admissions in 690 elderly patients over 64 years old. 312 patients, or 45%, reported taking more than five medications per day and about half, 347 patients, were dependent or needed assistance taking their medication. There were 433 patients (63%) taking at least one medication more than once per day and 148 (21%) taking at least one medication less than once per day [16].

Given the numerous medications some patients take, the complexity of medication regimes, and the potential for injury due to errors, one might assume that a concept as basic as the clinical staff having an accurate and complete listing of medications their patients are receiving would be considered a given for safe, complete medical care. However a review of the literature shows current practice fails to achieve this basic goal. Cornish et al. evaluated medication discrepancies at hospital

admission for elderly patients with an average age of 77 ± 10 years who were taking at least four medications at home [17]. Pharmacists reviewed the admission medication orders and noted that for 151 patients 53.9% had at least one medication discrepancy with an overall rate of 0.93 per patient (140 medication discrepancies). The most common error was an omission of a home medication during hospitalization, with cardiovascular and central nervous system medications missed most often. While 64% of the discrepancies were felt not to cause harm, 32% were judged as having potential to cause harm and 5.7% (8 discrepancies) were assessed for the potential to cause severe discomfort or clinical deterioration. For example, one patient's home prednisone medication was not reviewed at admission and not continued during hospitalization, while two additional patients continued taking personal supplies of non-steroidal anti-inflammatory medications during their hospitalization without their physician's knowledge.

Tam et al. performed a systematic review of 22 studies evaluating medical history errors at the time of admission and noted that medication errors were present in up to 67% of the 3755 patient cases reviewed [18]; this range increased to 83% when nonprescription drugs were included in the analysis. Omission of a home medication not continued during hospitalization was the most common error. They also noted significant heterogeneity of methods to collect medication histories and conduct medication reconciliation. They concluded a standard set of guidelines to develop and perform medication reconciliation and identify medication errors doesn't exist. This leaves it up to each institution to develop individual rules and practices.

In a later study, Wong et al. performed medication reconciliation at the time of hospital discharge and transition to home for 150 patients with average age 65.9 years (range 14-93) [19]. There were 1252 medication orders of which 322 (25.7%) had a discrepancy; 106 patient orders had at least one medication discrepancy. The most common discrepancy was a prescription that contained an inadequate amount of information such as administration route or frequency, $n = 52$. The concern of inadequate information on a prescription would be a delay in completing the prescription and initiating the medication. Again, the most common unintentional discrepancy was omission of a medication, $n = 24$, with cardiovascular medications being the most common medication group. However, probably more concerning was the finding that five medication discrepancies involved an incorrect medication dose.

Medication Identification

Medication reconciliation can be considered as a two phase process:

1. creation of a complete and accurate patient medication list, and
2. comparison of that gold standard list to other available sources listing patient medications.

Both phases must be completed correctly to assure reliable results and improve patient safety. The first phase involves developing a comprehensive longitudinal list of all standard prescription and over-the-counter medications, along with nutritive and herbal supplements, and defines the substances using a standardized language describing the active ingredient as well as the dosage and administrative form [tablet, powder, suspension...]. That is, to assure a valid comparison there must be a naming system so that the description of drug X in the hospital pharmacy medication list also appears exactly the same in the patient medication reconciliation list, referencing not only the medication name, but associated information such as strength, concentration and dose form. Use of United States Adopted Names (USAN) or "generic" names only partially addresses this challenge. As healthcare organizations adopt and implement information systems to document patient care and facilitate recordkeeping, these systems also may improve healthcare delivery and patient safety [29]. The absence of nationwide standards makes sharing data and implementing electronic practice guidelines and advanced clinical decision support difficult [21-24]. As a result, these varied and incompatible systems lack standardized clinical terminology and refer to medications and other clinically relevant data (lab test results, patient diagnoses) using a variety of different terms [25].

Successful systems often are built and implemented locally within a single institution or organization, or in a "proprietary" fashion as single software products that do not interconnect with or depend on other application programs [25]. Programmers of such systems can create products

locally as a matter of convenience without concern for outside communications or standards. As a result, a proliferation of local medication “dialects” has emerged with incompatible naming systems for clinical drugs that limit data sharing. In addition, medications often have multiple unrelated and unlinked names created at different points in the product lifecycle including chemical names, “lab” names (e.g. FK506) [26], “generic” names and commercial trade names, impairing the reliability of computerized information retrieval [27], and making patient medication data hard to gather and maintain. For example, manufacturers and distributors create approximately 4,000 new national drug codes (NDC) for packaged products each month. Sources of medication identification or administration miscommunications that lead to medical error and patient injury emerge at several points in the health care system. As noted at top of ▶ Figure 1, there are a variety of methods and systems to ‘name’ medications. The current de facto state of multiple drug naming systems adds complexity to medication reconciliation by requiring that mappings between systems be developed and maintained. The middle row of topics recognizes systems problems related to medication information access including the variable quality of drug information available on the Web, inconsistent name use for similar medications, and underuse of reviewed high-quality information Web-based resources. The bottom row identifies common hurdles encountered by many medical center electronic health and information systems attempting to support medication reconciliation processes. We suggest developers and supervisors of medication reconciliation projects carefully consider the accuracy of medication identification as a critical component of the medication reconciliation process.

