Integrating a Guideline-Based Clinical Care System into Nursing Practice using GLIF3

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Abstract

In Canada there is a movement to transform nursing practice by shifting the focus from tasks to outcomes oriented care. The Canadian Nursing Association, the Ontario Ministry of Health and Long Term Care and Canada Health Infoway promote the electronic collection of standardized evidenced-based nursing outcomes at point of care, deemed essential in planning for and evaluating nursing care. In this paper we investigate how the flexibility of flow-based computer interpretable guideline methodologies can benefit this transformation. Specifically, we examine how GLIF3 methodologies can facilitate the encoding of nursing practice into computer interpretable best practice guidelines, taking into consideration the point of care information needs of nurses. The importance of integrating data mining methodologies into guideline-based nursing care is examined for its potential to help build a Canadian nursing knowledge base that generates nursing sensitive outcomes. We conclude with a recommendation that incorporates online nursing documentation into a guideline-based clinical care system that ensures nurses will have the data, knowledge and tools that they need to do their job - no more no less – allowing them to provide the hands on care that their patients so desperately need.

KEYWORDS: GLIF3; Decision Support Systems; Nursing Practice; Best Practice Guidelines; Data Mining; Nursing Sensitive Outcomes; Patient State.

Introduction

Clinical guidelines are "Systematically developed statements to assist practitioners and patient decisions about appropriate health care for specific clinical circumstances[1]." They are a mechanism for translating evidence from scientific research into clinical practice with the intention of improving patient safety, quality of patient care and efficiency in health care delivery [2]. Clinical guidelines are multi-step plans that unfold over time, incorporate the latest practice evidence, identify a standard of care and are distributed to caregivers. In the nursing domain, the Registered Nurses Association of Ontario (RNAO) has developed more than 25 nursing Best Practice Guidelines (BPG) on such topics as falls prevention, post-partum depression, asthma, smoking cessation, breastfeeding, pain, and pressure ulcers [3].

Nurses are the largest group of point-of-care decision makers. Because their in-the-moment decisions about treatment options can have life and death consequences, it is recognized that these decisions must reflect current, evidence-based standards of care. Clinician decision-making behavior is most effectively influenced through patient-specific advice, especially if delivered at point of care. Unfortunately, accessing information contained in conventional guidelines can be difficult and it can be a challenge to apply them to specific patients during a nursing-client care encounter [4]. Studies have shown that dissemination and effective use of guidelines in clinical care remains a major bottleneck that inhibits efficient communication and care [2]. Guideline-based point-of-care decision support systems have the potential to address this problem.

We chose to investigate the computer interpretable representation of domain knowledge contained in clinical guidelines within the nursing domain in the area of decision support. This is an approach that consists of a hierarchical decomposition of guidelines into networks of component tasks that unfold over time [4]. In the last decade, attention has focused on guideline representation models and underlying languages. However, the real benefit of computer interpretable guidelines (CIG) lies in structuring and guiding the whole guideline development process (Figure 1) taking into consideration guideline representation, acquisition, verification and execution [5].

In this paper we investigate how knowledge management principles and computer interpretable, guideline-based decision support systems might apply to nursing practice. Specifically, we identify the major point-of-care information needs of nurses and match them with the features and capabilities of GLIF3 methodologies. The importance of integrating CIGs and data mining technology to help build a Canadian nursing knowledge base that generates "nursing sensitive outcomes", is emphasized. We conclude with recommendations for future research that will support current nursing informatics initiatives.

Nurses as knowledge workers

Information technology can help promote safe, high quality care and enhance the continuity of care by improving communication, providing support and making knowledge more accessible [6]. Yet, the increasing use of computers and clinical information systems has inundated nurses, and other healthcare providers, with an increasing volume of data and information that can interfere with decision - making [7]. Knowledge management (KM) is a business approach that can be used to manage this explosion of healthcare information and knowledge. Good KM means getting the right knowledge to the right place at the right time. [8]. Hsai et al recognized that the foundation of a nursing KM system can be built by integrating KM principles and tools (e.g. clinical decision support and data mining) with the nursing decision-making process [9].

