An Information Technology Architecture for Drug Effectiveness Reporting and Post-Marketing Surveillance

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Abstract

Adverse drug events impose a large cost on the society in terms of lives and healthcare costs. In this paper, we propose an information technology architecture for enabling the monitoring of adverse drug events in an outpatient setting as a part of the post marketing surveillance program. The proposed system architecture enables the development of a web based drug effectiveness reporting and monitoring system that builds on previous studies analyzing the involvement of community pharmacies in identifying and reporting adverse drug events. We define the key requirements of such a monitoring and reporting system, identify the critical factors that influence the successful implementation and use of the system, and propose information technology solutions that satisfy these requirements.

Keywords: Adverse event reporting, community pharmacy safety network, post-marketing surveillance

1. Introduction

Adverse drug reactions are estimated to result in more than 2.1 million injuries and 100,000 deaths each year in the US alone (Lazarou, Pomeranz and Corey, 1998). The annual economic cost of adverse drug events is estimated to be more than $75 billion (Johnson and Bootman, 1995). Mitigating the impact of adverse drug events requires the implementation of a comprehensive mechanism for monitoring and detecting adverse drug events. Such a mechanism can save lives and reduce healthcare costs.

Detecting adverse drug events is a difficult problem. Although some adverse drug reactions are detected early on during clinical trials, serious adverse drug effects can still go undetected during this phase due to the practical limitations associated with the size and duration of the clinical trials. Recent examples of such cases include Rofecoxib and Cerivastatin (Fontanarosa, Rennie and DeAngelis, 2004). The FDA monitors for adverse drug events in the post-marketing phase through the MedWatch program (www.fda.gov/MedWatch/report.htm). The MedWatch program, which is a voluntary reporting program, suffers from various problems, the most critical of which is the under-reporting of adverse events.

In a 1996 article titled “The Clinical Impact of Adverse Event Reporting” the FDA estimated that only 1% of the adverse drug events are reported through the MedWatch program (Food and Drug Administration [FDA], 1996, p.5). An alternative mechanism for detection of adverse drug events is the use of longitudinal medical records and hospitalization records. However, the availability of such records is limited and obtaining longitudinal medical is an expensive and time-consuming process. In addition, the extraction of meaningful conclusions from such data is difficult due to data integrity, heterogeneity, and missing data problems.

Several information-technology based solutions have been suggested to help monitor and reduce the adverse drug event problem. Most of the proposed solutions and studies conducted are limited to inpatient contexts and hospital settings. Although a major part of drug dispensing and medications takes place in an outpatient setting, there is limited literature discussing the detection of adverse drug events in an outpatient setting. In this paper, our focus is on the detection of adverse drug events in an outpatient setting and in the post marketing phase using a web-based reporting system. Specifically, our focus is developing the IT architecture for enabling a large-scale data collection mechanism to support the detection of unknown side effects and drug interactions for drugs newly introduced into the market. We propose an IT architecture for enabling a web-based reporting and surveillance solution called the Drug Effectiveness Reporting and Monitoring System (DERMS). The DERMS system is based on a community pharmacy based safety network and involves the participation of community pharmacies for the collection of adverse drug event information from patients. We describe the information technology architecture that forms the supporting infrastructure for the surveillance system and discuss the requirements and success factors necessary for successful implementation of the system.

This paper is structured as follows. In Section 2, we describe the post marketing surveillance program and discuss the limitations of the system in its current form. In Section 3, we review previous literature discussing technological solutions to the adverse event detection problem. We briefy describe the Drug Effectiveness Reporting and Monitoring System and propose the enabling IT architecture in Section 4 and discuss the success factors for its implementation in Section 5. We discuss the limitations of the system in Section 6 and make concluding observations in Section 7.

2. Post-Marketing Surveillance

An effective surveillance process that follows the introduction of a new drug into the market requires the efficient flow of information among the different affected entities including patients, drug companies, the FDA and healthcare professionals such as doctors and pharmacists. This should include information on drug usage, interactions, adverse effects, and treatment outcomes. At present, the primary mechanism of disseminating information from the drug companies and FDA are through press releases, information services, and pharmacy databases that enable timely dissemination of information on drug interactions and labeling information.

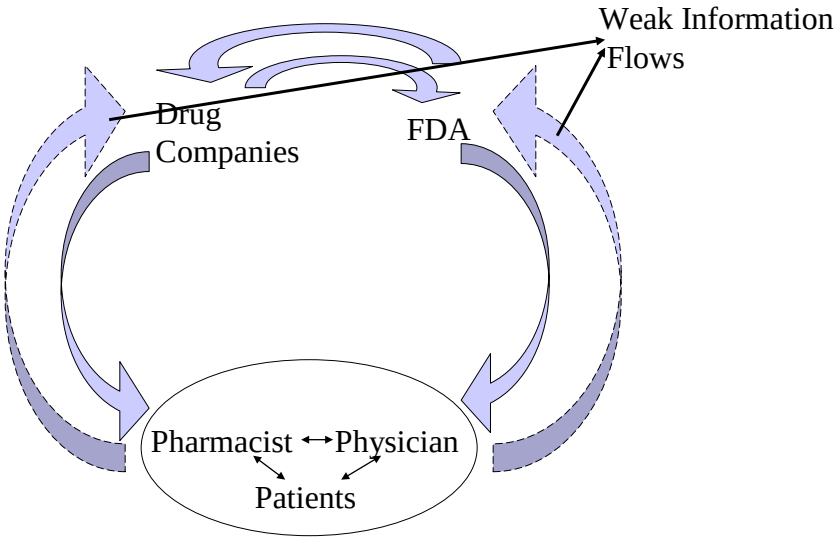

Figure 1. Information flows in the post approval phase

While the FDA and drug companies are able to use broadcast mechanisms and information services exist for disseminating information to physicians, pharmacists and patients, there are currently no widely implemented mechanism for the reverse flow of information on adverse events and medication and treatment outcomes from patients and healthcare practitioners to the

FDA on an on-going basis. This channel is weak, and is currently confined to MedWatch and other limited mechanisms.