Two important initiatives that address several of these core information challenges are Structured Product Labeling (SPL) and RxNorm. To help improve access to high quality medication information, The Food and Drug Administration (FDA) approves and distributes electronic versions of package inserts that are XML tagged using the Health Level Seven (HL7) Structured Product Labeling (SPL) document markup standard. These marked up electronic package inserts are available for browsing and download from the National Library of Medicine's DailyMed website.

The National Library of Medicine's RxNorm is a robust drug naming system that addresses challenges at all three levels of ▶ Figure 1. In late 2001, the National Library of Medicine (NLM), in collaboration with the Veterans Administration, began an experiment to develop standard representations for “clinical drugs,” and their components [28]. This experiment evolved into RxNorm, a naming system that represents medications in the way that clinicians order them (i.e. a “clinical drug”) in contrast to how manufacturers provide them. For example, some drugs are provided by the manufacturer as lyophilized powders for reconstitution but administered to the patient as intravenous solutions. RxNorm includes semantic clinical drug names (SCD, e.g., acetaminophen 325mg oral tablet), semantic branded clinical drug names (SBD, e.g., tylenol 325 mg oral tablet), representations of clinical drug components (e.g. acetaminophen 325 mg + codeine 30 mg) and ingredients and extensive resources for cross mappings. The RxNorm representation explicitly represents every active ingredient (e.g., propranolol), numerical ingredient quantifier (e.g., 10), units of strength (e.g., milligrams), and dose form as administered (e.g., tablet) for a given clinical drug preparation. Interrelationships among the various drug names supplied by major vendors (e.g., First Databank, Multum) and pharmaceutical trade names are included in RxNorm (▶ Figure 2). RxNorm allows sophisticated, computer supported linking between information systems by interrelating medication names (e.g., to know that “Ciprofloxacin 100 mg/50 mL intravenous infusion,” “Ciprofloxacin 400 mg/200 mL intravenous infusion,” “Ciprofloxacin Lactate 0.2% in Saline [Base Equiv],” and “Ciprofloxacin IV Soln 2 MG/ML” are “clinically” equivalent) [27, 29, 30].

The first version of RxNorm was released as part of the January, 2002 Unified Medical Language System (UMLS) Metathesaurus. Weekly updates and full monthly releases are available without charge from the NLM. As of July 6, 2010 RxNorm contained 18,898 standardized names for generic clinical drugs (semantic clinical drugs or SCD), and 15,663 names for branded clinical drugs (semantic branded drugs or SBD) [31]. As of the June 6, 2010 release RxNorm began to include VA (Veterans Administration) National Drug File Reference Terminology (NDF-RT) coded clinical drug properties including mechanism of action, physiologic effect, and therapeutic category.

RxNorm facilitates meaningful information exchange among the different computer systems that support electronic prescribing, clinical decision support and other clinical, research and administrative functions in use around the country [32]. For example, RxNorm is being used as an

interlingua for electronic medication data exchange between the Veterans Administration and the Department of Defense project undergoing interagency testing with translation and mediation success rates between 93% and 99% [33, 34].

Medication Reconciliation and Electronic Medical Records:

The Joint Commission (JCAHO) announced 2005 National Patient Safety Goal #8 to "accurately and completely reconcile medications across the continuum of care" [35]. This goal was decomposed into two requirements:

"8a) Implement a process for obtaining and documenting a complete list of the patient's current medications upon the patient's admission to the organization and with the involvement of the patient. This process includes a comparison of the medications the organization provides to those on the list. [Note: While this safety goal does not require a separate form for the medication list, many organizations have found it useful to develop and implement one or more forms to support the medication reconciliation process.]

8b) A complete list of the patient's medications is communicated to the next provider of service when a patient is referred or transferred to another setting, service, practitioner or level of care within or outside the organization."

The first task of creating a list of medications the patient is receiving on admission, commonly referred to as the Pre-admission Medication List (PAML) [36] is the initial focus of meeting The Joint Commission requirements. The second task, communicating the reconciled list to the next provider, termed the Discharge Medication Reconciliation (DMR), is dependent on implementation of the PAML. Researchers from Massachusetts provide detailed description of the PAML design [36], implementation [37], and effect of electronic medication reconciliation upon hospital admission and discharge [38]. Other medication reconciliation workflows targeted by The Joint Commission [39] that have not been extensively described in the literature include:

1. medication reconciliation in the Emergency Department (ED),
2. change in level of care from the intensive care unit (ICU) to Medical-Surgical stepdown and from Med-Surg to ICU, and
3. perioperative medication reconciliation [40].

In order to highlight practical challenges, we provide the following observations from our experiences developing and implementing electronic medication reconciliation at Vanderbilt University Medical Center's adult and pediatric hospitals and emergency departments, guided by the early work of Poon et al. [36].

Paper-based medication reconciliation

In a hospital that relies on paper-based processes, creation of the PAML on a single form puts responsibility on the individual completing the form to reconcile the various sources of medication information. These sources may include:

1. verbal communication with the patient, their family or caregiver,
2. medication bottles and pills brought in by patient,
3. reviewing orders from prior admissions as well as current orders,
4. contacting outpatient pharmacies or obtaining information regarding prescriptions and dispensing logs, and
5. reviewing the medical record (electronic or paper forms) from prior admission history and physicals as well as problem lists.

This simple paper list masks the complexity of a thorough reconciliation. The medications entered on the PAML may be obtained and updated by multiple members of the care team, but reviewed and signed by a single responsible provider. Updates and modifications to the paper PAML may not be explicitly recorded on the form and quality assurance of the PAML process requires manual

chart abstraction. To move beyond simply complying with Joint Commission guidance towards facilitating care, the organization must consider how paper-based or electronic medication reconciliation integrates into practice workflow to provide accurate patient information to the physician when admission and discharge orders are created.

