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# Knowledge-based Surveillance for Preventing Postoperative Surgical Site Infection

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**Abstract.** At least one out of every twenty people admitted to a Canadian hospital will acquire an infection. These hospital-acquired infections (HAIs) take a profound individual and system-wide toll, resulting in thousands of deaths and hundreds of millions of dollars in additional expenses each year. Surveillance for HAIs is essential to develop and evaluate prevention and control efforts. In nearly all healthcare institutions, however, surveillance for HAIs is a manual process, requiring highly trained infection control practitioners to consult multiple information systems and paper charts. The amount of effort required for discovery and integration of relevant data from multiple sources limits the current effectiveness of HAIs surveillance. In this research, we apply knowledge modeling and semantic technologies to facilitate the integration of disparate data and enable automatic reasoning with these integrated data to identify events of clinical interest. In this paper, we focus on Surgical Site Infections (SSIs), which account for a relatively large fraction of all hospital acquired infections.

**Keywords.** Bio-ontologies, Surgical Site infections, Hospital acquired infection, Knowledge management

## 1. Introduction

A Surgical Site Infection (SSI) is commonly described as a type of Hospital Acquired (or Healthcare-Associated) Infection (HAI), related to a surgical procedure and occurring at the site of a surgical incision. SSIs are divided into three categories: superficial incisional (occurs in skin and subcutaneous fat), deep incisional (occurs in fascia and muscle), and organ/space. SSIs have a major impact on morbidity and mortality, and result in substantially increased medical costs [1]. Several risk factors for SSIs are known [2], including patient-associated factors (e.g., nutritional impairment, immunocompromised state, old age, diabetes mellitus, smoking, obesity) and surgical operation-associated factors (e.g., length of the operation, malpractice of sterilization and decontamination methods). Currently, identification and diagnosis of

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SSIs relies mainly on direct observation of physical signs and symptoms of infection in an incisional wound and a case cannot be confirmed solely by analyzing data given in laboratory reports. An accurate surveillance method often requires close collaboration between several healthcare professionals, including physicians, surgeons, microbiology lab technicians, nurses, epidemiologists, and infection prevention and control professionals (IPCPs). To facilitate knowledge-based decision making, availability of a reference vocabulary is crucial. Despite several modifications and improvements to existing terminologies made by the Centers for Disease Control and Prevention (CDC) in the last decade, e.g., specifying the location of infections related to surgical operations and clarifying the criteria to identify the exact anatomic location of deep infections [3, 4], inconsistencies, discrepancies, and confusion in the application of the criteria in different medical/clinical practices still exist, and there is a need for further improvement and clarification of the current nomenclature [5, 6]. To develop common understanding about infection control domain and achieve data inter-operability in the area of hospital-acquired infections, we present the HAI Ontology as part of the HAIKU (Hospital Acquired Infections – Knowledge in Use) project (Figure 1).

