In 14th IEEE Symposium on Computer Based Medical Systems (CBMS'2001), 26-27 July, Bethesda (USA).

A Case for Supplementing Evidence Base Medicine with Inductive Clinical Knowledge: Towards a Technology-Enriched Integrated Clinical Evidence System

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Abstract

Clinical evidence exist in modalities other than published clinical literature, such as clinical data ranging from patient clinical profiles to clinical trials; clinical experiences of eminent medical practitioners; and medical knowledge bases encapsulating knowledge about patient care, healthcare guidelines and protocols, clinical workflow and so on. We propose a technology-enriched strategy to exploit advance computer technologies—Knowledge Management, Data Mining, Case Based Reasoning Strategies and Internet Technology—within traditional Evidence Based Medicine systems to derive all-encompassing clinical evidence derived from heterogeneous clinical evidence modalities. The paper features a conceptual overview of an Integrated Clinical Evidence System designed to augment the typical literature-based clinical evidence with additional technology-mediated clinical evidence.

1. Introduction

Evidence Based Medicine (EBM) is best described as "the explicit, judicious and conscientious consideration of current best evidence from research in making decisions about the care of individuals patients. The practice of evidence based medicine means integrating individual clinical expertise with best available external clinical evidence from systematic research" [1]. *Prime facie*, clinical evidence exist in different modalities—research findings from clinical trials published in medical journals/conference proceedings and citation indices, clinical experiences of healthcare professionals, medical data originating from clinical trials and research programs, best practices guidelines, textbooks, healthcare protocols and medical knowledge bases to name a few sources. Yet we note that present EBM systems tend to procure clinical evidence mainly from traditional sources, such as research findings reported in medical journals, citation indexes (such as ISI Science Citation Index), MEDLINE (now available over the Internet through PubMed which supports clinically oriented search filters) and *Meta-Analysis* resources [2]. Technical advances in the realm of EBM are also in keeping with the traditional model of EBM procurement and delivery, with research efforts focusing on improving (i) remote access services, (ii) search facilities for focused selection, (iii) retrieval speed, (iv) quality of consolidated summaries and (v) corpus size of clinical literature and so on.

Despite the heavy reliance of EBM systems on published clinical evidence, there is a growing realization that "not all types of published evidence containing pieces of information carry the same weight" [3]. What is implied here is that published clinical evidence is not necessarily comprehensive when it comes to providing 'holistic' diagnostic support to healthcare practitioners. This situation provides the rationale to evaluate the utility of alternate sources of clinical evidence to derive '*holistic*' and '*all-encompassing*' clinical evidence for broad-base diagnostic support. By holistic clinical evidence we mean collective multi-faceted clinical evidence derived from diverse clinical evidence resources and modalities. Our contention, therefore, purports a paradigm shift from consolidated summaries of published medical literature to clinical evidence derived by advance deductive and inductive techniques applied to diverse clinical evidence resources such as (i) clinical data ranging from patient clinical profiles to clinical trials; (ii) clinical experiences of eminent medical practitioners; and (iii) medical knowledge bases encapsulating knowledge about patient care, healthcare guidelines and protocols, clinical workflow and so on. We note that from a technological perspective the practicality of the said paradigm shift is quite feasible in line with the emergence of various data- and knowledge-centric computer technologies, such as *Knowledge Management*, *Data Mining*, *Artificial Intelligence*, *Intelligent Agents* and so on.

To address the need for 'holistic' clinical evidence, in this paper we propose a technology-enriched strategy that dictates the procurement of holistic clinical evidence from heterogeneous clinical resources by leveraging a combination of advance computer technologies. The proposed strategy intends to *augment* the traditional literature-based clinical evidence model with additional technology-mediated clinical evidence derived from diverse clinical evidence modalities such as clinical data, information and knowledge (bases) [4].