The promise of electronic medication reconciliation

In an environment with an electronic medical record (EMR) and clinical systems integration, computerizing medication reconciliation promises to reduce the time to collect and review the PAML by presenting pre-existing electronic medication sources that could be developed into an automated process. This optimism must be tempered with the understanding that system generated medication information may result in significant discrepancies; most commonly a medication listed in the EMR but no longer prescribed for the patient [41]. The latest medication list from an outpatient visit, electronic prescriptions, pharmacy benefits data, or even dispensing information does not always reflect what medications a patient is actually receiving. Instead, the objective of electronic medication reconciliation should focus on enhanced support for the clinicians conducting medication reconciliation. This includes

1. using existing electronic sources to prompt the patient,
2. assisting the reconciling individual to record and code accurately medications and natural products,
3. reusing the medication information for subsequent decision support within computerized provider order entry (CPOE) when writing admission orders or modifying orders during transfers in level of care, and
4. leveraging the PAML and existing orders during the discharge reconciliation process.

For example, Schnipper et al. found reductions in potential adverse drug events occurred during discharge in the hospital environment that had higher integration between the PAML and the CPOE system (0.60 potential ADEs per patient, 95% CI, 0.38-0.97 with CPOE/PAML integration; 0.87 potential ADEs per patient, 95% CI, 0.57-1.32 without; p-value for interaction, 0.32) [38]. Additionally, electronic systems can provide detailed user activity logs which allow daily, comprehensive quality assurance of the medication reconciliation process.

Establish the initiative

Organizational leadership in partnership with software designers/vendors need to define the purpose and goals of medication reconciliation within the institution. While inherently multidisciplinary, leaders need to establish roles and responsibilities for initiating and populating the patient medication list and timely review by providers. They must establish the overall implementation plan for the phases of medication reconciliation (admission, transfer, and discharge). Together they define the level of integration between electronic clinical systems and clinical services: is the medication reconciliation application used on inpatient floors, preoperatively in clinics, preoperatively in the holding room, in the emergency department, or in outpatient clinic visits? If a phased implementation, they must consider how medication reconciliation in one portion of the enterprise affects receiving services. The challenge is significant because the workflow of medication reconciliation may not be formalized or mandatory until the institution grapples with the Joint Commission recommendations. Finally, defining metrics and a quality assurance process to provide feedback and encouragement to the health care providers.

Anticipate cultural challenges

Existing methods to record medication information vary within institutions and individual creators may have a strong sense of ownership over “their” medication list. If implemented incorrectly,

creating a single reconciled patient medication list may heighten culture conflict between physicians, pharmacists, and nurses across different clinical services in the organization. Previously, a nurse might record medication history separate from the physician's admission history and physical, and neither may access outpatient prescription records available only to the pharmacist. ED medication lists often are disassociated from the medication list compiled by an admitting team. Tensions and blame may rise across teams and professions if there is failure to recognize the challenges faced by different services. Emergency medicine may be satisfied with the level of quality their nurses can obtain during triage in five minutes prior to treatment and understand that the patient could not recall the precise dose or even the name of a medication. Upon admission, the receiving team may view the ED triage nurse's list as superficial; not realizing triage time constraints. Similarly, medical leadership may need to consider the challenges faced by surgical services. Since surgeons are rarely a patient's primary care provider, they may be uncomfortable making significant changes to patients' home medications. Organizations may need to address staffing for perioperative admissions. When the surgeon is in the operating room, nurse practitioners or other physician extenders may be responsible for medication reconciliation at discharge. These responsibilities need coverage on nights and weekends. Finally, brief surgical admissions may challenge medication reconciliation processes designed for the average length of stay. In a worst-case scenario, the patient may arrive on a non-surgical inpatient unit, have routine medication reconciliation performed by the nurse, but be unaware that discharge medication reconciliation activities took place in the recovery room.

Decisions regarding medication persistence and integration

Organizations need to decide which electronic sources should be available to assist in medication reconciliation and understand from the software vendor when the data from that source "expires". For example, if a patient had an ED visit three days ago and a PAML was created, should that PAML be used as the starting point for a new visit?; what if the encounter was three years ago? Decide if prior active orders or medications from a problem list may be used as valid sources or if the clinician must re-enter all medications de novo for each episode of care. Some sources of information might have lower reliability (e.g. insurance or pharmacy benefits management claims) than others (e.g. a discharge summary medication list or a recent PAML verified by pharmacists). Decide if active confirmation is necessary to assure that the patient is actually taking each medication or herbal supplement appearing on the PAML. Address the organization's ability to refine an incomplete PAML across locations and throughout the course of an admission. Finally, create a prioritized list of the most beneficial integration points between medication reconciliation and existing clinical applications and workflows. Some key example systems include ED triage documentation systems, CPOE, nursing admission history documentation, physician admission and history, progress notes, and discharge summaries. Many of the decisions regarding data integration are mediated by the capabilities of the existing clinical software systems in place at the institution.