The FDA conducts post-approval monitoring through post marketing surveillance programs such as the MedWatch system. The MedWatch system relies on voluntary submission of reports by patients and healthcare providers. In this program, patients and healthcare providers can submit an adverse event report via several mechanisms including an online report form, fax, phone, and mail. The Medwatch reports, along with adverse event information reported by pharmaceutical companies, are stored in the Adverse Event Reporting System (AERS) database. The database is available for download by clinical reviewers and researchers on a quarterly basis for analyzing drug interactions and monitoring drug safety. (Center for Drug Evaluation and Research [CDER], 2005).

While the MedWatch program has been successful at identifying critical side effects that exhibit in the early stages of drug administration, it suffers from several major limitations that prevent the faster detection of the adverse drug effects. For example, although 15 drugs were withdrawn from the market between 1997 and 2005 based on MedWatch data, it took an average of 5.9 years post introduction of the drugs into the market to identify their adverse effects. In addition, the system is ineffective at identifying adverse effects that result from prolonged administration of drugs (Brewer and Colditz, 1999; US Department of Health and Human Services, 1999).

The limitations of MedWatch system include the poor quality of submitted reports, duplicate reporting of events, under-reporting of adverse events, and the absence of the denominator or baseline information required to make meaningful conclusions from the data (Fontanarosa et al., 2004). In addition, the detection of adverse effects resulting from prolonged

use of drugs requires the collection longitudinal medical records, which are not captured by the MedWatch system. Longitudinal medical records are necessary for the detection of adverse effects that manifest late in the chronic administration of a drug, such as in the case of Vioxx where the increased risk of heart attacks and strokes on prolonged use was not detected by the MedWatch system but rather through controlled clinical studies.

The MedWatch system is also deficient in providing background data on number of patients being administered a particular medication. Background rates of information such as the number of events per number of patients exposed is essential for the scientific evaluation of adverse event data. Other factors contributing to the noise and biased nature of MedWatch data include increases in adverse event reports in response to media publicity and "dear healthcare professional" letters. Given the various limitations with current adverse event reporting mechanisms, there is a need for a comprehensive adverse event data collection mechanism that can provide better quality of data and serve as an early alert system for newly introduced drugs.

3. Previous Work

Several studies have been conducted analyzing the use of Information Technology (IT) in managing Adverse Drug Events (ADE). Literature in this area focuses on the detection of adverse events using computer-based mechanisms and the prevention of ADE using IT tools. Computerization and the use of information technology tools for automating healthcare workflow have resulted in significant improvements in healthcare delivery and in the prevention of adverse drug events (Bates et al., 1999; Bates et al., 2001; Evans et al., 1992). Computerization and healthcare information technology systems such as computerized order entry and clinical decision support systems have led to significant reduction in medical errors and improvements in quality of care (Bates et al., 2001).

Surveillance mechanisms for the detection of adverse drug events can be classified as outpatient based monitoring mechanisms and inpatient based monitoring mechanisms. Bates et al., (2003) study the effectiveness of various information technology tools in detecting adverse events in inpatient and outpatient settings. They determine that information technology tools that analyze administrative data recorded using ICD9 codes are of limited use in identifying adverse drug events, while rule based detection mechanisms that rely on laboratory test results and antidote use are able to detect a significantly larger portion of the adverse events. Another finding of the study is the need for natural language processing tools to process free text data for the detection of adverse events. A significant portion of the patient related information such as visit notes, admission notes, progress notes, consultation notes, and nursing notes are stored in the form of free text. Although rule based mechanisms are able to identify a significant portion of the adverse events, they still under-perform chart review based methods for adverse event detection. This is primarily due to the inability of rule-based mechanisms to identify symptom changes, which are mostly recorded in free text form (Classen et al., 1991).

In outpatient care, free text processing tools greatly outperform rule-based mechanisms that rely on ICD-9 codes for the detection of adverse events. Honigman et al., (2001) report that code-based mechanism were able to detect only 3 % of the adverse events when applied to outpatient data, while free text processing mechanism were able to identify 91% of the adverse events. Anderson et al., (2002) present results from a simulation study designed to analyze the effect of information technology in reducing adverse events. Their primary focus is on the use of information technology tools to reduce prescription errors by automating the prescription workflow using electronic means and the prevention of adverse events by verifying prescription

against a database of known drug interactions. A detailed review of various methodologies for the detection of adverse events is given in Murff et al. (2003).

Although several systems have been developed for the detection of adverse drug events given various patient data, the reporting and collection of adverse drug event information itself has not been extensively investigated. Moreover, most of the proposed systems are limited to inpatient settings and single organizations. There is relatively limited literature analyzing the use of information technology for large scale adverse event reporting in an outpatient setting. A study by Tejal et al. (2000) reports the incidence of adverse drug events in outpatient care to be common and that most such events are not documented in the medical records. A majority of the events is preventable and proper monitoring for symptoms, response and adequate communication between outpatients and providers can prevent most of the adverse drug events (Tejal et al., 2003).

A series of studies have been conducted over the past few decades in evaluating alternative mechanisms for collection and reporting of adverse drug events in an outpatient setting. Fisher et al., (1987) conducted a study to analyze the effectiveness of post-marketing surveillance using outpatient adverse drug event reports. Based on the study, they conclude that outpatient based post-marketing surveillance programs that rely on patient initiated reports can be used to complement existing physician based surveillance systems. Fisher and Bryant (1990) observe that patients are correctly able to differentiate adverse drug events from other adverse clinical events under certain conditions. They observe that the discrimination between adverse drug events from other adverse clinical events was better when the reporting was initiated by a staff member and the reporting was spontaneous as opposed to an interviewer probed systematic enquiry. Data from patient drug attributions has been observed to be consistent with alternative

monitoring methods such as physician assessments and epidemiological data, and can also be used to improve the discriminatory power of such methods (Fisher et al., 1994). In addition to the Fisher et al. studies, a recent study by Cohen et al., (2005) analyzed the effect of interventions by pharmacists in a community pharmacy setting. The study showed a considerable reduction in adverse events through an audit of discharged patients and a subsequent 9-month follow-up.