2. Architecture of a technology-enriched EBM system

In this paper we present the functional blueprint of an 'experimental' *Integrated Clinical Evidence (ICE)* System (Figure 1), that leverages alternate clinical evidence resources to both derive and deliver (over the Internet) hitherto unutilized and implicit clinical evidence to healthcare professionals. We believe that there exist the possibility for extending the functionality of EBM systems via the strategic incorporation of advance computer technologies pertaining to medical information collection, operationalisation, dissemination and diagnostic support. Henceforth, we have designed a technology-enriched architecture that manifests the systematic combination of advance computer technologies, such as *Knowledge Management*, *Data Mining*, *Case-Based Reasoning* (CBR) and *Web based systems*, for augmenting the functional scope of existing EBM systems. The proposed utilization of diverse computer technologies within a unified EBM framework is anticipated to provide a value-added functionality to cater for the diverse modalities of clinical evidence resources. The correspondence between the functionality of aforementioned computer technologies and the modality of the clinical evidence resources is as follows: (a) medical ***Data*** can be operationalised using Data Mining techniques; (b) clinical experiential ***Information*** can be manipulated using artificial intelligence oriented CBR techniques; and (c) medical ***Knowledg***e can be utilized using Knowledge Management techniques. In essence, the cumulative functionality of the ICE system, derived from a set of technologically diverse components, provides diverse perspectives of clinical evidence which when synthesized

(or viewed in tandem) can yield the so-called 'all-encompassing' clinical evidence. Architecturally, the ICE system comprises four functionally independent modules (see Figure 1):

1. *Search Engines*: To provide medical literature-based clinical evidence.
2. *Data Mining Info-Structure*: To derive clinical evidence from clinical data.
3. *Case-Base Reasoning System*: To validate a current diagnostic hypothesis using past and proven clinical cases (representing the problem-solving strategy of medical experts).
4. *Medical Knowledge Memory*: To derive clinical evidence from medical knowledge bases, storing volumes of medical knowledge, and ontologies.

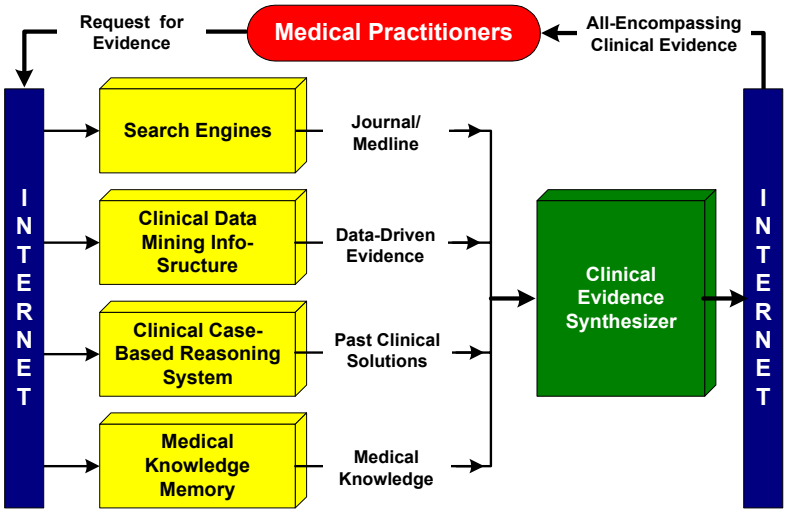

Figure 1. The architectural and functional overview of the ICE system

3. Functional overview of the ICE system

In a functional parlance, the usage of the ICE system is quite similar to that of traditional EBM systems, for instance: (1) framing of the clinical problem to be addressed; (2) presentation of the formulated problem to the ICE system; (3) collection/derivation of clinical evidence from diverse sources; (4) synthesis of the collected evidence (in a systematic manner); and (5) reporting the consolidated 'holistic' clinical evidence to the healthcare practitioners, possibly over the Internet.

In the below discussion, we will provide a brief overview of functionality of the independent modules of the ICE system. The architectural details of the same are beyond the scope of this paper and will be presented in a separate publication.

3.1. Data mining info-structure

In the realm of the ICE system, a data mining info-structure (see Figure 2) can be designed to provide a data-centric perspective of clinical evidence that is inductively derived from volumes of medical data [5]. Structured clinical trials produce volumes of data that implicitly withhold quite useful clinical knowledge which can ultimately serve as useful clinical evidence. The use of advance data mining techniques can yield clinical evidence in terms of complex association rules between various data elements, multiple combinations of data elements that jointly influence a given list of outcomes, clusters of similar data items, most significant features impacting a particular outcome,

classification of data elements into known categories, sequential patterns, predicted (future) values of certain data elements based on past values and so on. More attractively, the derived clinical evidence can be presented using sophisticated data visualization techniques, so as to make it easier for healthcare practitioners to readily utilize it for diagnostic purposes.