Technical system architecture considerations

Technical choices exist regarding medication data storage, drug naming and terminologies, and level of precision of the medication reconciliation process into the institution's current clinical applications. The organization must examine their overall information architecture, determine whether they depend on one predominant vendor for clinical applications, and assess their vendors' strategies. The vendor, in return, needs to provide a roadmap illustrating both integration with current software and communication with potential external consumers of personal health records, regional health information organizations, and evolving requirements for meaningful use [42]. Organizations that utilize applications from several clinical system vendors should provide requirements for information exchange and facilitate medication reconciliation with the institution's clinical workflows. Medication reconciliation's complex workflow may require an iterative process if integrating across multiple clinical systems. As illustrated by two hospital examples in Schnipper

[38], the lack of integration may impact the clinical benefit (potential adverse drug event reduction).

In a heterogeneous environment, decide if a centralized database storing patient medications will serve as a gold standard. If multiple systems (inpatient, perioperative, and ambulatory) author medication lists, determine how they interact or synchronize with the centralized database. Understand the terminologies used by the various systems to represent medications and whether they support herbal/natural products [43]. The formatting, structure, and storage of patient medication data should be determined prior to implementing the medication reconciliation process. Does the result of electronic medication reconciliation create individual transactions for each medication or is the activity of creating a PAML represented as a single clinical document? Would such a document follow a standardized format such as Health Level 7 (HL7) Clinical Document Architecture (CDA), or the American Society for Testing and Materials (ASTM) Continuity of Care Document (CCD) [44, 45]? Determine if systems query on demand for medication information or if the information exchange follows a publish/subscribe paradigm. Consider if the tools to create medication lists are embeddable within other applications and how are such components invoked. The handling of authentication and patient context between systems must also be addressed. Additionally, in environments with rich decision support, allowing easy ordering off the PAML medications may be in conflict with existing decision support stemming from either drug-drug interactions, evidence-based medicine protocols or formulary restrictions.

Measuring the reconciliation process

Finally, the organization must determine how they will use electronic data to measure the effectiveness of medication reconciliation. Complement overall quantitative compliance stratified by unit and service with techniques and tools that allow clinical improvement activities periodically to validate the quality of medication information recorded for individual encounters. Consider also how to manage feedback from physicians receiving information they may determine to be inaccurate. Can they clearly see who collected the information? Should they raise the issue with quality assurance personnel, unit managers, or the individual who collected the PAML? If electronic tools merely shorten the time to enter poorly validated information, it satisfies the regulatory requirement but jeopardizes its objective: improved patient safety [46].

Medication Reconciliation Experiences:

Medication reconciliation is an important practice to reduce medical errors and improve patient safety; yet, there are relatively few project descriptions detailing planning, development, implementation and evaluation of institutional medication reconciliation programs. This is likely because the process of successfully implementing and evaluating medication reconciliation with patient health records is a lengthy, time-consuming, and iterative process. Further, compared to other clinical tasks which have transitioned to electronic format such as laboratory data retrieval and computerized physician order entry (CPOE), workflow issues hinder implementation and acceptance of medication reconciliation by the clinical staff [47-49]. A significant benefit for clinicians using CPOE is completion of patient medication orders, a process necessary for patient admission [50-52]. On the other hand, personal gain of the health care provider performing medication reconciliation is not as clear since the patient primary benefits in the form of reduced errors, fewer injuries and improved safety. We summarize several medication reconciliation development and evaluation experiences to provide information and illustrate key concepts for project managers and participating clinicians to develop or extend medication reconciliation in their institution.

The initial evaluation and development of medication reconciliation at Bellevue Hospital, the university teaching hospital for New York University Medical Center, with a paper-based system was felt to be too cumbersome and would have been obsolete as their medical center transitioned to an electronic health record (Bails et al.) [53]. The housestaff also felt paper-based medication reconciliation represented '*just another form*' for completion. Using an electronic format for medica-

tion reconciliation also allowed network auditing of the system, broad access to medication lists by health care staff: pharmacists, physicians, nurses, and others, and the option of linking medication reconciliation to computerized physician order entry if compulsory participation was deemed necessary.

Implementation of electronic medication reconciliation was technically successful, but not clinically effective. Compliance was low at ~20% since participation was encouraged but not mandatory, and timing of medication reconciliation was not specified. Another hurdle was creating two patient medication lists since admission CPOE medication orders could not populate the medication reconciliation drug list. Additionally, complications and confusion with same drug/different dose, medication list duplications, manual creation of the initial electronic medication list, and minimal clinician feedback all inhibited adoption. Medical staff meetings identified barriers, and educational sessions with patient scenarios emphasized benefits of medication reconciliation. One example described a patient whose out-patient angiotensin-converting enzyme (ACE) inhibitor medication was changed during admission due to hospital formulary restrictions; at discharge her original (out-patient) ACE inhibitor was restarted for home use, but the hospital initiated ACE inhibitor was not discontinued, leaving her with a therapeutic drug class duplication error, and hyperkalemia.

Continued education and iterative revisions had little effect until a mandatory compliance policy was implemented. The policy prevented new CPOE medication orders for patients without medication reconciliation within 24 hours of admission and improved participation from ~20% to over 90% within 1-2 months (►Figure 3). Unfortunately, the 24 hour window often meant the in-house, night-coverage staff performed medication reconciliation for patients on other services with whom they were less familiar. Also, the housestaff timesaving request for the patient medication reconciliation list to populate the patient admission medication orders was never realized, necessitating recreation of the same medication list in CPOE.

