Pharmacy Informatics: Where Medication Use and Technology Meet

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INTRODUCTION

As technology and innovation continue to rapidly shape health care and medication management, the need for specialized roles to support and optimize clinical workflows, system usage, and data capture is ever more important.[1] Health informatics is an established field that bridges health care with information technology as a means to improve clinical care, ensure patient safety, and increase the efficiency and effectiveness of organizational processes.[2] Pharmacy informatics, a subset of health informatics, leverages both clinical expertise and knowledge about information technology to improve medication management processes and drug administration safety.[3] Pharmacy informaticists are pharmacists with a solid background in clinical pharmacy practice, knowledge of pharmacotherapy, and extensive working knowledge of clinical information systems and drug distribution systems.

EVOLUTION OF PHARMACY INFORMATICS

Hospital pharmacies are well known to embrace technology and automation to support drug distribution. Between the 1980s and the 1990s, information systems were primarily used to manage pharmacy inventory and produce financial reports; then, in the early 2000s, hospitals adopted computerized practitioner order entry (CPOE) and other computerized systems with **clinical decision support*** (CDS) software.[4] Clinicians were required to oversee and tailor these systems to actualize their utility, yet the early experience and research of these investigators described only general benefits, and they could not report or measure the systems' effectiveness or value.[5,6] During this period of rapid technological growth, hospital pharmacy departments were challenged to manage and maintain new hardware and software, employing technical analysts to support the devices and applications, while pharmacy staff optimized system use to meet clinical and dispensing needs. By the late 2000s, the health informatics field was emerging, with specialization in pharmacy practice ultimately defining the pharmacy informatics role. Pharmacy informaticists became a natural fit to engage health technology advancements, evaluate system limitations and risk, educate pharmacy end-users, and investigate system issues related to medication safety, while supporting pharmacy practice. The American Society of Health-System Pharmacists (ASHP) first described the pharmacist's role, responsibilities, and competencies in informatics in 2006, with a recent statement update in 2016.[7]

*Bold indicates terms that are defined in Appendix 1.

ENABLING GROWTH: COMPETENCIES OF PHARMACY INFORMATICISTS

The diversity in skills and pathways of those who work in pharmacy informatics has prompted the definition of core competencies that promote a technologically optimized medication-use process that is safe, effective, efficient, and timely. The ASHP defined 5 major competencies critical for pharmacy informaticists to successfully contribute to any health care organization: data, information, and knowledge management; information and knowledge delivery; practice analytics; applied clinical informatics; and leadership and management of change[7] (Table 1).

In the remainder of this article, we discuss the advanced practice of a pharmacy informaticist within our own Canadian hospital network by highlighting past work completed and projects currently underway within our hospital organization. Using these interrelated core competencies, as outlined below, we describe how pharmacy informatics aligns people, processes, and technologies with medication management.

Data, Information, and Knowledge Management

Pharmacy informaticists support the medication-use process through best practice management of data, information, and knowledge. Health care data, such as patients' birthdates,

Table 1. Core Competencies for Pharmacy Informaticists[8]*

Competency	Definition	Example of Roles and Responsibilities
Data, information, and knowledge management	The management of medication-related information while promoting integration, **interoperability**, and information exchange	• Data governance and stewardship • Control terminology, standards, and reference data • Ensure data accuracy • Audit and evaluate • Ensure data are easily understood • Maintenance ○ Corrective ○ Customized ○ Enhancement ○ Preventive
Information and knowledge delivery	The delivery of medication-related information and knowledge through the clinical knowledge life cycle: • Information and knowledge delivery • Knowledge application and delivery • Knowledge asset management	• Deliver clinical knowledge ○ Proactively ○ Interactively ○ Passively • Analyze data to understand performance, reporting, evaluation, prediction, and harvesting of new information to improve outcomes • Optimize use of **clinical decision support** and tool development • Reduce information overload to provider • Manage, support, and govern medication information ○ Cataloguing, encoding, versioning, updating, disseminating, and maintaining inventory of information
Practice analytics	The development of point-of-business analytic solutions to improve decision-making	• Ensure data are standardized, structured, and modelled to support **business intelligence** goals • Create effective tools that allow for multiple formats and layers of analysis • Develop, maintain, and ensure the quality of these tools to guide the achievement of treatment and strategic goals • Drive analytics to the front line by creating greater end-user accessibility • Monitor the effectiveness of tools and information to deploy or further develop point-of-care and analytical systems
Applied clinical informatics	The application of user experience, research, and theory of informatics to clinical practice and system usability	• Acquire professional perspective by understanding the profession's history and values and its relationship to other fields • Analyze problems • Produce solutions • Articulate rationale • Implement, evaluate, and refine • Innovate by creating new theories, frameworks, and processes to address informatics problems • Work collaboratively within and across all disciplines • Educate, share, and discuss with students and other disciplines
Leadership and management of change	The provision of leadership and management in the procurement, development, implementation, customization, evaluation, and continuous improvement of clinical information systems	• Lead local and external organizations to sound conclusions regarding use of technology in medication management • Lead and manage the risk/benefit evaluation and communication of a newly implemented technology • Translate user requirements into safe and effective designs • Implement project management best practices • Attain key leadership roles within the health care information technology industry and organizations, as well as pharmacy practice associations