A community pharmacist based outpatient post marketing surveillance system has several uses such as early detection of adverse drug reactions, discovery of new therapeutic benefits of the newly introduced drugs (Fisher and Bryant, 1992) and comparison between alternative medications (Fisher et al., 1993, Fisher et al., 1995). However, the previous studies were limited to short period and did not explore the use of emerging information technology to leverage the surveillance and monitoring mechanism.

The Critical Path Institute (C-Path, 2005) has proposed a community pharmacy based surveillance model that is characterized by the following aspects: (1) the data-collection is set in an outpatient setting and involves community pharmacies, which are visited by patients more frequently than hospitals. (2) The community pharmacy based model focuses on pharmacists and pharmacy technicians to collect large-scale data on adverse events and drug effectiveness. (3) The model is designed to collect baseline information and information on background rates to help conduct rigorous data analysis.

In this paper, we discuss a web-based information system called the Drug Effectiveness Reporting and Monitoring System (DERMS). The DERMS system was one of the models developed for consideration towards satisfying the requirements of the Community Pharmacy Safety Network (CPSN) developed by the Critical Path Institute. Although it is currently not a

part of the CPSN, the DERMS system can be adapted to serve as a general pharmacy based patient safety system.

4. Drug Effectiveness Reporting and Monitoring System

In this section, we give a brief overview of the Drug Effectiveness Reporting and Monitoring System described in (Gupta el al., 2007), describe the key processes of the DERMS system and propose a system architecture for supporting the key processes implemented in the DERMS system.

4.1 Overview

The key requirements of the DERMS system are derived from the community-pharmacy based model for post-marketing surveillance proposed by the C-PATH Institute. In the community pharmacy based model includes a large-scale data collection mechanism that involves pharmacists and pharmacy technicians to identify and collect adverse event information. Pharmacists and pharmacy technicians constitute the first point of contact with patients in the post-consultation period for outpatients. Hence, they can potentially collect and maintain evolving historical information on the patient's medication history. Such history would include comprehensive information on the various types of medications taken by the patient, along with the corresponding duration of use for each medication. Such records can serve as an alternative source of information for evaluating the long-term effects of clinical medicines. The perceived direct and indirect benefits of such as system include the following: (1) the creation of longitudinal medical records by integrating patient medication history with baseline and periodically collected follow-up information on the patient's medical condition, and (2) Faster detection of adverse events using a systematic monitoring procedure implemented at the point of medication dispensation.

4.2 Key Processes

The drug effectiveness reporting and monitoring system is characterized by three key processes that include the data collection process, surveillance and monitoring process and surveillance administration process. We describe each of these processes in detail below.

Surveillance Administration Process. The surveillance administration process basically captures the key tasks of the agency responsible for administering the surveillance mechanisms and the infrastructure. The surveillance administration process involves the identification of newly introduced drugs that need to be monitored. It also includes the identification of appropriate data items that need to be captured and the design and development of questionnaires for eliciting and capturing adverse event information. The questionnaires developed in this process are used in the data collection process which we describe next.

Data Collection Process. The data collection process is illustrated in Figure 2. The process is initiated when a patient visits a pharmacy to fill a prescription. If the prescribed drug has been selected by a surveillance administrator for surveillance, the Pharmacist proceeds to collect further information about the patient with the patients consent. For patients who are not already in the system, a basic patient information questionnaire is used to collect information on patient demographics.

A baseline information questionnaire is administered at the start of a medication to collect basic information about the patient's health status before medication. At the time of each refill, a follow-up questionnaire is administered to the patient to record the patient's health status and query for any adverse drug effects. In the case of severe adverse drug effects and MedWatch report is filed by the Pharmacist. Each of the questionnaires administered to the patient was designed during the surveillance administration process.

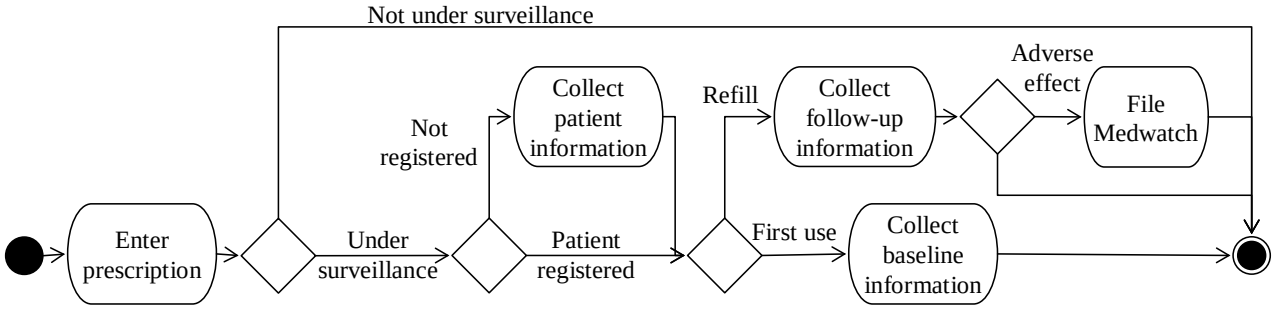

Figure 2. Data Collection Process

The questionnaires vary based on the type of the drug being monitored. In order to design these questionnaires, the research team studied previous examples and the work of others. This included examination of post-marketing surveillance programs of FDA, as well as of the allied research and monitoring endeavors. Further, the research team studied questionnaires designed by researchers of the Center for Research Therapeutics (CERT). Based on different needs, five types of forms were delineated. These were: the basic patient information form; the baseline information questionnaire; the routine follow-up questionnaire; the special follow-up questionnaire; and the adverse event reporting form. The special follow-up questionnaire is used for medications that are known to have potential harmful side effects usually occurring after a certain period has elapsed. A screenshot of the data collection process within the DERMS system is shown in Figure 3.