Kings County Hospital Center in New York City is the largest public hospital facility in Brooklyn, reporting 100,000 emergency visits and 25,000 hospital admissions per year. CPOE was activated at Kings County Hospital Center in over 100 outpatient clinics by February 2006 with electronic medication reconciliation, 'MedRecon', by May 2006 (Agrawal et al.) [54]. The admitting nurse or physician created the MedRecon medication list from the hospital records and patient interview. As patient admission medications were (re)ordered through CPOE, CPOE orders were reconciled with the MedRecon list. The hospital pharmacist reviewed the physician CPOE medication list with the MedRecon list; discrepancies were documented as errors and clarified with the physician.

Initial participation with the MedRecon system was poor despite consistent feedback to clinicians and e-mail reminders. Mandatory compliance was implemented with online reminders for the first 24 hours after admission and hard stops preventing creation of electronic progress notes after 24 hours. Hyperlinks to prompt completion of reconciliation were provided. Mandatory participation improved physician compliance from 25-35% to over 95% within two months (►Figure 4). 19,356 MedRecon events showed 264 discrepancies, or 1.4%, from 8/2006-12/2007, a comparatively low rate which may represent missed discrepancies. Omission of a home medication at was the most common discrepancy at 55.1%. The four characteristics associated with greater rates of medication reconciliation discrepancies were: patient age >65 years old, total medications >4, resident physician as the primary clinician, and nighttime admission (8 pm – 8 am).

The Mayo Clinic Preventive Medicine Clinic implemented interventions involving both patients and trained health care providers which included pre-appointment patient reminders to bring medications and paperwork to the clinic, and one-on-one training of the clinic's 12 physicians, 5 nurse practitioners and 3 fellows (Varkey et al.) [55]. The final 'gold standard' medication list was compared to the physician's EMR medication list. Medications with incorrect or missing doses, routes or times were identified as errors; any missing information was deemed an omission error. The intervention decreased patient prescription medication lists with at least one error from 88.9% to 66% and reduced physician admission notes with no medication list from 26% to 6%. The majority of discrepancies omitted the route of administration; yet, 9% of medications during preintervention contained an incorrect or missing dose. About 80% of all errors were considered minor as defined by Overhage [56]; however, one serious error before the intervention was a 10-fold high

dose of Synthroid, vs. none after training, and significant errors decreased from 70 during preintervention to 21 after intervention.

Complete and accurate medication reconciliation is difficult under the best of circumstances. Miller et al. [57] described significant challenges conducting reconciliation in the emergency department of a rural trauma population. The trauma team and admissions nurse compiled medication histories for 234 patients and recorded 1360 prescription medications. Complete drug histories were recorded for only 10 (4%) of the 234 patients by the trauma team compared to the admissions nurse rate of 26/234 (11%). There were obvious problems obtaining medication histories from patients with neurologic injury or impairment and no complete history was collected from any of the 20 patients with a Glasgow Coma Score (GCS) ≤ 12 . However, 204 of 214 (95%) medication histories collected by the trauma team from patients with GCS >12 contained at least one medication history component that was inaccurate or incomplete. The GCS is a 15 point scoring system reflecting the level of consciousness and responsivity in patients with suspected neurologic impairment, often due to injury or trauma [58]. The medication name was collected correctly 59% of the time, but accuracies of the dose (19 %), route (7%), and frequency (16%) were notably lower. Ten medication order errors were identified which included ordering an incorrect medication, incorrectly discontinuing or restarting a medication, or a medication overdose. Nine were detected by the pharmacist, but one patient developed hypoglycemia after the wrong dose of insulin was ordered and administered twice.

Infants in the neonatal ICU (NICU) are a unique patient group receiving multiple intravenous medications provided on a per-kilogram basis and have poor tolerance for errors [59]. We measured match rates between our bedside electronic health record, Neodata (Lisle, IL) [60], and the Central Pharmacy database for 26 of the most common neonatal drugs. Neodata facilitates patient documentation but is not linked to the Central Pharmacy Database. Bedside medication orders are forwarded to the Central Pharmacy Database, the gold standard. The match rate of daily patient medications listed in the Central Pharmacy Database with the Neodata patient medication listing for a six month period was 2621 of 4193, or 62%. Daily medications with a fixed time interval such as antibiotics and indomethacin showed the highest match rates compared to episodic medications like diuretics and nutritional supplements. Meropenem showed the highest match rate of 98.1%, while ferrous sulfate showed the lowest rate of 26.5%. During the evaluation it was discovered that nitric oxide, a neonatal pulmonary hypertension medication, did not appear in the Central Pharmacy Database because it was ordered and administered by the Respiratory Therapy Department. Thus, centers relying on the Central Pharmacy Database to analyze pulmonary medications may miss an important, commonly used neonatal medication.

A pilot study compared admission medication orders compiled by pharmacists and interns at Froedtert Hospital in Milwaukee, WI with home medications for 53 patients and identified 101 medication discrepancies, 19% of patient medication orders had four or more discrepancies (Murphy et al.) [61]. Their findings prompted funding of a pharmacist directed reconciliation program funded by 3.5 FTE (Full Time Equivalent). Compiling and comparing the pharmacist's comprehensive medication list to the medical team's medication orders took 32 minutes per patient. 525 home medications for 92 patients showed 163 discrepancies, 1.8 per patient. The most common discrepancy was omission of a home medication. The new system reduced rates of surgical unit medication errors from 90% to 47% and medical unit medication errors from 57% to 33%. Problems with implementation included clinical staff resistance to '*another paper form*', the electronic medication listing was confusing, and delayed transfer of information caused some patient discharges before medication reconciliation was completed. Modifications included simplifying medication lists, changing the paper form layout, and forwarding a patient discharge medication list to the pharmacy early enough to complete reconciliation before discharge.

