International Journal of Pediatrics and Adolescent Medicine (2015) 2, 64—69

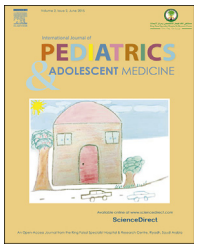
HOSTED BY

ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: http://www.elsevier.com/locate/ijpam



ORIGINAL RESEARCH ARTICLE

Data visualization for truth maintenance in clinical decision support systems

Gilbert Chien Liu [a,*], Jere D. Odell [b], Elizabeth C. Whipple [c], Rick Ralston [b], Aaron E. Carroll [c], Stephen M. Downs [d]

[a] *Department of Pediatrics, University of Louisville, Louisville, KY, USA*
[b] *Ruth Lilly Medical Library, Indiana University School of Medicine, Indianapolis, IN, USA*
[c] *Department of Pediatrics, Indiana University School of Medicine, Indianapolis, IN, USA*
[d] *Children's Health Services Research, Indiana University School of Medicine, Indianapolis, IN, USA*

Received 16 September 2014; received in revised form 29 May 2015; accepted 1 June 2015
Available online 19 June 2015

KEYWORDS
Decision support systems;
Management;
Electronic health records;
Information science

Abstract *Background and objectives:* The goal is to inform proactive initiatives to expand the knowledge base of clinical decision support systems.
Design and setting: We describe an initiative in which research informationists and health services researchers employ visualization tools to map logic models for clinical decision support within an electronic health record.
Materials and methods: We mapped relationships using software for social network analysis: NodeXL and CMAP. We defined relationships by shared observations, such as two Arden rules within medical logic modules that consider the same clinical observation, or by the presence of common keywords that were used to label rules according to standardized vocabularies.
Results: We studied the Child Health Improvement through Computer Automation (CHICA) system, an electronic medical record that contains 170 unique variables representing discrete clinical observations. These variables were used in 300 medical logic modules (MLM's) that prompted health care providers to deliver preventive counseling or otherwise served as clinical decision support. Using data visualization tools, we generated maps that illustrate connections, or lack thereof, between clinical topics within CHICA's MLMs.
Conclusions: The development of such maps may allow multiple disciplines commonly interacting over EMR platforms, and various perspectives (clinicians, programmers, informationists) to work more effectively as teams to refine the EMR by programming logic routines to address co-morbidities or other instances where domains of medical knowledge should be connected.

* Corresponding author. Tel.: +1 (502) 852 3737; fax: +1 (502) 852 2203.
E-mail address: gil.liu@louisville.edu (G.C. Liu).
Peer review under responsibility of King Faisal Specialist Hospital & Research Centre (General Organization), Saudi Arabia.

http://dx.doi.org/10.1016/j.ijpam.2015.06.001

1. Introduction

The purpose of clinical decision support (CDS) is to provide information that improves health care decision-making. Examples of CDS tools include order sets created for particular conditions or types of patients; databases that can provide information relevant to particular patients; reminders for preventive care, and alerts about potentially dangerous situations. CDS can potentially lower costs, improve efficiency, and reduce patient inconvenience.

The refining of knowledge bases within clinical decision support represents a challenge of 'truth maintenance' [1]. Those developing the logic foundations of decision support programs for health care applications must construct computational models of clinical situations. To keep these models consistent with new knowledge, the reasoning programs frequently need to remove or update portions of their models. Truth maintenance involves determining the current set of beliefs from the current set of reasons, and updating the current set of beliefs in accord with new reasons in a typically incremental fashion.

We describe a truth management initiative that employs visualization tools to map computational models within an electronic medical record (EMR), the Child Health Improvement through Computer Automation (CHICA) system. The goal for mapping CHICA's computational models is to inform proactive initiatives to expand the knowledge base of CHICA's decision support system. The maps define geographies in which there are topic "continents" that indicate well connected clinical domains versus topic "islands and oceans." Knowledge islands may indicate scenarios where there is an absence of related content to support coordinated delivery of clinical services that should connected. An example of such connected services is how clinicians approach the diagnosis of obesity, the possibility of associated metabolic disorders (e.g. dyslipidemia, hypertension, insulin resistance), and the need to explore relevant health behaviors (e.g. exercise, diet). The development of such maps may allow multiple disciplines commonly interacting over EMR platforms, and various perspectives (clinicians, programmers, informationists) to work more effectively as teams to refine the EMR [2].

2. Materials and methods

CHICA is a decision-support and electronic medical record system for pediatric health maintenance and disease management [3–6]. The HL7 International (www.hl7.org) Arden Syntax for Medical Logic Modules (MLMs) is an ANSI-approved American National Standard language for encoding medical knowledge and representing and sharing that knowledge among personnel, information systems and institutions. CHICA uses a library of Arden Syntax rules that utilize existing patient clinical data to deploy patient screening instruments, as well as prompt health professionals to deliver specific aspects of care. CHICA also uses a global prioritization scheme to determine which information is most relevant for inclusion on forms printed for patients or health care providers. These various systems effectively constrain the number of topics that CHICA recommends to be addressed a feasible number for any given patient encounter.

In CHICA's Arden rules based syntax, there are stored observations contained in medical logic modules (MLMs). We assigned Medical Subject Headings (MeSH: http://www.ncbi.nlm.nih.gov/mesh) terms and Unified Medical Language System (UMLS: http://www.nlm.nih.gov/research/umls/) terms to 450 MLMs, taking into account the hierarchical nature of stored observations. We then created pivot tables that contained all categories of stored observations to analyze how observations were shared by MLMs.

We mapped relationships within CHICA's knowledge base using software for social network analysis: NodeXL by Cody Dunne and Ben Schneiderman at the University of Maryland (for more information, please see http://nodexl.codeplex.com) and CMAP (Florida Institute for Human & Machine Cognition, Pensacola, FL). Both knowledge visualization tools have multiple options for laying out diagrams — options were selected and chosen to optimize ease of visualization, incorporating factors such as readability and recognizability. We defined relationships by shared observations, such as two Arden rules that consider the same clinical observation, or by the presence of common keywords that were used to label rules according to standardized vocabularies.

3. Results

At the time of the mapping process, three hundred MLMs were actively storing observations in CHICA, and as a result, there were 170 unique variables. MLMs generate a range of one to five variables. The median number of variables per MLM is one, and the average number of variables per MLM is 1.5 (see Table 1). The number of MLMs referencing any single variable ranged from one MLM to a maximum of twenty MLMs. The median number of MLMs that referred to a specific variable was two, and the average number was 2.8 (see Table 2).

Using data visualization tools, we generated maps that indicate the geography of CHICA's MLMs consists primarily of islands. For example, evidence strongly supports grouping body mass index (BMI) screening, cholesterol screening, blood pressure evaluation, and counseling about

Table 1 Distribution of Medical Logic Module (MLMs) counts by number of stored observations within a single module.

Number of stored observations per MLM	Count of MLMs
5	5
4	13
3	17
2	76
1	189
	Total MLMs = 300