*Bold indicates terms that are defined in Appendix 1.

laboratory test results, or drug doses, are represented by discrete numbers, descriptions, or measurements. Information is a collection of data that has been interpreted via relationships within and between separate data points, with knowledge transforming information into deliberate action.[8] For example, a single blood glucose reading cannot compare (in terms of usefulness for diagnosis and treatment) to an assessment of the patient's blood glucose trend, family history, oral glucose tolerance test result, and hemoglobin A1c (HbA1c) level. When considering these data points and information together, a clinician develops knowledge about the patient's blood glucose control, which can be used to determine if the patient is diabetic. Related information is organized into records and files, which make up a database.

Pharmacy informaticists manage the databases that support the pharmacist's clinical and administrative role, which is guided by the pharmacist's practice setting and responsibilities. It is necessary that the databases, electronic medical records (EMRs), and drug distribution systems are built to promote the safe use of high-risk medications, to highlight therapeutic order sets or dosing guidelines for clinicians, and to deliver and document best practices in pharmaceutical care. The other core competencies (described in subsequent sections) are critically dependent on how data, information, and knowledge are managed, and the various examples we discuss later will relate back to this competency. The remainder of this section focuses on management of the drug database.

Developing standardized drug and order set nomenclature in the drug database is important, to provide a consistent description of a medication regardless of which system is being used. Standardized nomenclature avoids confusion within and between systems and ensures that a clinician who is ordering, validating, or administering a drug can safely identify the intended medication. In our organization, we faced numerous challenges in creating a safe medication-use system, such as identifying drugs despite character limits within our pharmacy and prescriber systems, using a US National Drug Code system for Canadian drug content, and integrating data between overlapping clinical information systems. As such, it was necessary to develop guiding principles and standard operating procedures that specified the use of generic names (versus brand names), an approval process for use of medication abbreviations, and truncation rules that prioritized the display of a drug's salt, formulation, extended-release modifier, or strength. For example, new drug additions to the medication databases must undergo an evaluation process to ensure alignment with the database conventions and to prevent selection errors by the end-user. In a recent review for subcutaneous (SC) rituximab (Rituxan SC 120 mg/mL), we mitigated the risk of erroneously selecting intravenous (IV) rituximab (10 mg/mL) by adding the concentration and route to the drug name. We also employed this strategy when new biosimilar drugs were recently added to the formulary. In the case of filgrastim, the brand names Grastofil and Neupogen were displayed and capitalized in all systems. The naming convention we chose also aligns with Health Canada's policy statement[9] on the naming of biologic drugs, which was released earlier this year.

In another example from our organization, pharmacy informaticists discovered a system limitation that led to a database improvement. In a case of a "wrong drug" administration error, a patient incorrectly received Humalog instead of the intended order Humalog Mix 25. A review highlighted that, because of a limit on the number of characters available, the "Mix 25" text wrapped to a second line in the medication administration software, which obscured the critical information required for the nurse to select the correct product right before medication administration. In response to this incident, a comprehensive risk reduction review was completed, which led to the renaming of multiple medications to ensure that key drug data needed for identification would always be visible to clinicians at the time of medication ordering, dispensing, and administration.

