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Knowledge Management and Electronic Health Record Facilitate Clinical Support to Improve Healthcare Quality

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Abstract - **Background, Purpose & Methodology – Even though Healthcare (HC) is an expensive investment, its quality suffers today, due to lacking evidence-based clinical decision support (CDS) during patient-care. This theoretical research examines thoughts on knowledge management (KM), electronic health record (EHR), decision support system (DSS), clinical practice guidelines (CPGs) and ontologies to narrow the decision-making gap. Findings & Research limitations– This paper develops a pragmatic and strategically viable conceptual grounded in theory architecture model that needs testing in a real/simulated and transcultural HC environments. This model illustrates how EHR and KM facilitate DSS to effectively facilitate decisions making or CDS. Practical implications & Originality/Value – The expressed harmonious relation between KM and EHR is a relation that is under researched and hence a soft area of KM. Its absence is the reason for the costly medical errors that continue to raise HC costs today.**

Keywords- Healthcare Knowledge Management; Electronic Health Record; Personal Health Record; Clinical Practice Guidelines; Ontology; e-Health; Decision Support System; Clinical Decision Support.

I. Introduction

Healthcare (HC) professionals make decisions lacking in evidence and information, which result in medical errors and losses in patients lives. Electronic health records (EHRs) faciliate patient-centered decision-making. The next promising solution, which are CPGs, codify knowledge but do not translate knowledge to practice. EHR does not enable real-time access to such codified knowledge thus requiring decision-support capabilities to translate CPGs into practice. Hence EHRs can guide clinical decision-making. EHR and clinical decision support (CDS) fuse to facilitate where CPGs fall short [1]. Ontologies, work with knowledge management (KM), data exchange, semantic interoperability and decision support reasoning, facilitate huge data management and allow integration of EHR and DSS [2]. Data is warehoused in databases (DBs) and EHR. Information is based on evidence using DSS. Knowledge is facilitated by expert systems [3].

HC quality improvement initiative leads to personalized medicine where future HC strategies will rely on genomic technologies and molecular therapies posing challenges. HC quality is: (1) greater therapeutic options, (2) more effective and (3) precise patient care for individual patients, increasing knowledge and data. CDS. Since doctors cannot remain abreast with evolving knowledge of medication their decision-making must be facilitate by EHRs integrated with CDS, e.g.: e-prescription to prescribe medicine or order tests. Hence an EHR system can cross reference test results with prescribed medications to suggest evidence-based alternative evidence-based decisions. A patient can seek medical advice with past family disease history for precautionary reasons. The doctor can utilize patient family history in a personal digital assistant's software. EHRs with CDS risk predicting tools utilize pre-entered patient's family history by cross referencing it with external disease sources in order to suggest a patient to visit a doctor or to take precautions. This recommendation is based upon evidence-based practice guidelines [4].

II. Literature Review

Most frequent and ignored medical errors are diagnostic errors. Statistics state that 1 out of every 10 diagnoses in US are concluded wrong [5] costing $ 55.6 billion annually [6] while 40 out of every 100 Americans visit the emergency room (ER) where evidence-based and quick decision-making is very critical [7]. Most clinical decision-making lacks or is without knowledge. Clinicians are asked to: (1) gather and interpret information and (2) implicitly or explicitly bridge the daily inferential gap even when lacking evidence needed to reason a decision. An inferential gap is experienced between the scarcity of what is proven for a selected group of patients versus the ample and complex decisions required for individual patients. The wideness of this gap depends on factors like: (1) available knowledge and its relevance to decision-making, (2) what physician knows at the time to make a decision, (3) how knowledge is interpreted and translated to make a decision, (4) patient requirements, etc. The inferential gap can be narrowed by EHR since it: (1) facilitate daily knowledge creation for decision support and (2) increase daily access to required knowledge for practice [1].