In practice, nurses formulate a nursing diagnosis (e.g. nausea, restlessness, pain, anxiety, skin breakdown etc.) based on the condition or state of the patient. This requires a collection of patient data, domain expertise and knowledge. The nursing diagnosis leads to the formulation of a patient specific care plan. Once a care plan is developed and implemented, the patient response or outcome is assessed (their current state is compared to patient goals and preferences). Currently, this process of care plan development and outcome analysis is documented to some degree but often poorly represented in the patient record [10].

This nursing process is iterative, is usually performed cognitively with little visible record and continues until the patient problem is no longer identified –

nursing treatment is then discontinued. Banning identified two models commonly used in nursing decision-making: a) the information - processing model and b) the intuitive-humanist model, These models have been extended into a c) third multi-dimensional decision-making model. This more holistic model contains elements of the information-processing model in addition to patient specific elements that are necessary for cue and pattern recognition[11].

KM offers a framework for identifying, organizing, analyzing, and translating knowledge into nursing practice. It is a valuable conceptual tool for organizing the growing body of nursing knowledge when applied in the development of a guideline-based, multi-dimensional decision support systems to translate best practice guidelines into nursing practice [8].

Information needs of nurses

The Canadian Nursing Association states that "healthcare providers need reliable and accurate patient health information at the point of care and the best evidence available to determine treatment options, and to know that electronic tools to manage this information are a necessity[12]." It is reported that 64% of nurses have information needs on a regular basis, yet two thirds report never reading journals and 52% do not actively draw from research in practice [13]. Chen and Coffey pointed out that It can take 17 years for research to trickle down to practice, a fact that spurs us to promote more timely access to knowledge [14].

The majority of nursing information needs are related to patient-specific data such as lists of medications, problems lists, and laboratory and other test results [15]. Many of these information needs remain unmet due to time constraints, difficulty in obtaining and finding information, and finding inaccurate or outdated information [15]. Nurses tend to prefer to obtain information from resources that are convenient, easy to use, and reliable. Colleagues, and other health care providers use favorite resources for nursing information [16]. The medical record was identified as the most common resource used by nurses to satisfy the majority of patient information [15].Doran et al [17] identified that the resources Ontario nurses require at point of care include: a vital sign module, a drug handbook, nursing sensitive outcomes, and RNAO best practice guidelines.

Later in this paper we discuss how the most important of these data and information needs can be met using flow-based computer interpretable guideline methodologies, and summarize our findings in a table in Appendix 1.

Translating nursing best practices into computer interpretable guidelines

Nursing practices are increasingly being encoded as nursing guidelines and protocols that drive health-care service delivery [9]. Guideline-based decision sup-port systems have evolved from condition-specific, event-driven software applications to a wider systems perspective that enables standards and flow-based guide-lines to be integrated with electronic patient management systems that have reference and information retrieval sup-port available at the point of care.

To help standardize care, guideline sharing has become a important goal. This goal is now possible, due to the technical ability to separate the code for describing the guideline content from the code that implements the decision support system [18]. This broad and more holistic systems approach is integral to clinical workflow, is generalisable and scalable, and is applicable to multiple diseases and multiple clinical settings [2]. The success of CIGs requires that they be clinically relevant, that user requirements be understood, and most importantly, that there is a good understanding of how the knowledge incorporated into guidelines best fits or is fed into the model [2]. Figure 1 below illustrates guideline development as a dynamic, multi-step life cycle.

Six discrete steps are identified which include:

- creation
- dissemination
- implementation
- utilization
- evaluation
- modification.

These steps involve the collaboration between the authors of the guidelines (informaticians) and the clinicians who use the guideline.

This model not only represents the steps involved in guideline development but also how guidelines are used in clinical practice. Of note is the loop that allows the guideline to be systematically updated with new scientific evidence. Most importantly, it portrays the ultimate goal of guideline use which is to improve health care outcomes [19].