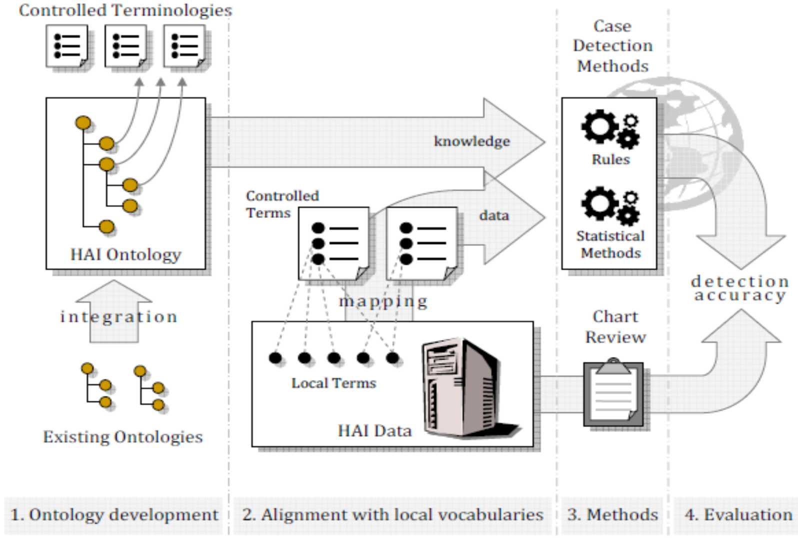


**Figure 1.** Overview of the Hospital-Acquired Infections: Knowledge in Use (HAIKU) project.

## 2. Method

HAIKU has four specific aims: i) Development of HAI Ontology, which will rely, where possible, on the existing knowledge from published ontologies and controlled vocabularies; ii) Mapping of local terminologies onto concepts in HAI Ontology, by specifying how the ontology primitives can be used to express clusters of data using local terminologies in the form of RDF graph fragments; iii) Development of ontology-powered, rule-based and statistical methods for case detection, which will be deployed as web services and operate on mapped HAI data; iv) Evaluation of accuracy of case detection methods using the results of patient chart review as a gold standard; v) providing uniform semantic interface to the data via querying and browsing, to facilitate research in the form of discovery and hypothesis testing.

For the experimental part of our work, we are using data from the McGill University Health Centre (MUHC) and the Ottawa Hospital (TOH) that are already assembled in research data warehouses at each site. The data warehouses draw from multiple-source information systems, including laboratory (microbiology and clinical chemistry), pharmacy, operating room, and patient demographics and movement. In addition, at both sites we have already identified through exhaustive chart review, patients that have experienced SSIs. We use clinical data and chart review results for these patients to develop and validate detection methods. For surveillance of SSIs, the demographic and operational data about selected patients undergoing one or more operative procedures during a specific observation time period are collected. The use of two clinical sites is critical to the proposed research so that we can evaluate the transferability of methods. Several databases (e.g., those containing information on hospital morbidity and discharge abstracts), existing bio-ontologies (e.g., SNOMED, MeSH, ICD9, HL7, FMA, CheBI[2], Infectious Disease Ontology (IDO)[3]), and textual resources have been used to design and implement the integrated HAI Ontology (Figure 2). We use OWL 2.0[4] as the formal representation language. To validate the ontology, we have used OWL reasoners such as RACER [7] and Pellet [8].

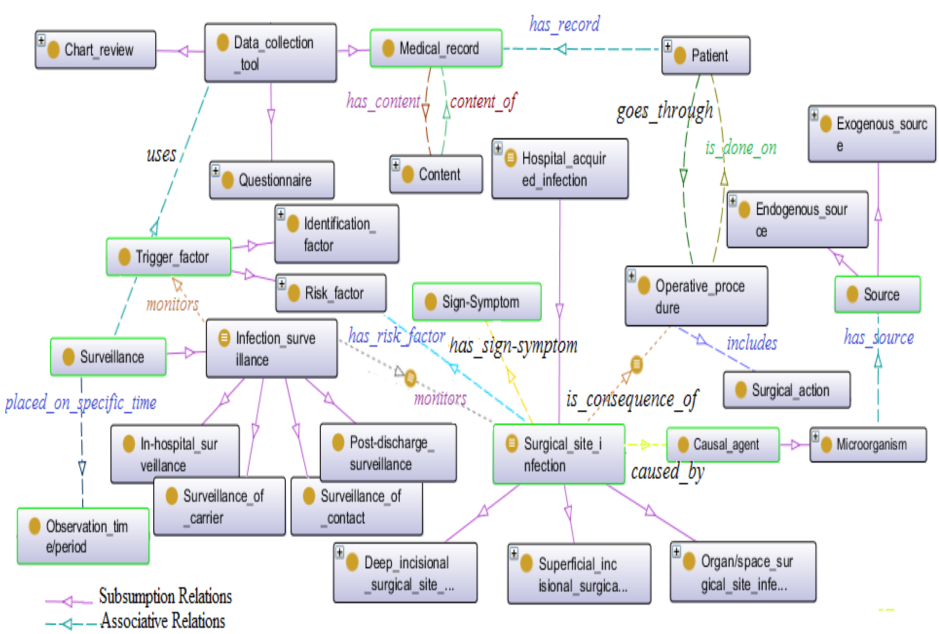


**Figure 2.** Partial view of the major components of the HAI ontology for surveillance of SSIs (visualized using OntoGraph[5]).