A. EHR - History and Importance

Electronic patient record (EPR) got in demand to solve the high rate of medical errors [8]. EHR is a secure web-based patient health information (summary of bio data and care log history) record used by HC professionals and patients [9] holding patient's life-long electronic record composed of many EPRs of that patient while possessing evidence-based practice [10]. Case reports created clinical knowledge, evolved to observational studies that evolved in turn to controlled trials and finally to randomized controlled trials (RCT). RCT also was not sufficient since it was used for clinical knowledge creation to test treatment benefits for highly selected group with low comorbidity disease burdens. RCT was not suitable to address population-based questions for a wide group and sub-group of patients. Also with the US aging population, clinical decision-making becomes more intricate. The primary challenge is dealing with confusion, inherent in many clinical decisions, when a medical condition pinpoints a risky treatment; e.g.: disease severity influences treatment choice difficult to distinguish signs for a treatment versus risk/benefits associated with that treatment. Hence a new drug gets implicitly linked with the disease severity showing that traditional research designs are slow, expensive and limited. The solution - EHRs closed the inference gap by making patient-centered evidence-based treatment decisions by CPGs for individual patients. Newly emerging science will promote practice standards for interpreting EHR-based evidence. CPGs do not translate knowledge into practice. Hence, EHRs need to be fused with clinical decision-support technology to for effective CPGs [1]. EHRs facilitate HC quality improvement by patient data exchange and interoperable functions [4].

B. CPG –Importance and relation with EHR

CPGs are knowledge codifications facilitating quicker knowledge access by summarizing evidence (Downing, et al, 2009. They are also natural language document-based, patient-care specific medical evidence assisting HC professionals for decision-making. CPGs express processes like: (1) flow charts for algorithm-based problem solving, (2) disease-state map to illustrate concluded decisions (3) goal-meeting sequenced activities and (4) work-flow modeled care processes. Guidelines are related to EHRs because CPG specifies what data needs to be recorded when (i.e.: EHR content) and how to make decisions (figure 1). Here observations are observed diagnoses, goals and targets achieved to record clinical statements. Evaluation is analyzed, interpreted statement i.e.: recommended treatments and follow-up visits for recording into an EHR. Instruction directs a HC professional on what to do [11].

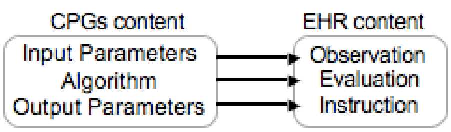

Figure 1. CPG informs EHR Adapted from - Barretto, et al, [11]

CPGs promote HC quality by improving patient care [12], capable of providing published information. A gap arises between this information and the necessary knowledge to implement guidelines in practice. Guidelines lack tacit knowledge needed for making effective decisions based on guidelines [13]. Even good CPGs do not facilitate practice hence is dependent on DSS tools [14]. CPGs gain importance because clinicians lack time to learn fraction of them. CPGs only represent knowledge but do not describe how to apply recommended tasks. Current EHRs do not enable real-time access to such codified knowledge thus need decision-support capabilities to translate CPGs into practice, via a rule engine, that can evaluate patient-related real-time data against rules and existing knowledge to recommend physicians what action to take. Therefore EHRs will guide clinical decision-making when multiple treatments simultaneously need decisions. In the face of uncertainty, EHRs randomize clinical decisions to evaluate outcomes accordingly by embedding a real-time protocol within a system to randomly prioritize a decision pathway over another, which is not possible via traditional RCTs or observational studies [1].