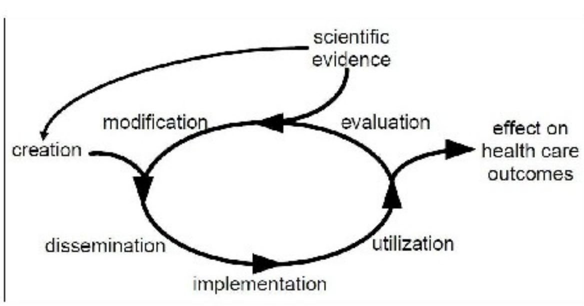

Figure 1. Lifecycle of a Clinical Guideline [19]

It can be said that the process of clinical care is encoded in an algorithm of a guideline One of the obstacles to CIG development in nursing is related to the definition of "algorithm"; the concept is different for the guideline developer and the nurse. A nursing algorithm is embedded in practice and requires domain knowledge, skill, and judgment beyond the linearity of traditionally static computer algorithms. Nursing algorithms require flexibility, sequencing and the ability to "loop" information flow in order to incorporate outcomes into a patient specific care plan. [14].

Building a guideline-based clinical care system involves encoding the nursing knowledge in guideline documents for interpretation by computers. The life cycle model of guideline development is highly representative of the nursing process and has the potential to accommodate the information needs of nurses as previously identified. As well, "It is anticipated that nursing guidelines will translate easily into the GLIF [Guideline Interchange Format] because nursing guidelines often incorporate patient states as a basis for recommendations [17]." In the following sections we discuss how the flexibility of GLIF modeling can be used to create CIGs that address the dynamic "algorithm" of nursing practice.

GLIF3 Overview

Guideline Interchange Format (GLIF) was created by the InterMed collaboratory to facilitate and standardize the transfer of paper-based guidelines into computer readable format. The latest version, GLIF3, supports the iterative nature of guideline development with specific flow-control functions. GLIF3 facilitates the integration of guidelines with clinical information systems by modeling interfaces for patient data and external medical knowledge during guideline execution. GLIF3 adopts open standards such as HL7 and enables the incorporation of clinical terminologies – necessary to map sharable guidelines.

GLIF3 Modeling Language

GLIF3 is made up of three levels: 1) a conceptual flow chart, 2) a computable specification and 3) an implementation specification. At this first level, a UML-based object-oriented language is used to specify clinical guidelines as flowcharts of temporally ordered nodes called guideline steps.

These steps are represented by an abstract class called the Guideline_Step [20]. The *Guideline_Step* class has the following subclasses:

- **Action_Steps** are specific clinical actions to be performed (such as applying therapy, carrying out an examination or measurement). They can also name a sub-guideline.
- **Decision_Steps** are used for conditional branching and consist of two kinds: a) *Choice Steps* are enacted when the decision cannot be precisely specified in the guidelines themselves, therefore the decision should be made by the user, and b) *Case Steps* are used when branching is determined by the evaluation of defined logical criteria based on data items.
- **Branch_Steps** enable concurrency in the model; guideline steps that follow a branch step can be performed at the same time. *Synchronization_Steps* force a number of previous steps to be completed before the next step can be initiated.
- **Patient_State_Steps** characterize the patient's clinical state and can function as a label that summarizes or describes the current clinical state of a patient after a previous step's application. These steps can also function as a guideline entry point and end point [20, 21].

GLIF3 Editor

Information must be broken down logically into relationships and "if then" scenarios in order for guidelines to become interpretable by the computer. This requires a lengthy, ongoing iterative process of clarifying understanding between the domain experts and informaticians. This process is facilitated by a guideline editing tool such as Protégé-2000.

This tool assists guideline developers with the representation and management of domain ontologies and can be successfully used to encode practice guidelines for clinical decision support systems. Protégé-2000 has an extensive software architecture and an easy to use graphical user interface (GUI).

To use this tool, An informatician enters data into the appropriate classes, slots, facets, instances and constraints. This categorization of the data enables Protégé-2000 to automatically generate and display classes and their relationships on the GUI using a number of different visualization methods. Additional pieces of information, called widgets, may be added to refine the generated output. Output can be reviewed and checked for inaccuracies based on the original guideline.

Actual scenarios can be applied to the CIG and be assessed by the domain expert. Further refinements can be made quite easily to the guideline [22]. The Protégé-2000 tool addresses a classic eHealth development dilemma in which domain experts are restricted by their area of expertise and need a common language in which to communicate

GLIF3 Execution Engine

GLEE (guideline execution engine) is a modular middleware product that can be used to execute guidelines encoded in the GLIF3 format. GLEE is JAVA-based and has multiple functions that enable the application and integration of CIGs. The key roles of GLEE include an interface that works with GLIF3 and a backend user interface that works with clinical applications that have the ability to draw patient specific information from the EMR to the guideline.