Information and Knowledge Delivery

The next core competency, information and knowledge delivery, involves how the databases are utilized. Pharmacy informaticists ensure that there is **interoperability** between the pharmacy information system and all other medication-related systems. With constant changes to clinical practice and complexities within health care, integrated systems are needed to support the delivery of accurate medication-related information to the end-user at the point of clinical decision-making. Pharmacy informaticists support best practices and apply knowledge of informatics principles, human factors, and systems design to the user interface, to ensure that there is no confusion or incorrect information at the point of care. This information delivery can be provided before decisions are made or passively as reference information. Pharmacy informaticists not only support and oversee the creation, application, delivery, and management of clinical information and knowledge, but they also inform how systems should be developed and why **interoperability** is essential to safe medication management.[7]

CDS software aids clinicians during the decision-making process by way of **event-driven alerts**, **forcing functions**, care plans, evidence-based order sets, documentation templates, and patient data summaries. With in-depth knowledge of EMR functionalities and limitations, pharmacy informaticists can translate clinical requirements and determine the best way to incorporate CDS to meet the needs of clinical workflows and patient safety. Considerations of national practice standards or locally created policies and procedures should also drive the selection of the types of CDS tools that are best suited to specific clinical scenarios, such as managing high-risk medications or guiding dose adjustments in special populations.

One such example involves using evidence-based research and clinical quality outcome data for thromboprophylaxis risk assessment to develop preprinted order sets or guideline-based risk assessment models[10] and thus to reduce the unnecessary use of pharmacologic thromboprophylaxis. One of the sites within our organization implemented a mandatory CPOE module for venous thromboembolism (VTE) prophylaxis within all admission order sets, whereby the prescriber is required to document if pharmacologic thromboprophylaxis is required or contraindicated. This mandatory module serves as a **forcing function** for assessment and documentation for VTE prophylaxis within 24 hours of admission.

At another site in our organization, the use of **medical logic modules** allows flexibility to develop and customize electronic CDS tools, such as custom pop-up alerts that prompt independent double checks to be completed by nursing staff for specific medications or automatic display of important patient-specific laboratory values (e.g., serum creatinine) or key findings (e.g., weight) on the order screen to aid with decision-making at the point of order entry. In our organization, pharmacy informaticists worked with the Antimicrobial Stewardship Program to create custom reports that consolidate unit-specific treatment courses and antibiotic information to trigger prompt reassessment on the basis of specified criteria, such as critical care patients presenting with sepsis.[11] CDS has also been developed to guide antibiotic prescribing based on indication, renal function, and clinical criteria for use.

Although the use of CDS systems is an asset to clinicians and their workflows, it is important to monitor and evaluate the effectiveness of these systems on the basis of ordering practices or user feedback, and adjust when required. Pharmacy informaticists play an integral role in reviewing medication safety incidents to determine whether the root cause is information system–based. They also identify opportunities to incorporate changes that will prevent potential medication incidents in the future. Given the quantity of **alerts** presented to clinicians, including drug interactions, allergy verification, and critical laboratory values, **alert fatigue** can develop. It has been reported that the override rate for medication alerts often exceeds 80%–90%, which can result in preventable adverse events leading to morbidity or mortality.[12] Guidelines exist on how to effectively use and monitor **alerts**, given that alerts with low effectiveness and ones upon which clinicians may not agree can lead to the creation of workaround solutions.[13] To mitigate these issues, it is necessary for pharmacy informaticists to take **alert fatigue** and data overload into account when designing CDS. At our organization, retrospective data are collected concerning alert use and overrides associated with medical incidents; these data are then reviewed by both a committee and the clinicians who commonly override alerts. It is necessary to continually perform system maintenance to ensure that CDS remains clinically appropriate, relevant, and effective for the end-user.[14]

Practice Analytics

The third core competency of pharmacy informaticists is to play a significant role in practice analytics with respect to medication management. Practice analytics refers to a **business intelligence** process that uses technology and database creation to study clinical and fiscal processes and to improve decision-making in these areas.[15] Pharmacy informaticists must understand the capabilities of their system, as well as the "big picture", to help drive pharmacy practice improvements and increase performance in the medication-use process.

As an opportunity to evaluate and measure pharmacy practice and services, one of the sites in our organization recently launched documentation of clinical pharmacy key performance indicators (cpKPIs)[16] within our EMR. The existing pharmacist assessment form was enhanced, piloted, and implemented. Our updated documentation tool allowed clinical pharmacists to document their initial patient assessment with follow-up notes, and now they can select which cpKPIs have been completed throughout a patient's admission. The data from this electronic form can be easily extracted and audited with the intention of improving clinical pharmacy services and achieving optimal patient care and safety.[17]

Another major undertaking at one of our sites involved the development of an **enterprise data warehouse**. Pharmacy informaticists were involved in this project as subject matter experts, collaborating with the decision support, project management, and research departments. The warehouse will provide clinicians with easier access to a large repository of business, operational, and clinical data that can be used for research, quality improvement initiatives, and predictive analytics. Data generated from the **enterprise data warehouse** are reviewed by the pharmacy informaticists to provide background understanding, to ensure queries are accurate, and to ensure that data are used in the correct context.