Medication reconciliation training for nurses, pharmacists and physicians was conducted in small group or individual training sessions at Wesley Medical Center in Wichita, KS and promoted using poster flow charts (Kramer et al.) [62]. Paper reports produced from electronic data were reconciled by physicians, nurses and pharmacists for 283 patients. The total number of patient medications recorded at admission was greater after the training session, 6.0 ± 4.0 vs. 8.3 ± 5.2 medications, mean \pm 1SD, $p < 0.001$, likely reflecting a more thorough medication history. Despite the training and a modest 12-16 minutes for patient histories, post training discharge medication rec-

conciliation was not completed for 34 of 136, 25%, of the patients. Patient satisfaction survey scores for home medications were higher after training, including “Overall, I feel like I understand my medicines”, which increased from 4.22 ± 0.99 to 4.68 ± 0.53 on a 5 point Likert scale, $p = 0.001$. Personnel requirements for the project included a pharmacy computer programmer dedicated to maintaining the software and only daytime patients were included. For full night and weekend coverage at least two additional full time pharmacists would be required.

Discussion and Key Concepts

This review was developed to illustrate that an institutional medication reconciliation program can be as challenging to create and implement as it is important. Several central issues central to developing an effective medication reconciliation program have been examined including accurate medication identification, interaction with the electronic patient health record, and institutional reports of medication reconciliation implementation. However, some major concepts remain poorly defined including changes in clinician workload vs. benefit, allocation of institutional financial and personnel resources, and the timing of reconciliation with processes to resolve discrepancies. Effective medication reconciliation can meet the goal to reduce medical errors and injury, and enhance patient safety. We review several key concepts (► Table 1) to assist program directors and clinicians as they develop and improve their own institutional programs.

1. **Multidisciplinary Process:** Institutional leaders are in the position to promote the concept of medication reconciliation by recognizing publically the health and safety benefits, and defining project goals and timelines. Additional resources may include creating a leadership liaison position, allocating financial resources for personnel and materials [63], and sponsoring advisory committees and pilot programs. Further, leaders can promote an institutional culture of safety with educational instruction and nonpunitive error identification and reduction systems [2, 64].
2. **Personnel and Responsibilities:** A variety of personnel roles have been described for medication reconciliation from creating medication lists to clarifying discrepancies. In some centers the inpatient physician reconciled admission medication orders and corrected medication errors (Bails et al.); whereas, in other centers the ‘gold standard’ patient medication list was compared to the patient admission medication orders by pharmacists and pharmacy interns (Murphy et al.). Identifying and assigning specific roles early during the development process helps to clarify roles for performance and evaluation of medication reconciliation.
3. **Education and Feedback:** Medication reconciliation should promote a safety environment, but effective performance requires education of health care providers. Project leaders need to incorporate educational logistics early during planning sessions, whether health care providers are trained in groups (Kramer et al.), or by individual one-on-one instruction sessions as per outpatient clinic providers (Varkey et al.). Although most large institutions already have education programs in place for clinical update purposes, training all personnel in the largest medical centers may require weeks to months even with a pyramid/top-down training model. Ongoing education resources will be necessary for new personnel and updates as the reconciliation process is refined within the institution.
4. **Assess and Reassess:** Despite the Joint Commission recommendation for medication reconciliation in 2006, there is limited guidance detailing how medication reconciliation should be evaluated and improved within institutions. Unlike electronic laboratory results retrieval or CPOE in which inaccuracies or failures within the system come to light relatively quickly because clinician practices are impeded or patient care is affected, the effect of ineffective or incomplete medication reconciliation may not come to light until a patient is injured or a serious medication-related error is recognized. Medication reconciliation as an institutional process will require continued support and regular reassessment.
5. **Drug Identification:** Medication identification remains a challenge since often there is sparse discussion of the drug identification system used during development of electronic pharmacy systems. Information sources often are created internally or are proprietary because intercommunication is not a primary concern of the developer or purchaser. Facilities with multiple electronic information systems having limited data transfer result in the creation of multiple patient

medication lists. During initial medication reconciliation development project leaders need to identify the (Gold) Standard Patient Medication List, and methods to distribute or make the list available for general access.

6. **Clinician Culture and Attitude:** Publication of *To Err is Human* spurred development of programs designed to reduce medical errors and improve patient safety. The single largest category of medical errors involved medications and as a result, promoting a culture emphasizing medication accuracy is a major patient safety priority [65]. As medical care has grown more complex, using a systems approach to promote patient safety and change practice has become the primary goal rather than blaming individual health care providers when errors occur. This concept is realized in action as procedural time-outs, the second provider medication check, and medication reconciliation have entered clinical practice [66].
7. **Use the Carrot and Stick:** One would hope reduced medical errors and enhanced patient safety would stimulate enthusiasm of the clinic staff for medication reconciliation and reminder warnings for staff to complete medication reconciliation within a prescribed time frame would be sufficient. However, as described with institutional support of CPOE [67] and the reports noted above, medical center leaders should be prepared to use alternative methods such as workflow interruption to improve compliance if staff participation is inadequate.