[2] Chemical Entities of Biological Interest (ChEBI): http://www.ebi.ac.uk/chebi/
[3] http://infectiousdiseaseontology.org/page/Main_Page
[4] http://www.w3.org/TR/owl2-overview/
[5] http://protegewiki.stanford.edu/wiki/OntoGraf

## 3. Results

Partial view of the major components of the HAI ontology is presented in Figure 2. We evaluate the ontology using OWL reasoners to check for consistency, satisfiability, expected or unexpected inferred relationships, and subsumption. For example, we can define a query that checks whether the concept "*Postoperative mediastinitis*" is satisfiable over our defined axioms, or if our conceptualization allows for existence of "*Stitch abscess*" as a surgical site infection (based on the CDC guideline, it is not permitted by our ontology). To evaluate case detection methods, we rely on results from the MUHC and TOH's ongoing chart review process for HAI. We assess the ontology based on ability to meet initial design requirements, e.g. by defining different queries over the defined axioms. To do this, we have defined a set of potential application scenarios to address specific tasks divided into three categories (Table 1).

**Table 1.** Application scenarios to perform specific tasks using the HAI ontology.

| Category | Potential Use | Potential Users |
|---|---|---|
| (I)<br>HAI case identification | -Case enumeration<br>-Care/product evaluation<br>-Intervention (e.g., outbreak analysis) and outcome analysis | -IPCP<br>-Public health<br>-Medical staff<br>-Health care workers (HCW), Manufacturers<br>-Patients/lawyers/risk management<br>- Researchers |
| (II)<br>Risk/causative factor identification/evaluation | -To evaluate outcomes singly or across multiple HAIs<br>-To look for modifiable risk factors<br>-To look for interactions between risk factors<br>-To evaluate the strength of association or attributable risk | -IPCP<br>-Medical staff<br>-HCW<br>-Manufacturers<br>-Researchers |
| (III)<br>Diagnostic factor identification/evaluation | -Calculation of diagnostic accuracy of factors for surveillance or clinical purposes<br>-Creation of models or algorithms for case detection<br>-Identification of new detection method<br>-Evaluation of interactions among/between identification factors and risk factors | -IPCP<br>-Medical staff<br>-HCW<br>-Manufacturers<br>-Researchers |

For each category we define a set of queries. For example for Category I, the following queries can be answered:

- What are common patient-associated risk factors for both SSIs and Catheter Associated Urinary Tract Infections (CAUTIs)?
- What effect has installation of new alcohol hand gel dispensers had on the *Serratia* SSI incidence in Cardiac Surgery Intensive Care Unit (CSICU)?
- Are patients with SSI at risk of developing severe sepsis?
- How many SSIs have been associated with our new brand of implantable ventricular assist device (VAD)?

For Category II we can define queries such as:

- Potentially discontinuable medications associated with development of SSI
- Interaction between hypoxia (decreased oxygen supply) and hypoalbuminemia (reduced serum albumin concentration) in development of SSI

Moreover, the following queries can be asked for Category III:

- Combination of laboratory and radiographic findings that best identifies cases of prosthetic hip infections following hip replacement surgery?
- Given that C-reactive protein elevation is sensitive and specific in patients with HAIs, what other potential acute phase reactants may be used for diagnosis?
- What effect does the use of drugs with anti-inflammatory side effects have on the sensitivity of CT (computed tomography) findings of post-operatic abscess formation?

## 4. Discussion and Conclusions

The HAI Ontology as a part of the HAIKU framework is compatible with the definitions, recommendations, and specific criteria that are specified by the Centers for Disease Control and Prevention (CDC) [3] for identifying and preventing SSIs. Different releases of the ontology are freely accessible through the HAIKU wiki[6] and can be used for HAI case identification, diagnostic identification/evaluation, and risk/causative factor identification/evaluation. One of the major challenges in our research is integration process and dealing with several mismatches at the language level and model level between different knowledge sources. At this point the integration has been mostly performed semi-automatically under human supervision and control. Our future work will focus on improving the integration process and population of the ontology using the local terminologies, as well as utilizing the rule-based and statistical methods for case detection. Moreover we will leverage the SADI [9] framework as a medium for ontology-based query answering of HAI-related data, especially in the form of relational databases, possibly in combination with analytical resources, such as dynamic computation of various index values and scores.

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