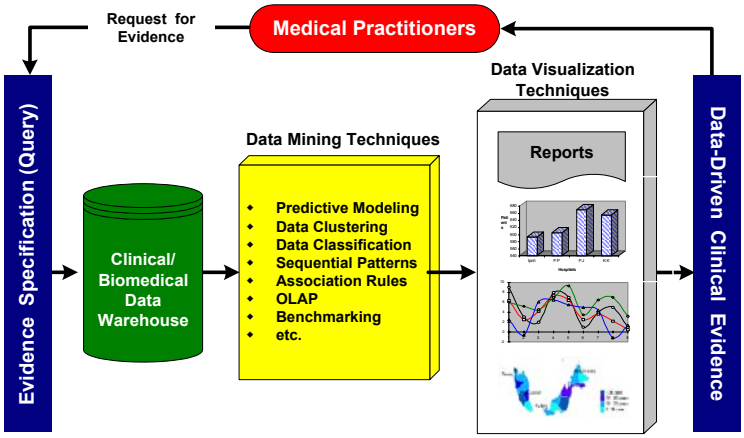

Figure 2. The proposed data mining info-structure

3.2. Case based reasoning system

In the realm of the ICE system, a Case Base Reasoning System can offer the functionality to manipulate past clinical experiences of eminent medical experts to derive an experience-oriented perspective of clinical evidence (see Figure 3). The kind of clinical evidence provided by the Case Base Reasoning System is intended to be utilized as a pro-active 'diagnostic critique', whereby clinicians can instantly refer to an ensemble of past similar solved cases, either to confirm their hypothesis or seek solutions that are known to have worked in the past. Functionally, the proposed Case Base Reasoning System will be driven by driven by a request (for evidence) by a clinician. The Case Base Reasoning System will (a) retrieve a set of similar past cases (which can be introspected in detail by the healthcare practitioner) from the library of clinical cases; next (b) intelligently synthesize the solutions of all the retrieved past cases to prepare a 'meta-solution' for the given clinical case; or (c) intelligently adapt the solution(s) of similar past clinical case(s) to suggest the most amicable, experimental clinical evidence for diagnostic support purposes [6].

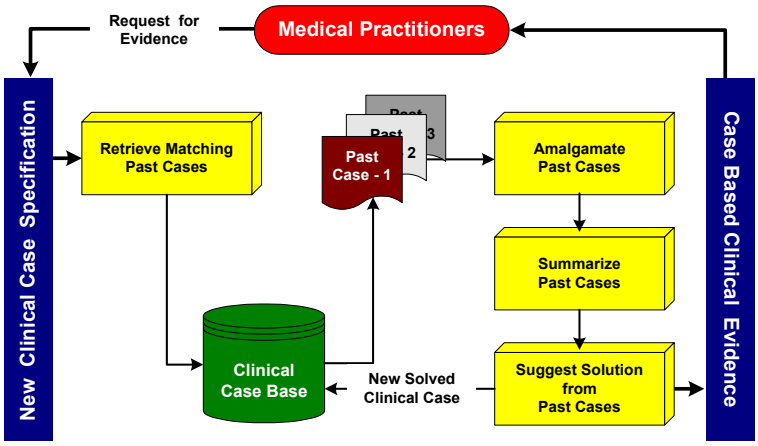

Figure 3. The proposed clinical case based reasoning system

3.3. Medical knowledge memory

The *Medical Knowledge Memory* manifests a knowledge-theoretic environment—a repository of all-encompassing medical knowledge, know-how, protocols, process workflows and lessons learnt—that is supported by Knowledge Management (KM) technology (see Figure 4). Put simply, the incorporation of knowledge management tools and techniques facilitate the creation, identification, acquisition, development, dissemination, utilization, and preservation of an (healthcare) enterprise's knowledge[7].

