Ontology-based Modeling of Breast Cancer Follow-up Clinical Practice Guidelines: A Decision Support System

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Objective:
To computerize the Canadian breast cancer follow-up CPG and then operationalize it using patient data to assist the practitioner to make CPG mediated decisions, recommendations and referrals.

Background:
Breast cancer is the most common cancer among women in Canada. Due to recent advancements in treatment and diagnosis, breast cancer survivors are the most prevalent female cancer survivor group in Nova Scotia. As a consequence, the delivery of long-term follow-up care, which has traditionally been provided at the specialized cancer clinics, places a strain on specialist resources. However, there is evidence that family physician follow-up of women with breast cancer who are in remission is a safe and viable alternative to follow-up in the cancer centers. In this regard, as a first step, Cancer Care Nova Scotia has developed a Breast cancer follow-up clinical practice guideline for use by the family physicians. For most family physicians this will be new and added responsibility and it is expected that this guideline will be beneficial. However the adoption of the said CPG is a challenge. Purpose of our research is to provide the CPG knowledge which is accurate, adequate and in operable format and at the point of care.

System Design Challenges:
In order to establish a CPG-guided CDSS, we take the following challenges into consideration:
• How to encode CPG in a computerized format whilst encoding the underlying semantics.
• How to transform the CPG’s inherent decision logic into medically salient decision rules
• How to execute the computerized CPG to achieve decision support.
• How to ensure the validity of the transformed knowledge and to provide trust in the recommended actions

In order to meet the above challenges, we took Semantic Web approach to develop our methodology for the implementation of breast cancer decision support system.

Methodology:
We present an ontology-based semantic web-approach towards the development of Breast Cancer Follow-up Decision Support System (BCF-DSS) based on the CPG for the Care and Treatment of Breast Cancer. We have developed three ontologies: (a) CPG ontology that models the structure of the CPG based on the Guideline Element Model
(GEM); (b) Breast Cancer Ontology that represents the medical knowledge encapsulated within the CPG and general BC related concepts; and (c) Patient Ontology that models the patient’s parameters. The ontologies are developed using Protégé and are in OWL format. We have developed a logic-based reasoning engine that reasons over the knowledge from these three ontologies. Our BCF-DSS allows family physicians to collect patient data and assists them to make CPG mediated decisions, recommendations and referrals for BC survivors. The main phases during the development of BC-DSS are as follows;

1. Computerization of CPG:
In order to convert the breast cancer follow-up guideline in computerized format we have used Guideline Element Model or GEM, developed at Yale University. GEM is an XML based model which store and organize knowledge in clinical practice guidelines. We used GEM Before computerization of the guideline we studied the entire CPG text with special emphasis on the recommendations so that any ambiguities in the natural language can be determined and removed if possible. In fact we identify certain terms and phrases, for example, ‘vaginal bleeding is present in the absence of obvious cause, ‘physiological causes of fatigue’ and ‘other risk factors of osteoporosis’, which were not explicitly stated. In order to resolve such ambiguities we consulted one of the authors of the guideline and the medical literature and also used personal clinical experience and knowledge. During the modeling process particular attention was given to certain abstracts terms such as ‘earlier age’ since such terms might have implications on the type of data which would be input during the execution of guideline.

2. Development of Domain Ontology:
After conversion of the document in GEM format we used the conditional recommendation within the CPG to develop the domain ontology. We started developing the domain ontology by enumerating all the key terms in the CPG text in the conditional elements of the GEM template and studying their relationships. One of the key components in the execution engine which has been used in this project is the CPG ontology which corresponds to the GEM DTD. with one exception that an additional property called the variable.name is added to the decision variable class, so that the domain of this property is decision.variable and the range is all the properties in our Domain Ontology. Another feature of the execution engine which was considered during the ontology development was the fact that although logical recommendations containing ‘AND’ operator can be executed, the engine is not designed to process statements containing ‘OR’ and ‘NOT’ Boolean logical operators.

3. Execution of CPG:
The execution engine has two main sub-modules; Rule Authoring Module and Execution Module. The Rule Authoring Module provides an interface to the users to specify decision logic rules using abstract rule syntax called CPG Rule Syntax. According to this syntax, decision.variable for the CPG rule is a sub-class in the CPG ontology which is based on GEM DTD. A new property variable.name has been added to the decision.variable in the CPG ontology. Its value is derived from all the properties in our
Domain Ontology, meaning that although the Domain for the variable.name is decision.variable, its Range is properties in Domain Ontology.

In order to execute the conditional recommendations we first assign the variable names i.e. properties to decision variables as well as action variables. In case of a rule
IF dv1 i.e. Patient_is_on_medication = Tamoxifen (property of class Patient_Type)  
AND dv2 i.e. Rx_apply_to_recommendation = ? (property of class Rx_Recommended) 
THEN 
a1 i.e. Patient_is_recommended. (property of class Patient_Type) = dv5 
where dv1 and dv2 are the decision variables, and a1 is the action variable. The derivation for this rule is as follows. The Patient_Type_1 which is the instance of class Patient_Type is on medication, Tamoxifen. Patient_Type_1 is the resource for this rule. This treatment i.e. Tamoxifen is an instance of class Treatment, which has a property apply to recommendation, whose value is ‘query about vaginal bleeding’. Since we have specified in the rule that the value for the action variable i.e. a1 (Patient_is_recommended) is same as the value for the dv2 (Rx_apply_to_recommendation), which according to the ontology is ‘query about vaginal bleeding’, the recommendation for this patient type is to query about vaginal bleeding

Concluding Remarks:
We have developed a CPG based interactive clinical decision support system for the breast cancer follow-up to be used in the primary care setting. Our methodology is innovative since we have linked the CPG ontology to the breast cancer domain ontology from which rules for the conditional recommendations has been derived. This methodology can also be applied to Clinical Practice Guidelines in other medical specialties. The objective of this project is to promote knowledge translation to primary care settings in Nova Scotia so that family physicians can take on the responsibility for the breast cancer follow-up care and patient education into their clinical practice, thereby reducing the strain on specialist cancer centers within Nova Scotia. The purpose of this system is not only to provide access to the above CPG at the point of care but also to create an interactive environment whereby the family practitioners can benefit from customized patient management and educational information for an individual patient.

Future Work:
The next steps are the deployment of the clinical decision support system within two clinics in Nova Scotia, followed by an evaluation study to measure the efficacy of the CDSS in terms of providing point-of-care support to family physicians conducting breast cancer follow-up.