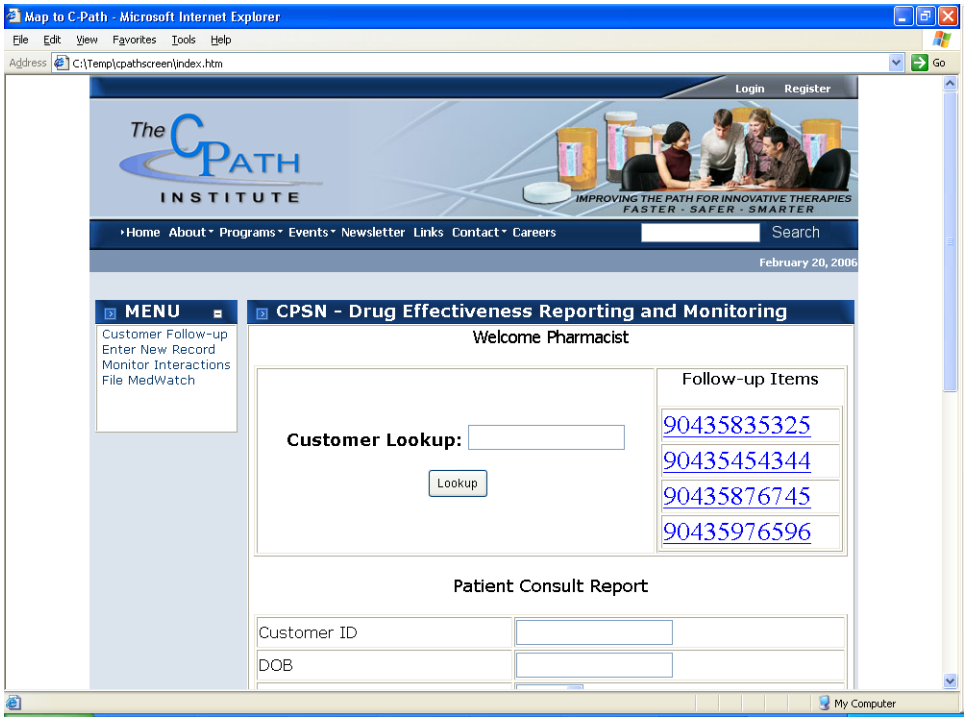

Figure 3. Data Collection Forms

Surveillance and Monitoring Process. While the data collection process is executed by the Pharmacist, the surveillance and monitoring process is primarily executed by research and quality improvement organizations. An overview of the process is given in Figure 4. In this process, the data collected during the data collection process is analyzed by researchers to identify possible drug interactions and serious side effects.

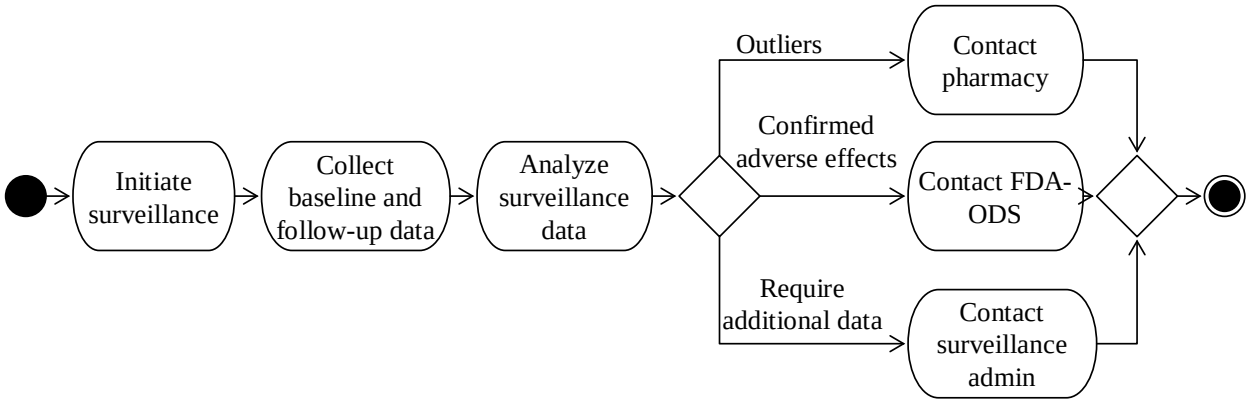

Figure 4. Surveillance Process

Following the analysis, three possible actions are supported by the DERMS system. In the case of suspect data points or outliers, a researcher can contact the concerned pharmacy for follow-up information. In the case of confirmed adverse effects, a report can be sent to the FDA's office of drug safety. If the researcher requires the collection of additional information through follow-up questionnaires, the surveillance administration can be contacted for modifications or the design of specialized follow-up questionnaires to be administered during the surveillance process. A screenshot from the surveillance process within the DERMS system is shown in Figure 5.