C. Ontologies fuse DSS with EHR

HC quality is improving by personalized medicine - focused on a unique patient's clinical information, genetic, genomic or biological characteristics to fuse disease understandings with individual facts to apply preventative HC strategies on patients with early disease stages. Future HC strategies will rely on genomic technologies and molecular therapies that will face challenges asking for CDS and requiring KM with EHR as a pre-requisite. EHRs also improve CDS element within EHR. CDS and personalized medicine are interdependent. CDS helps increase clinical decisions and accelerates knowledge development manageable by EHR systems. CDS assists in individualized patient management with genomic variables and cannot measure complex quantitative measurements. Personalized medicine can become a reality once it processes, collects and uses complex clinical information, for which CDS capable EHR infrastructure is required. CDS tools customize, filter and combine personalized information for HC providers complying with clinical practice guidelines to report timely and accurate diagnoses. CDS facilitates patients' decision-making and embed evidence-based practice guidelines to assess clinical outcome. CDS transparently integrates clinical variables, genetic tests results, and clinical documents to support evidence-based recommendations (Downing, et al, 2009). Since 19th century ontology existed in UK evolving from a classification of diseases. Ontologies, i.e.: systemized nomenclature of medicine – clinical terms (SNOMED/CT):

EHR standard terminology), LOYNC, FMA, Gene Ontology, RxNorm, the nation cancer institute thesaurus, international classification of diseases (ICD), and UMLS are a vocabulary source representing biomedical entities, their relations and terms. Ontologies play KM, decision-support and reasoning roles in decision support. Indexing for biomedical information retrieval uses UMLS and MeSH. Patients can search for physicians using SNOMED/CT. ICD. Document classification (i.e.: categorizing MEDLINE documentation) is possible by MeSH. Mapping identifies similar concepts clustered into concepts using UMLS across ontologies when ample ontologies become messy. SAGE maintains, shares and interoperates data in an EHR system to represent knowledge. Ontologies select, aggregate, support decision-making, process natural language and discover knowledge to support a decision [2].

D. Fusing EHR and DSS

Ubiquitous information is popular yet a challenge. It requires common standard terminology and utilizes cost effective information and communication technology (ICT). Hence a commonly sharable EPR architecture utilizes routine data for multiple purposes and clinical research. This architecture is made up of: (1) TMS - terminology management system, (2) data recording and management core system and (3) research-based modules for data recording and general tools. TMS, (figure 2) formally represents items with their corresponding answer options to make reference ontology available. These items are represented within the context of the research question to derive the research specific terminologies. Core system (independent application) works consistently with TMS's reference terminologies. This system implements a minimum basic data set for routine data. Then its functions manage, record and analyze data as per user's requirements on the data set. Module is a dependent data recording application. All its items are consistent with TMS's standard terminologies. This application can record data within its own DB. It extends data in the core system with data necessary for research question and hence not relevant to an institution or all patient but only those patients fulfilling selected criteria. Many modules can extend it. This module is inherent within the identification of a research question for which it answers and provides items. Then, this information is integrated by the core system. This system uses its functions to operate on core system and module's data so this data can be prepared for research purposes. Module generation tool generates modules, based on reference terminology and data provided by TMS. Module is registered in the core system, which is hence implementable in the medical center to transmit routine data to the research institute. The module is integrated in the core system. Automatically a relational DB is generated for modules as well as the research set.

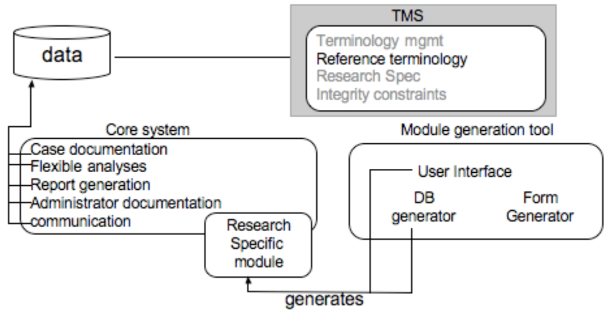

Figure 2. *Module* generation *tool and Core System Adapted from - Knaup, et al, [15]*

When all these EHR architecture components are integrated (figure 3) the following steps execute First, when a new research question is asked, the research institute needs to specify terminologies from TMS. Second, module generation tool accesses TMS and generates a DB for the research institute. Third, electronic case report forms get generated. Fourth, a module is integrated within the core system. Fifth, core system offers functionality to communicate and transmit routine patient data. Finally, the research institute analyzes the data to answer the research question [15].