Conflict of Interest

The authors have no conflicts of interest to disclose. Funding was provided in part for Dr. Waitman through NIH R01 LM007995-04. The portion of this study related to NICU medication reconciliation was reviewed and approved by the Forsyth Medical Center IRB in agreement with Wake Forest University Health Sciences IRB.

Naming Problems	Unrecognized Synonymy among Drug and Chemical Names	Proliferation of "Local Dialects" & Classifications	No Standard Naming or Coding System
Information Access Problems	Approved Government Drug Information Underutilized	Drug Information on the Web of Variable Quality	Inconsistent Naming Provides No Support for Linkages
Computer System Problems	Comprehensive Data Hard to Obtain and Maintain	Decision Support Often Limited By Local Dialects & Classifications	Standard Updates Inconsistent with Local Versions

Fig. 1 Current Medication Information Distribution Problems. Sources of medication misidentification or administration miscommunication, leading to medical error and patient injury emerge at several points along the health care process. As noted along the top row there are numerous methods and classification systems to 'name' medications, but without a single recognized system, multiple incommunicable systems emerge containing nontransferable information. The middle row of topics recognizes the variable quality of drug information available on the Web, inconsistent name use for similar medications, and underuse of reviewed high-quality information Web-based resources. The bottom row identifies common administrative, technical and educational information hurdles encountered with many medical center electronic health information systems.

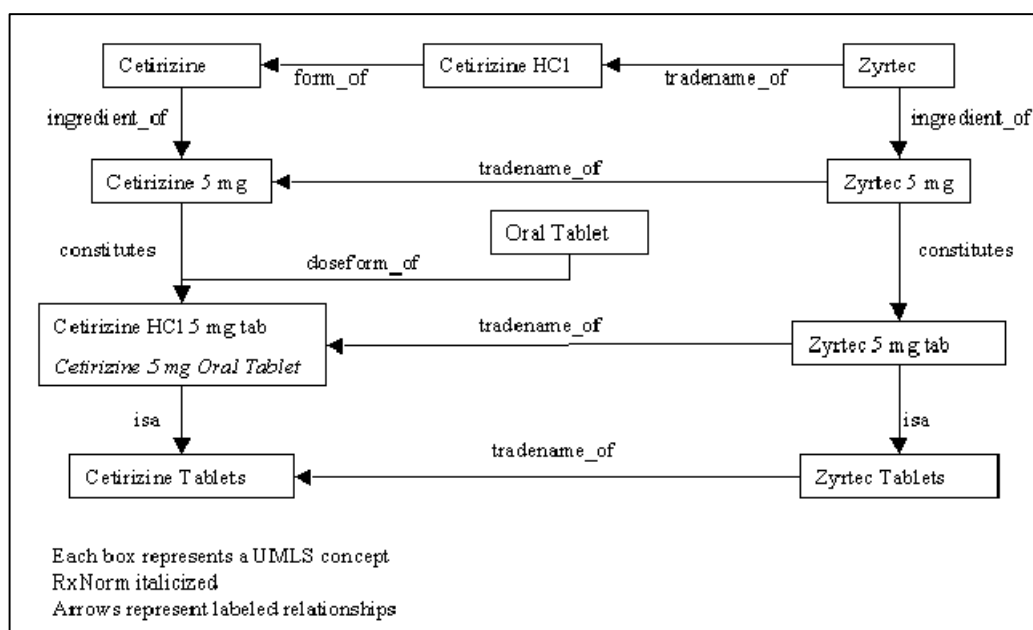


Fig 2 Naming and concept relationships in UMLS. This graphic steps through the commercial name of the drug sold as Zyrtec in 5 mg tablets, continues to the chemical form of the drug, cetirizine HCl supplied as an oral tablet, to the active drug ingredient and dose, cetirizine @ 5 mg, and finally to the basic active ingredient, cetirizine [28]. This format utilizes standard nomenclature on several levels, allowing identification and integration of medications with information systems that use different criteria to specify medications: trade and generic names, generic names and dose, salt form of the drug, and active ingredient.

Update the Patient's Outpatient Medication List (when done, click on this button -->) [List is Complete](#)

Current Medication List (Includes Prescriptions, OTCs, Herbal and Dietary Supplements) [Print Version](#) [View Help File](#)

If the patient is not on any medications or you are unable to assess, please indicate so here.

[Show Medication List Activity](#)

The patient is not currently on any medications.
I am unable to assess the patient's medications at this time.

☐ select all

	Name	Dose/Rt/Freq	#	Refill	Instructions/Comments/ Indications/Last Dose	Start Date	Last Activity		
							Date	Type	Src
<input type="checkbox"/> Edit	Tylenol 325 MG Oral Tablet	2 po daily							Hx
<input type="checkbox"/> Edit	Plavix 75 MG Oral Tablet	1 po qhs			hold for 1wk pre surg			new	Hx
<input type="checkbox"/> Edit	Celebra 20 MG Oral Tablet	1 po daily			md said not take			new	Hx
<input type="checkbox"/> Edit	*Isosorbide Dinitrate 10 mg Oral Tablet	x 1 tab po bid	60			16 Apr 2007	16 Apr 07	new	Rx
<input type="checkbox"/> Edit	Mylanta Double Strength Suspension, 150 mL	5 mL susp po Friday, 4 May 07 0939	1			4 May 2007	4 May 07	new	Rx
<input type="checkbox"/> Edit	*Ranitidine HCl 150 mg Oral Tablet	x 1 tab po bid	60	0		4 May 2007	4 May 07	new	Rx
<input type="checkbox"/> Edit	Albuterol SQ4 HFA Metered Dose Inhaler, 6.7 g	2 puff inhal oral q 4-6h prn	1	0	As directed	4 May 2007	7 Jun 07	renew	Rx
<input type="checkbox"/> Edit	Hydrochlorothiazide 50 mg Oral Tablet	x 1 tab po daily	30	5		4 May 2007	7 Jun 07	renew	Rx
<input type="checkbox"/> Edit	Unknown drug 123	1 po daily			for research study	1 Aug 2007	1 Aug 07	new	Hx