A unique characteristic of GLEE is its flexibility. GLEE enables clinicians to enter and exit guidelines as needed through the patient state steps and allows for deviation from recommended guidelines so that in-dividualized patient care plans may be followed if guideline recommendations do not apply. Additionally, GLEE has the ability to trace the guideline execution history for a patient eliminating the need to re-enter from the top of the algorithm each time the CIG is run on the patient. These features address previous frus-trations encountered by clinicians when using CIGs that did not allow for flexibility and clinical judgment based on knowledge and experience.

By providing an interface between GLIF3 and a clinical application such as an EMR, GLEE promotes seamless integration of the CIG into clinical practice. GLEE also enables a guideline to be run in multiple EMRs at the same time and for multiple guidelines to be applied concurrently to one EMR. GLEE has a standalone GUI that shows the algorithm of the GLIF3 guideline. This permits the developers to have an all-encompassing view of the tool, and provides a workable interface in which to make changes in guideline maintenance and execution [23].

GLIF3 Research

Although GLIF3-related technologies are not readily available on the market, research continues to be conducted that refines the concepts in an attempt to push the methodologies forward. A number of these studies, as described below, can be extrapolated to the development and implementation of guideline-based clin-ical decision support system for nursing practice.

Choi et al. [24] modeled a depression screening guideline using GLIF3, Protégé-2000, and GLEE. The authors of this study suggested that these are useful methods and tools for preparing nursing clinical practice guidelines for implementation in a decision support system.

Similarly, a diabetes foot care guideline was encoded using GLIF3, authored with Protégé-2000 and executed (simulated) using GLEE. A web-based interface to an Oracle data base was included in the design for EMR integration. The purpose of this research was to analyze the changes that had to be made to GLIF3 during the encoding process. The authors of this work suggested that GLIF3 is flexible enough to accommodate localization (customization) of the guide-lines and can be generalized to nursing practice [25].

Peleg and Kantor [26] used GLIF3 to develop a versioning tool to capture and visualize differences between guideline versions. Specifying and explaining changes made to guidelines, instead of encoding revised guidelines from scratch, may help clinicians understand and adopt these changes better. This study may be the first step toward creating a mega-guideline which could encompass all published guidelines in a certain field, such as nursing.

The use of GLIF3 and Protégé-2000, helped Mailhot et al [27] create an ontology that described behavioral interventions and extended GLIF3 with new decision nodes that facilitated a formal analysis of behavioral interventions and the reuse and retesting of their components. This work extended GLIF3 applications into the behavioral sciences and is especially applicable to the behavior-based nursing best practice guidelines like smoking cessation, post-partum depression and suicidal ideation and behaviors.

Research that applies data mining methodologies to CIGs and GLIF3 is critically important to guideline-based nursing practice thus warrants a section of its own in this paper.

Data Mining in Nursing

Data mining is a powerful and active methodology that can assist in building knowledge directly from clinical practice data for decision support and evidence-based practice in nursing. As data mining studies in nursing proliferate, more will be learned about improving data quality and defining nursing data that not only captures the essential and unique tasks that nurses perform but the effect these actions have on patient outcomes as well [7].

Data mining and knowledge discovery algorithms have been applied to clinical data sets relevant to nursing diagnoses, interventions and patient outcomes and to derive meaningful decision rules. The main goal of these studies is to use data mining to identify the contribution of nursing care to patients' health and to facilitate timely health care, less biased decisions, and improved patient outcomes. [28, 29]

Sherafat & Sartipi [30] extended the GLIF3 model to incorporate data mining decision nodes capable of interpreting knowledge extracted by data mining analysis. They proposed a guideline execution environment that can dispatch data mining specific modules to retrieve and store data and mined knowledge from a local or distributed repository and then use the execution engine to interpret the data and mined knowledge within a specialized guideline node.

Finally, it has been suggested that GLEE can be used to record data about clinical guideline use and outcomes. Creating a database for recording comprehensive data for subsequent statistical analysis and data mining is possible. The results of this analysis can then be fed back into the guideline life cycle [31].