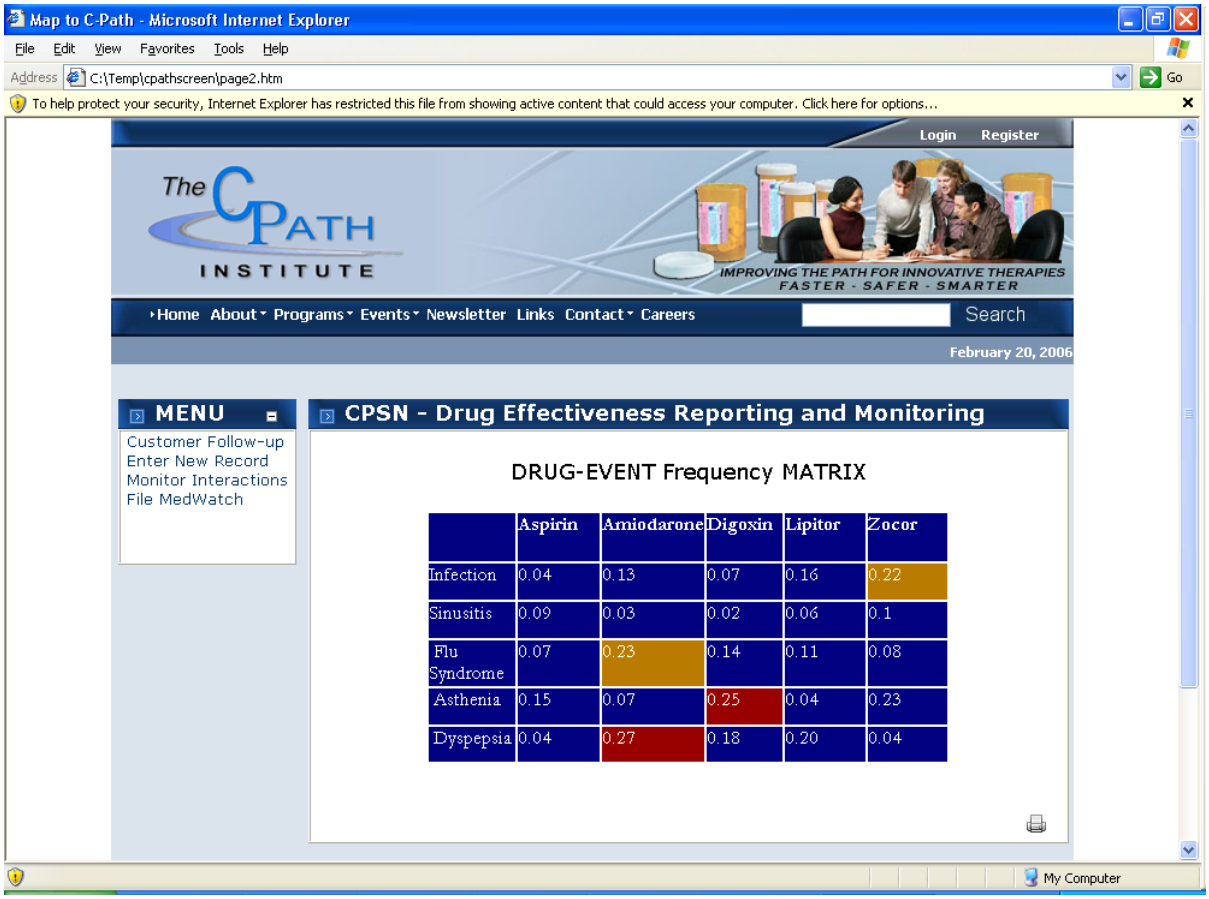

Figure 5. Surveillance Visualization Screenshot

4.2 System Architecture

In order to support the above mentioned key processes, we propose a three layer system architecture as illustrated in Figure 6. It consists of a core infrastructure layer, an application layer and an interface layer. The core IT infrastructure supporting the drug effectiveness reporting and monitoring system consists of a centralized relational database and file system for storing the surveillance data and associated documents. The core infrastructure also includes an application server, a workflow engine and a statistics and data-mining module that help execute the business logic implemented in the DERMS modules. Three application modules corresponding to the key processes supported by the DERMS system are included in the

application layer. They implement the business logic and processes that support the data collection, administration and surveillance and monitoring mechanisms.

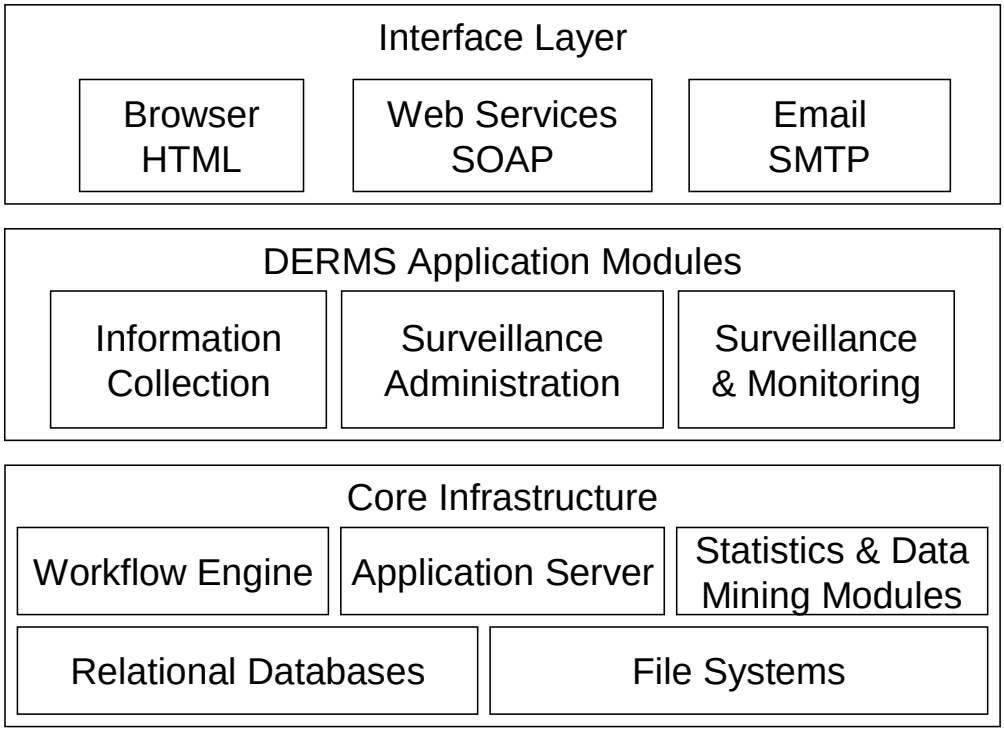

Figure 6. System Architecture

The interface layer consists of a HTML interface accessible through a web browser, a web service interface, and an email interface. The HTML interface is the primary web-based interface used by the pharmacists to execute the data collection process. The web service interface can be used to interface with pharmacy information systems to directly retrieve data from pharmacy systems. The web service interface can also be by researchers to interface with statistical and analysis software. The email interface is used for communication between various entities involved in the data collection, administration and surveillance and monitoring processes.

5. Critical Success Factors

The proposed large-scale post marketing surveillance system involves the participation of multiple stakeholders and is influenced by several factors that determine its adoption and successful implementation. We reviewed literature in the area of event reporting systems (Barach and Small, 2000), post-marketing surveillance methods (Fisher et al., 1987), pharmaco-epidemiological studies involving the participation of community pharmacists (Farris et al., 2002; Oh et al., 2002; Schommer et al., 2002; Weinberger 2002) and information technology adoption (Menachemi et al., 2004) to determine the key factors that influence the successful implementation of such a system.