Applied Clinical Informatics

The next core competency of pharmacy informatics practice is applied clinical informatics, which improves clinical practice and the usability, efficiency, and safety of systems by applying "user experiences, research, and theoretical informatics principles".[7] Applied clinical informatics focuses on providing solutions that are advantageous to clinical workflows and improve every stage of medication use: ordering, processing, dispensing, and administration. Pharmacy informaticists leverage their clinical experiences to identify and evaluate the feasibility of technology-based solutions, identify gaps, and determine risks to support departmental and organizational initiatives related to medication use and electronic systems. At one of our sites, pharmacy informaticists recently led the implementation of **automated dispensing units** (ADUs) on inpatient and outpatient clinical units, collaborating with nursing leadership to develop key principles for system configuration and decisions surrounding emergency overrides and discrepancy management.

Although ADUs represent one of our latest improvements in stock management, our pharmacy informaticists continue to collaboratively manage back orders, nonformulary ordering, and the use of autosubstitution or therapeutic interchanges. With increased integration of technology in the drug procurement process, system changes have a broader impact, and careful consideration is required before such changes are implemented. Drug shortages and back orders have become increasingly difficult to manage in the hospital setting and require that pharmacy informaticists work alongside pharmacy technical operations staff. The severity of each shortage is assessed by evaluating existing inventory, estimated usage patterns, and availability of alternative products, while considering the impact or degree of changes on order entry and medication administration. CDS may be added to CPOE or pharmacy order processing systems to alert system users to the shortage and offer alternative actions as appropriate. For example, one site in our organization followed best practices and customized various strategies during a recent shortage of IV levofloxacin that considerably affected multiple clinical areas and medical specialties. Depending on the clinical scenario, prescribers were instructed to change the order to oral levofloxacin, use a different IV antibiotic, or use some of the limited supply of IV levofloxacin if indicated. Pharmacy informaticists updated all systems to provide guidance and information to prescribers, and careful monitoring and ongoing collaboration with distribution team members enabled pharmacy informaticists to respond rapidly when the back order was lifted.

Leadership and Management of Change

The final core competency calls upon pharmacy informaticists to be engaged and to participate in impact analyses and change initiatives while also providing oversight of and leadership concerning the medication management systems.[7] Pharmacy informaticists can manage and lead change through their involvement in project work, engagement at any stage of the project life cycle (from initiation to closing), and participation in a variety of tasks such as building, testing, and optimizing a solution. A pharmacy informaticist's scope of practice includes clinical and policy knowledge, change management skills, project management, and also an understanding of systems technology enabling participation in or leadership of projects and initiatives within or across all sites.

Over the last few years within our organization, pharmacy informaticists have contributed their specialized knowledge and strong guidance to corporate projects such as the implementation of CPOE, IV smart pumps, ADUs, and electronic medication reconciliation. They continue to work with stakeholders in drug distribution, drug information and utilization, pharmacy clinical and technical operations, and corporate medication safety. To facilitate change management processes and knowledge transfer, one of the sites in our organization formed a committee to coordinate upcoming changes to clinical systems, determine potential impacts on end-users, support upcoming initiatives, and manage issues related to drug shortages or formulation changes. The committee includes staff members involved in medication management, such as pharmacists, pharmacy technicians, nurses, informatics specialists, and managers, and acts as a forum for continuous process improvement through biweekly meetings, which ensure that issues arising are addressed in a timely manner. A recent example of our pharmacy informaticists being leaders in change involved revision of IV bag labels to include diluent volume plus overfill. This labelling change was evaluated by the committee, and a clear communication plan was developed to address changes to the clinical systems, batch labelling, worksheets, and IV pumps to ensure that all parties involved were aware and on board.

Our pharmacy informatics team has also worked on national initiatives such as Choosing Wisely Canada. A recently implemented recommendation consisted of decreasing unnecessary blood work monitoring (e.g., international normalized ratio [INR], HbA1c, and thyroid-stimulating hormone [TSH]), improving formulary management, and revising order sets. Work efforts included decoupling the laboratory orders for INR and activated partial thromboplastin time, and the addition of CDS to affected admission order sets helped prescribers to select the suggested options. Also, routine orders for TSH and HbA1c were discouraged, both to educate prescribers about the utility of these tests and to disallow repeat ordering within specified time frames.

FUTURE DIRECTIONS

There are many more interesting areas within health and pharmacy informatics to learn about and further develop. We have described only some examples of a pharmacy informaticist's operational responsibilities and current initiatives, but we foresee that the future holds many exciting changes.