The amalgamation of mined knowledge with nursing best practice guidelines facilitates development of a much needed nursing knowledge base that clearly identifies patterns and important links between patient data, nursing interventions, and patient outcomes. As nurses better understand these important links, they may be able to use this knowledge to improve quality of care and patient outcomes [7].

Conclusions

"A coordinated, centralized system to collect, store, and retrieve data about nursing practice in Canada is missing. These data are essential to expand knowledge, to evaluate the quality and impact of nursing care, to promote patient safety and to support integrated human resources planning[12]."

It is believed that well constructed guidelines could play a significant role in ensuring patient safety and reducing medical errors [32]. However, there is no one standard instrument that measures the impact of practice guidelines on patient outcomes [33]. In an attempt to address these problems, this paper examined how GLIF3 methodologies, together with the use of collaborative KM tools like Protégé-2000 and GLEE can facilitate the encoding of nursing practice into computer-interpretable best practice guidelines. Appendix 1 summarizes the information needs of nurses and matches GLIF3 functions and related technologies to these needs. This illustrates that GLIF3 does in fact accommodate the needs of a dynamic, iterative nursing process.

The nursing profession continues to identify, structure, and standardize nursing data. A guideline-based clinical information system that collects those data will provide a knowledge base for data mining analyses that has the potential to build nursing knowledge based on the relationships between patient data, nursing interventions, and patient outcomes. The integration of technologies like GLIF3, decision support systems and data mining, offer solutions to help manage the data and information overload that affects nursing decision-making and help to build a knowledge base essential to generating information on nursing sensitive outcomes.

Recommendations

We propose that future research be conducted that investigates the incorporation of GLIF3 data mining decision nodes into patient specific, guideline-driven, electronic nursing documentation records. This would allow relevant patient data that is related to best practice guidelines to be drawn from the patient EMR. As a result, only those fields appropriate for charting the patient will be displayed on the nurse's screen. In Appendix 2 a use case diagram is provided to help visualize this recommendation.

Integrating nursing guidelines with an EMR and electronic documentation will help streamline patient specific care, prompting nurses to perform evidenced based practice at the point of care.

In an attempt to produce relevant mined knowledge at the point of care, we also recommend that the supplemental material functionality enabled by GLIF3 be used to provide access to or display patient specific health teaching that is triggered by the guideline and is based on the patient EMR data.

Providing nurses with the data, knowledge, and tools that they need to do their job - no more no less - and by reducing the time-consuming activities of clicking through drop down menus and numerous screens, will free up nurses' time to provide the hands-on care that their patients so desperately need.