Barach and Small (2000) draw lessons from an analysis of various non-medical critical event reporting systems to prescribe a set of guidelines for the design of medical event reporting systems. They identify six different factors as being critical to the successful adoption and high quality of a medical event reporting system: "immunity (as far as practical); confidentiality or data de-identification (making data untraceable to caregivers, patients, institutions, time); independent outsourcing of report collection and analysis by peer experts; rapid meaningful feedback to reporters and all interested parties; ease of reporting; and sustained leadership support." We analyze each of these factors and identify the critical elements of the community pharmacy based surveillance model to derive the technological requirements of the DERMS model.

Immunity: A key barrier to adoption of an incident reporting system is the fear of reprisal or a lack of trust for an individual and fear of litigation for organizations. As such, immunity to the greatest extent possible is important for successful adoption of an incident reporting system. In the context of the community pharmacy-based adverse event reporting system, this translates

into immunity for pharmacists and the community pharmacy participating in the reporting program. From a technical requirements point of view, enabling immunity requires the use of mechanism that provide confidentiality of users, anonymity to the pharmacists and pharmacies, and mechanisms that prevent the traceability of actions by unauthorized users.

Confidentiality: Confidentiality of data is an important element for a successful reporting system. For healthcare applications, confidentiality implies protecting the privacy rights of the patients by de-identifying patient data. However, de-identification of data sometimes leads to duplication of records. Therefore, data management mechanisms that enable de-duplication of records and the identification of unique individual records while preserving patient privacy need to be developed. Access control mechanisms and data encryption technologies need to be provided in order to ensure the security of data and prevent unauthorized use of the data.

Evaluation: Barach and Small (2000) report that independent collection of reports and analysis by peer evaluation is an important factor influencing the quality of an incident reporting system. In the community pharmacy based approach, this is achieved by outsourcing the data evaluation to regional quality improvement organizations, data collection to community pharmacies, and monitoring and overview to an independent administrative entity. Providing the above features would require a scalable and flexible mechanism that would enable multiple diverse entities to seamlessly exchange data by integrating heterogeneous applications and data sources and at the same time provide privacy, data security, and prevent unauthorized access. Recent developments in information technology such as workflow system, web services, service oriented architecture (SOA) and grid computing can provide a successful implementation to support the independent collection and evaluation features of the community pharmacy based system.

Feedback: Feedback to incident reporters and all participating stakeholders is necessary for successful adoption and implementation of an incident reporting system. The reporting and data analysis modules, along with workflow and communication tools can be used to provide meaningful feedback to the interested participating users.

Reporting: Two major factors need to be considered when designing the data collection process: the ease of reporting the data and the quality of the data being collected. Previous studies (Bates et al., 2003) have shown that typical hospital incident reports and ICD-9 based reporting mechanisms are inadequate for detecting adverse drug events. Reporting mechanisms need to be customized for each drug and drug combinations to collect relevant symptomatic information. While the data fields determine the quality of the data being collected, the design of the report affects the adoption of the reporting system. Complexity and amount of time spent reporting is a major barrier to large scale adoption of a reporting system. The reporting system needs to be designed such that it leverages the users familiarity with other computer based systems, minimizes the amount of data to be manually entered and the overall reporting time.

Leadership: Continued leadership is necessary to maintain and manage an incident reporting system and to effectively respond to changing needs. Monitoring and communication capability are key to enabling effective leadership. In the DERMS system, an administrative module is provided to initiate and monitor the surveillance process. Graphical tools, integrated email, and messaging mechanisms can be used to provide this functionality.

Workload Minimization: A key barrier to adoption of the system is the addition to workload because of increased reporting responsibilities. Time and motion studies indicate that pharmacist spend around 6-7% of their time in computer entry activities (Murray et al., 1998). A study by Oh, et al., (2002) estimates that pharmacists need to spend an additional 3 minutes of time for

patient consultation and adverse drug effect monitoring. As long as the additional computer order entry time is minimal, resistance to adoption should be minimal.

The introduction of additional workload is a key problem especially in locations with shortages in pharmacist. However, the following mechanisms can be considered to alleviate the problem. First, the additional workload can be distributed between a pharmacists and a pharmacy technician such that the computer entry activities are handled by a pharmacy technician while the activities related to the elicitation and identification of adverse events are delegated to a pharmacist. Second, depending on resource constraints, the surveillance mechanism can be limited to patients who are prescribe certain newly introduced drugs thereby lowering the additional workload.

Incentives: Previous studies have indicated that the provision of financial incentives has had a positive effect on patient counseling activities of pharmacist resulting into reduced adverse events (Farris et al., 2002). As such, financial incentives can serve an additional factor in promoting the adoption of a community-pharmacy based system. In addition to financial incentives, job satisfaction, is a key driver in increased pharmacist involvement in patient counseling and drug therapy reviews. A study by Schommer (2002) concludes that pharmacists prefer to spend more time on patient consultation and drug use management instead of medication dispensing and business management.

Success Factor	**Implementation**	**Possible IT Solutions**
Immunity	Anonymity of reporters, participants	Data Encryption and de-identification. Access control.
Independent Reporting and Evaluation	Involvement of Community Pharmacies, Quality Improvement Organizations	Workflow systems, Mediators and Web Services for heterogeneous data and

Success Factor	Implementation	Possible IT Solutions
	and administrative entity.	application integration. Access control and relational views.
Confidentiality	Patient Privacy, Data de-identification	Data element identification and Probabilistic de-duplication algorithms.
Feedback	Summary reports and information	Reporting modules and data validation and verification algorithms
Ease of Reporting	Minimal reporting time, Capture of key and minimal data elements	Assistive technologies and intuitive user interfaces.
Leadership	Surveillance Administration, Dashboards, Real-time monitoring of key metrics, problem detection and communication capability.	Communication modules, Monitoring and reporting modules.
Workload Minimization	Financial Incentives, Workload distribution between Pharmacists and Pharmacy Technicians	Integration with pharmacy systems to minimize computer entry.