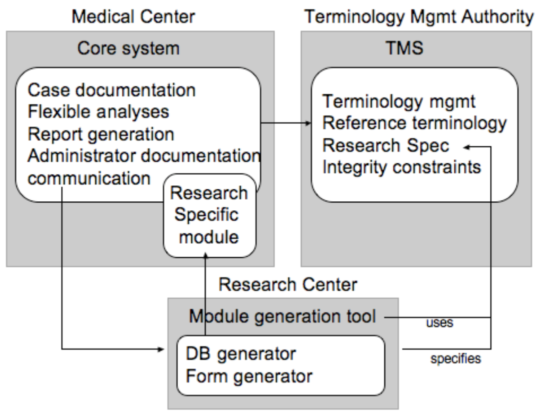

Figure 3. Corporation of all components of the EHR architecture Adapted from - Knaup, et al, [15]

E. Importance of KM in decision making

Much HC literature related to decision support does not show the importance of HC KM and its integration with CDS and EHR for decision-making. Organizations share knowledge to stay competitive. Senior management contributes to a knowledge-sharing environment applying tacit and explicit knowledge for problem solving. Researchers define knowledge as relevant information processed and power to act to make decisions. Information is relevant data analyzed and processed for meaning. Knowledge is either explicit or tacit. While explicit knowledge can be articulated and is inspectable, tacit knowledge resides within experts' actions and experiences and is not inspectable. In a knowledge hierarchy, data is required to create information, required to create knowledge. A knowledge creator sees knowledge necessary to create information, necessary to create data. The knowledge hierarchy is not always accurate since knowledge can be transformed from data rather than from information e.g.: an expert needs only tacit knowledge rather than also explicit knowledge to solve a problem. Data is also attainable directly from knowledge. Tacit knowledge exists everywhere [3]. KM is an interdisciplinary business model that manages knowledge through processes Wickramasingha, Gupta & Sharma [16] illustrated in figure 4.

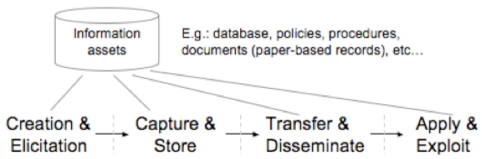

Figure 4. KM environment Adapted from - Wickramasingha, Gupta & Sharma [16] and Bose [17]

F. *Barriers and Significant Challenges*

CPGs represent knowledge but do not describe how to apply recommended tasks [1]. Moreover clinicians lack time to update their knowledge. On the other hand current EHRs do not enable real-time access to codified knowledge thus requiring decision-support capabilities to translate CPGs into practice, via a rule engine, that can understand patient real-time relevant data evaluated against rules and existing knowledge to recommend physicians what action they should take. This way EHRs will guide clinical decision-making [1]. There are barriers to ontologies being: (1) availability, (2) discoverability, (3) formalism, (4) integration and (5) quality - some ontology are poor in quality negatively effecting applications they support [2]. EHR has failed to quantify its impact on patients. HC institutions are comfortable using health IT systems (HIT). There is however CDS adaptation and use challenges due to its lacking incorporation with HIT. CDS are rapid and reliable but need to become a standard practice requiring standardization and interoperability. Since current EHRs come with proprietary applications, this slows down the gooks of CDS. Ample research is required before tools like EHR and CDS are incorporated to facilitate personalized medicine [4]

III. Methodology

The aim of this research is to investigate the effects and challenges that the current HC organizations face during applicability of EHRs, CDS, ontologies and CPGs. Firstly, we analyzed through a qualitative study the in-depth meaning, purpose, functionality and inter-relativity phenomenon between the concepts mentioned above. Secondly, we proposed a conceptual and practically viable integrated architecture model (figure 7) to express how KM can facilitate CDS along with EHRs. Our model narrows many above-mentioned barriers.