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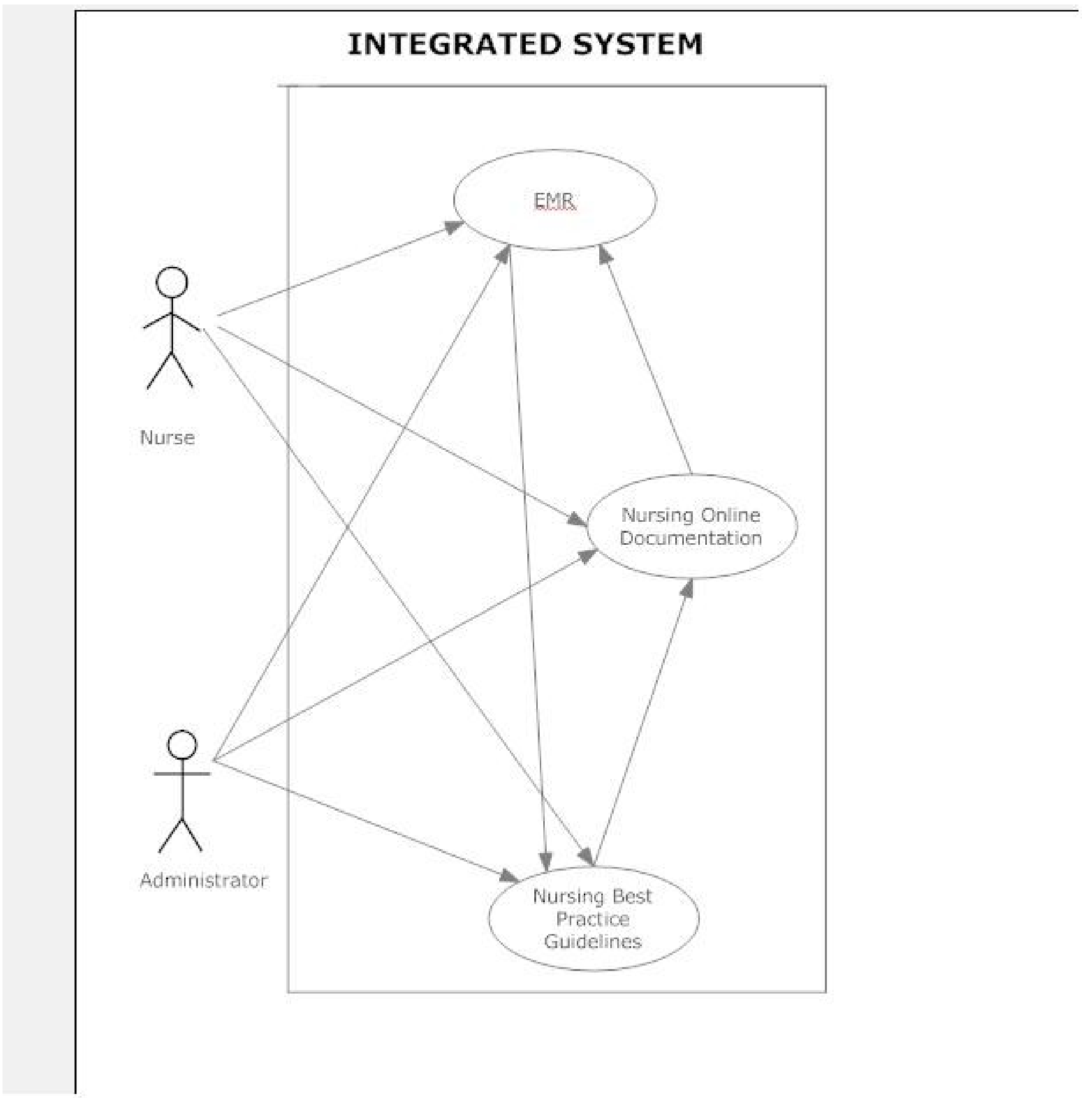
Appendix 1
Nursing practice and information needs met by GLIF3 and related technologies

Nursing Practice/ Information Needs	**GLIF3 Component**	**Comments / Research**
Best Practice Guidelines (Doran)	GLIF3	▪ Depression Study/Footcare study ▪ RNAO BPG on PDAs
Patient Status • CNA clinical data element[1] • Vital signs (Doran)	Patient_State_Step	▪ Entry and exit points in guideline ▪ Nursing guidelines are expected to translate well into GLIF3 as patient state is basis for nursing diagnosis development [17]. ▪ Remote and local providers can view the execution time of each node including data input and the paths taken through the system
Nursing Intervention • CNA clinical data element	Decision_Step	▪ Capture and display the nursing intervention at this step
Patient Outcome • CNA clinical data element	GLIF3 data mining node	▪ Capture nursing sensitive outcomes for guideline refinement and analysis ▪ We propose future application could refine nursing online documentation as part of patient specific EMR
Clinical care terminology: • International Classification for Nursing Practice (ICNP)	GLEE	▪ Compliant with standards such as HL7v3 ▪ encoders may choose terminology and patient data models [23] therefore has potential to support ICNP terminologies

[1] http://www.cna-aiic.ca/CNA/documents/pdf/publications/PS87-Nursing-info-knowledge-e.pdf

Nursing Practice/ Information Needs	GLIF3 Component	Comments / Research
Integration with EMR/EHR (CNA)	GLEE	▪ direct comparing of clinical guidelines with EMR data
Ensure capture of clinical data is standardized (CNA)	GELLO	▪ HL7 Standard
Aggregate data + -compare + report (CNA)	Data Mining and EMR	
Iterative, Dynamic Practice	All tools	▪ e.g. Nursing depression study
Evidence-based practice	Protégé-2000	▪ Authoring tool used for collaboration ▪ versioning tool created for GLIF3 CIGS

Appendix 2 – Use case diagram that integrates nursing practice guidelines with an EMR and online documentation



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