Table 1. Critical Success Factors

5.1 Factors Influencing Pharmacy Participation

The successful adoption and continued use of the proposed system by community pharmacies and pharmacists is dependent on several factors. In order to promote the successful adoption of the new surveillance system, the features of the system also need to be aligned with the interests of the community pharmacy and the professional interests of the pharmacists. Based on previous studies on IT adoption, we hypothesize that while organizational buy-in is necessary for initial adoption of a new system, its continued use is dependent on the perceived usefulness of the system and its alignment towards the skill and professional interests of the pharmacists.

Several operational factors also need to be considered for the successful implementation of the proposed surveillance system. For example, a paper describing randomized control trials conducted to evaluate the effectiveness of pharmaceutical care programs in Indianapolis (Weinberger, 2002) highlights several operational difficulties that occur in programs involving community pharmacies. The study, initiated at Revco pharmacy chain, analyzed new pharmaceutical care programs aimed at giving the pharmacists a greater role in providing the patients with better healthcare. The data were initially transmitted from Revco to the Indianapolis Network for Patient Care (INPC) for purposes of consolidation and analysis. As this experimental study progressed, CVS acquired Revco in a corporate acquisition. Apart from the problems caused by differences in computer systems of the two organizations, there were problems created by major differences in their management policies. For example, CVS required the patients to give their categorical affirmative response before patient data could be utilized in any manner. In order to address this new requirement, a decision was made to offer a sum of $60 as incentive to patients who were willing to let their data be used for purposes of this experimental study. With this incentive, 21% of the patients responded to CVS, with five-sevenths of them agreeing to let the data be used, and the balance two-sevenths declining the offer. In order to increase the response rate, CVS personnel initiated follow-up efforts. Finally, one-fifths of the persons originally contacted agreed to accept the offer of $60 in lieu of data be utilized for the experimental study.

The above experience emphasizes four critical success factors for achieving progress in this area. First, senior management must accept the need for such studies and be prepared to explicitly support the endeavor through its entire lifestyle; without such close involvement, the effort will

fail. Second, pharmacists should view this function as an integral part of their job of dispensing drugs and interacting with patients on issues related to drugs; in order to make this scenario feasible, financial incentives may need to be provided to pharmacists. Third, the policies of major pharmacy chains vary significantly from each other; discussions need to occur among them in order to generate consensus on this critical issue that impacts human lives. Fourth, new mechanisms need to be developed to share relevant chains across otherwise competing entities in a manner that meets applicable guidelines for information, security, and safety, while simultaneously ensuring that the risks to human lives is minimized.

6. Limitations

At the beginning of this paper, we had identified some of the weaknesses of the current MedWatch system. The concept demonstration prototype described in this paper mitigates some of the problems, but several of them still remain and need further research and attention. The areas requiring further attention are discussed in the following paragraphs.

First, the concept demonstration prototype system studied the relevant issues in one city only (Tucson, Arizona). The automated assimilation of the information from diverse information systems, each characterized by its own design and significantly different from others, will require use of advanced concepts from the realm of integration of heterogeneous information systems. Similarly, state-of-the-art ideas related to data mining and knowledge discovery will need to be employed. The scalability of the concept demonstration prototype needs to be examined in detail in order to evaluate the potential feasibility of utilizing the proposed approach over an extended geographic area.

Second, the prototype system tracks drugs that are provided to customers across the counters at retail outlets of major pharmaceutical chains. If this concept is extended to smaller chains and individual shops, it will need to deal with still greater variety of legacy hardware and software. The problem is further complicated by the fact that patients now acquire drugs by mail, both from outlets in the US and abroad, using web-based and telephone-based mechanisms to place the concerned purchase orders for drugs. No effective mechanism currently exists for tracking the purchase of such drugs. To address the latter need, the creation of new national and international drug purchase monitoring systems need to be considered, possibly under the aegis of, or in close collaboration with, the World Health Organization (WHO).

Third, our approach lacks the ability to track samples of drugs that have been provided by the medical physician to the patient. Such dispensation of drugs by the physicians may need to be monitored, especially for drugs that have been introduced in the recent past. The same web-based interface could be used to enter the requisite information by personnel in the physician's office. Also, some pharmaceutical companies now provide magnetic cards that can be redeemed at pharmacies for samples of drugs. If this new concept is used for all samples, this limitation will be overcome in terms of monitoring of drug samples.

Fourth, our system relies heavily on pharmacists in terms of their expertise and goodwill in terms of talking with the patients, eliciting requisite information from them, and entering the same using the web-based interface.

Fifth, the prototype system deals with certain drugs only. As such, it is unable to deal with situations where the use of two drugs creates unexpected problems. In order to cater to this need, all drugs taken by patients will need to be monitored.

Fifth, patients currently obtain drugs from multiple pharmacy outlets that may belong to different chains. Without a common identifier, it is difficult to track that the medicines were indeed purchased for use by the same patient. The most obvious identifier would be the social security number in the US. However, current regulations and concerns for patient privacy prevent such usage. New options need to be explored.

7. Conclusion

In this paper, we propose an IT architecture that forms the enabling infrastructure for a new post-marketing surveillance tool for newly introduced drugs called the Drug Effectiveness Reporting and Monitoring System. We briefly define the key characteristics of the DERMS system and propose a system architecture for supporting the key processes implemented in the DERMS system. We then analyze the critical success factors for the DERMS-based post marketing surveillance mechanism and identify supporting IT solutions.

Future work in this area involves further investigation of the critical success factors and development of instruments to validate the hypothesized critical success factors. In addition, large-scale implementation of such as system requires further investigation of the privacy and security issues related to data collection, storage and sharing processes.