IV. Discussion

Literature that suggests that clinical decision support systems can solve clinical problems when making decisions falls short to emphasize that knowledge and not only information facilitates medical decision-making. Data is analyzed to make useful information. Information is utilized to improve knowledge to make better decisions. Figure 5 below illustrates the relation between information and knowledge. Ontology can be used to manage huge amounts of data and also link EHR with DSS since ontology holds terms and vocabulary referencing. Therefore ontologies link EHRs with DSSs [2]. The EHR architecture in figure 3 supports: (1) how ontologies bind EHR and DSS and (2) + combines EHR and DSS to facilitate CPG [15].

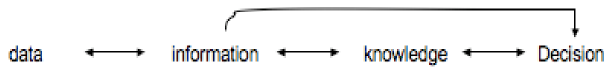

Figure 5. Relationship between data, information and Knowledge

CDS follows key steps for information development (figure 6) so CDS facilitates personalized medicine. This framework shows clinically applied EHR technology used to continuously flow information from evidence development (bases for personalized medicine) attained from population-based longitudinal studies and research studies (e.g.: RCT). These two inputs are bases for algorithms and recommendations that are then integrated in proactive guidelines that are then inputs for: (1) CDS tools integrated with knowledge base for recommendations making rules for individualized decision-making and (2) measuring quality of compliance with medical recommendation and decision making [4].

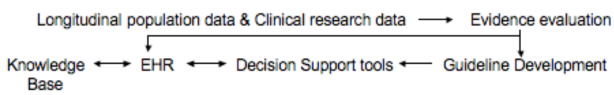

Figure 6. Corporation of all components of the EHR architecture

V. Proposed Solution

CPGs are facilitated by DSSs that store information facilitated by EHRs that house patient data. DSS supports HC professionals by providing them decision-making information. However it is knowledge (i.e.: know-how, know-who, etc.) that HC professionals need to take a decision. Literature describing DSS solutions fails to emphasize the importance of knowledge and KM. Since as mentioned in this paper EHR facilitates KM to facilitate personalized medicine, figure 7 is emended to fuse with the KM model and the EHR architecture.

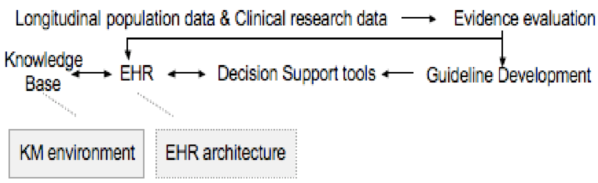

Figure 7. KM and EHR facilitate CDS

The above-proposed architecture shows how HER and KM facilitate CDS that is facilitated by guideline development. The KM environment creates, elucidates, captures, stores, transfers, disseminates, applies and exploits knowledge that is processed from data within EHR architecture. This model narrows earlier mentioned challenges and gaps. Even though CPGs only represent knowledge, they do not describe how to recommend tasks. CDS facilitates CPGs by providing supportive recommendations and knowledge is represented in CPGs that can be managed by KM tools that warehouse knowledge in a knowledge base. EHRs allow access to data transformable to information and/or directly to knowledge where information is facilitated by CDS and knowledge is management though KM tools. A common standard for ontologies needs emphasis so EHRs, CDSs, KM tools and CPGs will integrate and interoperate together.

VI. Conclusion

The architecture model (figure 7) shows the importance of KM to support decision-making. Decision-making is not enough by just DSS facilitating information portrayed for decision makers in form of reminders. CDS needs to assist HC professional make quick evidence based decisions. Decisions are not made just on EHRs or just DSSs. Any decision maker needs information that fuses with a decision maker's prior knowledge (tacit and explicit). Information is only explicit. Experience of a decision maker is knowledge hence proving that knowledge also needs to facilitate DSS. In addition the architecture model is an integration of EHR architecture (figure 3) and KM environment (figure 4).

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