The health informatics curriculum is well established in medical and nursing training; however, in pharmacy, it has been slower to evolve.[18] A 2017 survey of pharmacy curriculums in the United States showed that only 36% included an informatics course, which was not much of an improvement from 10 years before.[19] Pharmacy or health informatics courses are now offered in most Canadian pharmacy faculties; however, many of those currently working in the field entered with little to no formal education or training. Rather, skills have been gained through on-the-job experience, by working alongside nonpharmacy clinical informatics colleagues, through education provided by information system vendors, by attending public interest conferences, or through continuing education. There is a recognized need for advanced training in the pharmacy informatics field to support systems innovation to "enable a shift to a more fully system-supported pharmacy practice".[20]

"Big data", a term referring to large and complex data sets from many data sources,[21] is being leveraged to improve clinical decision-making and pharmacy research.[22] Artificial intelligence and machine learning are becoming the future of health care, whereby computers are used to simulate learning, analysis, and prediction.[23] In terms of application to pharmacy and medication management, development is currently underway to assist in many areas, such as drug design,[24] formulary selection, choice of drug therapy,[25] treatment predictions and results, health care data processing (e.g., diagnostic tests, wearable devices, and natural language processing[26]), potential drug interactions or adverse event alerts, and adherence monitoring.[27] In the coming years, pharmacy informaticists will be essential to the development and adoption of artificial intelligence tools to ensure that data currently captured and used for computation are meaningful and accurate.

The creation of larger hospital networks will prompt the work of understanding needs across various clinical and financial systems for the affected institutions. Challenges to harmonize the practices of multiple hospitals of different sizes, using different information systems and with different levels of patient acuity, must be anticipated, and it is important that pharmacy informatics is represented at all sites, with collaboration at all organizational levels.[28] Increased representation of pharmacy informatics would certainly create opportunities to encourage further growth of the field and to promote pharmacy informaticists' role as leaders at the place where information technology and medication management meet.

CONCLUSION

Although it is not new, the practice of pharmacy informatics is in a state of rapid growth. This diverse and evolving field leads the use of technology at multiple levels of pharmacy practice, from departmental projects to national collaboratives. Equipped with a strong understanding of medication management workflows and knowledge of clinical system functionalities, pharmacy informaticists are in a great position to collaborate with other health care providers to optimize information management, improve workflow, and reduce medication errors. By supporting and developing the pharmacy informaticist role, the profession of hospital pharmacy can optimize innovations to medication-related processes so that pharmacists can continue to improve patient care and outcomes.

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Appendix 1. Definitions of key terms

Term	Definition
Alert, event-driven	An urgent, patient-specific notice generated by a CDS system and directed to clinicians at their decision-making point. Some alerts are prompted when an event or a series of events has occurred. Some require a response before the clinician can continue. Examples: • A warning regarding a documented action/decision (or lack thereof) • A notification of a new clinical condition, circumstance, or change in a patient, test, or drug status that requires immediate attention
Alert fatigue	A state of irritability, exhaustion, or bewilderment triggered in clinicians who have been exposed to too many alerts, or alerts with perceived irrelevance, causing the user to ignore some or all of the alerts. This situation reduces the safety benefit of the CDS system.
Automated dispensing unit (ADU)	A secure storage unit typically in a decentralized location in patient care units. An ADU is capable of maintaining medication inventory via an audit trail of activity, automating drug cost charging of medication products when dispensed for patient use, and reporting the need for inventory replacement according to usage and par levels.
Business intelligence	A term to describe the strategic integration of technology and process that enables organizations to leverage their data to make better decisions.
Clinical decision support (CDS)	The provision of basic clinical knowledge and appropriate patient-specific information to aid health care providers in making the appropriate or best possible clinical decision.
Enterprise data warehouse (EDW)	A large database containing data from numerous systems, designed to provide real-time information to support organizational decision-making.
Forcing function	A design that prevents the user from taking an action without consciously considering information relevant to that action. It forces the user's attention upon something and deliberately disrupts the efficient or automatic performance of a task.
Interoperability	The ability of different information technology systems and software applications to communicate; to exchange data accurately, effectively, and consistently; and to use the information that has been exchanged.
Medical logic module (MLM)	An encoded clinical rule that contains enough logic to make a single clinical decision. Examples: • Clinical alerts, recommendations, reminders, informational notices, interpretations, diagnoses, quality assurance functions, continuous quality improvement, biosurveillance, administrative support, and clinical research

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