8. References

1. Anderson JG, Jay SJ, Anderson M, and Hunt, TJ "Evaluating the Capability of Information Technology to Prevent Adverse Drug Events: A Computer Simulation Approach", *Journal of American Medical Informatics Association*, 9, 479-490.
2. Barach, P. and Small, S. (2000) "Reporting and preventing medical mishaps: lessons from non-medical near miss reporting systems", *British Medical Journal*, 320:759-763.
3. Bates DW, Cohen M, Leape LL et al. (2001), "Reducing the frequency of errors in medicine using information technology" *Journal of American Medical Informatics Association*, 8:299-308.
4. Bates DW, Evans RS, Murff H, Stetson PD, Pizziferri L, Hripcsak G. (2003) "Detecting adverse events using information technology", *Journal of American Medical Informatics Association*, 10:115–28
5. Brewer, T and Colditz, GA (1999) "Postmarketing Surveillance and Adverse Drug Reactions: Current Perspectives and Future Needs", *Journal of the American Medical Association*, 281:824-829.
6. The Critical Path Institute, C-Path Newsletter, Spring 2005.
7. Center for Drug Evaluation and Research, "Adverse Event Reporting System", http://www.fda.gov/cder/aers/default.htm
8. Classen DC, Pestotnik SL, Evans RS, Burke JP. (1991) "Computerized surveillance of adverse drug events in hospital patients" *Journal American Medical Association*, 266:2847–2851.
9. Cohen MM, Kimmel NL, et al. (2005) "Medication Safety Program Reduces Adverse Drug Events in a Community Hospital", *Qual Saf Health Care* 14:169-174

10. Evans R, Pestotnik S, Classen D et al. (1992) “Prevention of adverse drug events through computerized surveillance” *Proc Annu Symp Comput Appl Med Care,* 437-41.
11. Farris, KB, Kumbera, P., Halterman, T. and Fang, G (2002) "Outcomes-based Pharmacist Reimbursement: Reimbursing Pharmacists for Cognitive Services", *J Managed Care Pharm*. (8)5:383-93
12. Fisher S, Bryant SG, Solovitz BL and Kluge RM. (1987) “Patient-initiated postmarketing surveillance: a validation study” *J Clin Pharmacol* 27: 843-854, 1987
13. Fisher S and Bryant SG. (1990) “Postmarketing surveillance: accuracy of patient drug attribution judgments” *Clin Pharmacol Ther* 48: 102-107
14. Fisher S and Bryant SG. (1992) “Postmarketing surveillance of adverse drug reactions: patient self-monitoring” *J Am Board Fam Pract* 5: 17-25
15. Fisher S, Bryant SG and Kent TA. (1993) “Postmarketing surveillance by patient self-monitoring: trazodone versus fluoxetine” *J Clin Psychopharmacol* 13: 235-242
16. Fisher S, Bryant SG, Kent TA and Davis JE. (1994) “Patient drug attributions and postmarketing surveillance” *Pharmacotherapy* 14: 202-209
17. Fisher S, Kent TA and Bryant SG. (1995) “Postmarketing surveillance by patient self-monitoring: preliminary data for sertraline versus fluoxetine” *J Clin Psychiatry* 56: 288-296
18. Fontanarosa, P., Rennie, D. and DeAngelis, C (2004) "Postmarketing Surveillance — Lack of Vigilance, Lack of Trust" *Journal of American Medical Association*, 292(21)
19. Food and Drug Administration, “The Clinical Impact of Adverse Event Reporting”, October 1996.
20. Gandhi TK, Burstin HR, Cook EF, Puopolo AL, Haas JS, Brennan TA, Bates DW. (2000) "Drug complications in outpatients", *Journal of General Internal Medicine*,15(3):207-8.

21. Gandhi TK, Weingart SN, Borus J, Seger AC, Peterson J, Burdick E, Seger DL, Shu K, Federico F, Leape LL, Bates DW. (2003) "Adverse drug events in ambulatory care", *New England Journal of Medicine*, 348(16),1556-64.
22. Gurwitz, J.H., Field, T.S., Avorn, J. et al. (2000) “Incidence and preventability of adverse drug events in nursing homes” *American Journal of Medicine,* 109:87-94.
23. Honigman B, Lee J, Rothschild J, Light P, et al. (2001) “Using computerized data to identify adverse drug events in outpatients” *Journal of American Medical Informatics Association,* 8:254–266
24. Johnson JA and Bootman JL (1995) "Drug-related morbidity and mortality. A cost-of-illness model", *Archives of Internal Medicine,* 155(18), 1949-1956.
25. Lazarou J., Pomeranz B., Corey P. (1998) “Incidence of Adverse Drug Reactions in Hospitalized Patients”, *Journal of American Medical Association* 279:1200-1205Murff HJ, Patel VL, Hripcsak G, Bates DW. (2003) "Detecting adverse events for patient safety research: a review of current methodologies", *Journal of Biomedical Informatics*, 36(1-2):131-43.
26. Menachemi N, Burke D, Brooks RG. (2004) "Adoption factors associated with patient safety-related information technology", *J Healthc Qual*. 26(6): 39-44.
27. Murray MD, Loos B, Tu W, Eckert GJ, Zhou XH, Tierney WM. (1998) "Effects of computer-based prescribing on pharmacist work patterns", *Journal of American Medical Informatics Association*, 5(6):585-6.
28. National Academy of Sciences. (2000). “Crossing the Quality of Chasm: A New Health System for the 21st Century”

29. Oh, Y., McCombs, J. S., Cheng, R. A., & Johnson, K. A. (2002).”Pharmacist Time Required for Counseling in an Outpatient Pharmacy” *American Journal of Health-System Pharmacy*, 59(23):2346-2355.

30. Schommer JC, Pedersen CA, Doucette WR, Gaither CA, Mott DA. (2002) "Community pharmacists' work activities in the United States during 2000." *Journal of American Pharmacists Association*, 42(3):399-406.

31. US Department of Health and Human Services “Managing the Risk from Medical Product Use, Creating a Risk Management Framework.” Taskforce on Risk Management Report, May 1999.

32. Weinberger M, Murray MD, Marrero DG, Brewer N, Lykens M, Harris LE, Newell JA, Collins J, Tierney WM (2002) "Issues in conducting randomized controlled trials of health services research interventions in nonacademic practice settings: the case of retail pharmacies" *Health Services Research*, August 2002.