[List is Complete](#)

Fig. 3 Sample Longitudinal Medication List. Bails et al. [53] created an electronic outpatient medication list as the first step of medication reconciliation. The list included the drug name, dose and frequency, the number of pills in the prescription and refills, specific administration instructions or comments, and dates of initial prescribing, and latest activity. Modification of the list identified medications as new or renewal medications and identified the information source for the drug. The list included prescription medications, but also over-the-counter medications and herbal or dietary supplements. This medication list could be populated from the electronic health record, but also from pharmacy records and the patients verbal history.

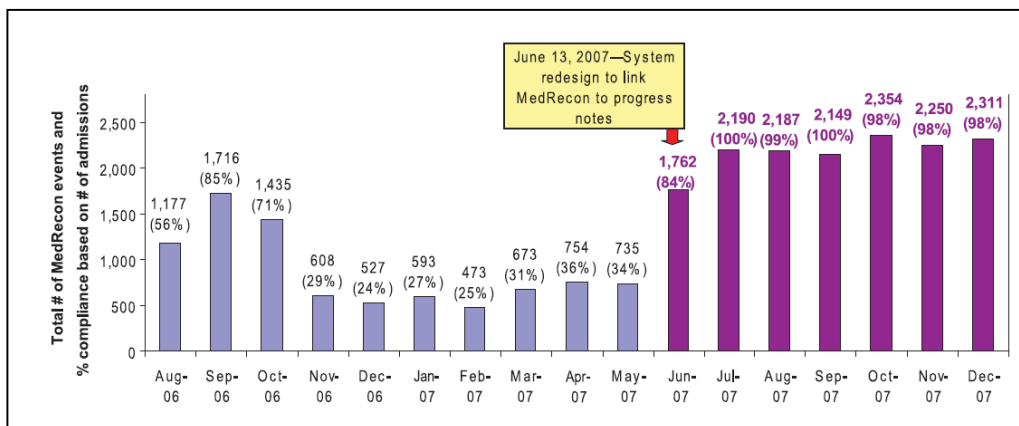


Fig. 4 Physician Compliance Before and After Mandatory Participation. Agrawal et al. [54] measured physician compliance with medication reconciliation before and after institution of soft stop warnings with a hard stop workflow interruption. During the process of creating electronic daily progress notes for patients with incomplete medication reconciliation, physicians initially were warned using a soft stop reminder alert. After 24 hours, a hard stop technique required medication reconciliation completion prior to creating the progress note. Physician compliance rose following initial rollout, which was not unusual, but then declined to the 25-35% range. Compliance rose to over 95% within two months of initiating mandatory medication reconciliation completion using the hard stop technique.

Table 1 Key Concepts for Medication Reconciliation.

Multidisciplinary Process	<ul style="list-style-type: none"> Medication reconciliation is a multidisciplinary process. To improve institutional acceptance and use, it is necessary to communicate with medical center stakeholders and clinician leaders early and throughout the development, implementation, and evaluation process, keeping them informed participants throughout the process.
Personnel and Responsibilities	<ul style="list-style-type: none"> As a multidisciplinary process, specific roles and responsibilities need to be assigned early and reevaluated on a regular basis. Team leaders should be best able to assess workflow impact of the medication reconciliation process and recommend adjustments as needed. Special situations may require specific procedures. [i.e. patients moving from the ED to the ICU may need a more rapid medication reconciliation process than those transferred to the floor]
Education and Feedback	<ul style="list-style-type: none"> As a patient safety and information issue, medication reconciliation is an easily justifiable clinical process. However, initial educational sessions, feedback to participants and continued recognition and encouragement of the process are key components necessary to justify and maintain clinician participation.
Assess and Reassess	<ul style="list-style-type: none"> Leaders of the institution's medication reconciliation process should perform an extensive initial clinical workflow evaluation and expect sequential meetings with the clinical staff to adjust the process as needed. These iterative loops maintain participation and interest and can be used to provide feedback and recognition.
Drug Identification	<ul style="list-style-type: none"> Selecting a drug naming system that is portable and can be applied across applications and systems within the institution is encouraged to minimize confusion and assure clinicians are comparing 'apples to apples'. Misidentification of drugs will undermine confidence in the medication reconciliation process and may cause patient injury.
Clinician Culture and Attitude	<ul style="list-style-type: none"> Software installation will provide the tools for clinicians to perform medication reconciliation, but integrating medication reconciliation as part of the culture of patient safety may represent an attitude change for some. The combination of knowledge and motivation is needed for medication reconciliation to become an accepted regular clinical procedure.
Use the Carrot and Stick	<ul style="list-style-type: none"> While educational sessions, regular feedback and professional encouragement should improve the knowledge and emphasize importance of medication reconciliation, project leaders should be ready to justify to senior hospital clinicians and administrators why mandatory participation may require clinical workflow interruptions or other institutional 'sticks' to assure participation.

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