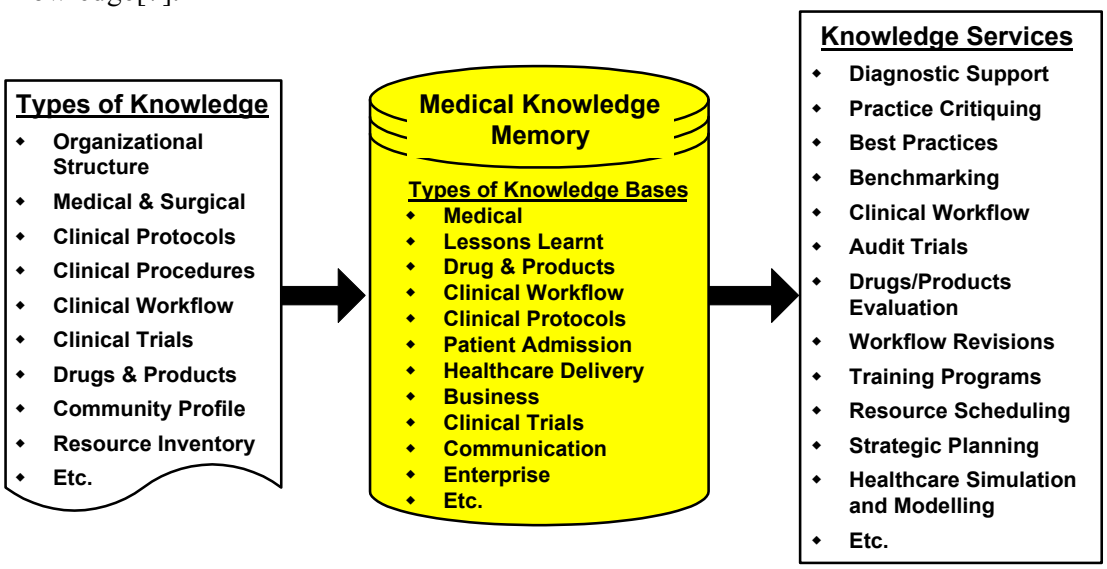

Figure 4. The proposed medical knowledge memory: Illustrating the types of knowledge, knowledge bases and services derived from the medical knowledge memory.

In the realm of the ICE system, the Medical Knowledge Memory can lead to knowledge-oriented perspectives of clinical evidence by providing a number of knowledge-driven diagnostic-support services, such as the dissemination of medical knowledge and experience, transformation of clinical information to clinical practices and above all *clinical modeling* [8]. Of particular interest to clinicians will be the provision of 'on-the-spot' healthcare modeling facilities, which basically entails the development and simulation of *clinical process models* (addressing a specific goal). To acquire an understanding of the outcome of a particular procedure under varying conditions, clinicians may submit different (experimental) values to the various parameters of the clinical model and note the influence of the parameter's values towards the efficacy of the procedure/process being modeled. Vis-à-vis, EBM the value-added aspect of such a clinical model is that it is derived from the manipulation of vast medical knowledge contained within the Medical Knowledge Memory. Hence, the clinical modeling outcome can be deemed as being informed, context sensitive and aware of relationships between disparate knowledge entities. Figure 4 shows the various types of (a) knowledge that can be captured from the medical environment, (b) knowledge bases, and (c) knowledge-driven clinical evidence that can be derived from the so-called Medical Knowledge Memory.

4. Discussion—The way forward

Indeed, the healthcare enterprise is data-rich, information-rich and knowledge-rich. This realization leads to a number of telling issues in the realm of EBM—i.e. how can we harness this (evidential) wealth in routine clinical (diagnostic) practices; how can we extend the scope of clinical evidence; how can we get diverse perspectives of clinical evidence; how can we integrate diverse modalities of clinical evidence; and how can we translate consolidated clinical diagnostic evidence into evidence-driven diagnostic practices. All these are intriguing issues whose solutions are vehemently sought by medical informatics researchers—the emergence of meta-analysis [2] is a case in point. We believe that our proposed technology-enriched strategy to be one of the many ways of answering the aforementioned issues. Our approach of harnessing holistic clinical evidence for diagnostic support is an attempt to charter a pragmatic path from clinical evidence to clinical practice. Furthermore, the specifications of the ICE system can serve as building blocks for creating evidence-based clinical decision-support systems. But, on a cautious note, we do realize that the ideas presented here need further crystallization and their efficacy can only be ascertained once the ICE system is fully implemented, operationalised and validated by healthcare practitioners.

To conclude, we argue that the way forward in the practice of EBM is to leverage upon a confluence of computer/information technologies to acquire a holistic perspective of clinical evidence. Perhaps, this may instigate a paradigm shift whereby we will be required to venture with novel and untested methodologies in order to work towards the realization of innovative, all-encompassing EBM systems and solutions.

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