Building a Smart Assistant for Improving Chronic Pain Management in Primary Care

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Abstract

Chronic pain is affecting a growing populations around the world as a result of global aging. The need for chronic pain specialists and care providers has posed great stress on hospitals. The use of health information technology has relieved many laborious work and the rise of artificial intelligence in medicine is producing its promising impact. Primary care physicians are regarded as one of the first lines of defense in pain care. The efficiency in primary care has a significant effect on the overall healthcare outcomes. However, the inadequate pain management training and support for primary care physicians have limited their ability to deliver quality care. And the lack of professional guidance and effective assistance prevent them from providing in time coordination and first care. The mission of our research is to build up a smart assistant to optimize the quality of chronic pain management in primary care, in order to increase the opportunity of shortening treatment cycle and achieving better final results for patients. Following the usability criteria and pain management guidelines, our smart assistant is designed and implemented with the participation of pain specialists and potential end users. It involves the necessary functionalities in primary care settings to support primary care physicians to manage chronic pain more easily and safely.

Keyword: chronic pain management, health information technology, decision support system, machine learning, user-friendly system design.

I. Introduction

As a result of global aging, chronic pain is becoming prevalent in many countries at an alarming rate [11,12,13]. Chronic pain — pain lasting for at least three months or more — has now been considered by experts as a disease [14]. The demand for chronic pain management is over-burdening pain specialists and clinicians. It is reported that chronic pain affects more Americans than diabetes, cancer and heart disease combined [10]. As many as one in four people in the United States lives with chronic pain. Specialist care is often required for effective intervention as chronic pain is a complicated problem to manage. Such complexity often manifests as the physiological and psychosocial changes that occur in the long-term pain [15]. To achieve effective management for that, a multidisciplinary treatment is often the most appropriate strategy with support from the coordinated care of the management team.

The first step in pain management is scheduling an appointment with your doctor to determine pain causes and learn which pain management approach is the most effective to manage it. These doctors are often scheduled through primary care physicians (PCPs). Primary care physicians are trusted and regarded as one of the first lines of defense in pain care. They are responsible to refer patients to a variety of specialists and coordinate care with specialists accordingly. Since PCPs work with a consistent patient base, guiding individuals through multiple instances of pain or disability, they have closer relationships with patients than specialists do. This can contribute to greater knowledge about each patient, better communication and increased levels of trust [6].

However, PCPs are disadvantaged by limited access to pain specialists, and inadequate pain management training and support [9]. They are highly trained on a wide variety of conditions and health issues, but there are areas in which their training differs from that obtained by specialists. These areas include the advanced multidisciplinary therapies or medications for pain management, where the professional knowledge and training are not adequately supported. Understandably, many primary care physicians don’t feel adequately prepared to manage pain. In fact, in a survey of 500

PCPs, only 34% reported feeling confident in treating people with chronic pain [7]. A 2011 report from the Institute of Medicine recommended that "primary care physicians – who handle most frontline pain care – should collaborate with pain specialists in cases where pain persists" [8]. This is urgent especially when they are dealing with long-lasting pain or pain that are difficult to treat. Nevertheless, training primary care physicians the same way as specialists is almost impossible and requires much resource and funding. There is a need of assistantship for those care providers to deliver appropriate first care and even quality care as much as possible in a convenient way.

We can mitigate this dilemma with the advantages of computer technology. The safety and quality in primary care can be ensured and improved by equipping a smart assistant that can advise PCPs with the knowledge of pain specialists. Therefore, our research aims to design and build up such a smart assistant system to help primary care physicians improve their ability to deliver quality care upon the first step of pain management. With such assistant tool, we can help existing healthcare teams to achieve best possible outcomes in pain management by optimizing the quality of coordinated care between primary care physicians and pain specialists. In summary, our contributions lie in following aspects: 1) raise a critical problem existed in the primary care of pain management and propose the solution of using health information technology; 2) review and summarize the related literature of chronic pain management and health IT systems hitherto; 3) propose an approach of employing the advanced technology of software engineering and display the overall architecture of the smart assistant system with each scalable module explained in detail; and 4) list out the promising research plans that will improve the smart assistant to deliver better and more quality support for primary care on chronic pain.

II. Literature Review

Chronic pain is not easy to resolve due to its variety in patients and changes that exist in the long-term battle. As a solution, multidisciplinary treatments are often employed to adapt to patients individually based on their treatment goals and health conditions. Such multidisciplinary approach is

often practiced in hospitals and rehabilitation centres and often requires a management team to collaborate with each other. The best treatment outcomes cannot be achieved without the ensured quality of coordinated care among team members. And this optimization should start from primary care settings, which is the first line of management workflow. Health information technology has been implemented as a variety of applications and systems for a long time. They mainly serve as tool for managing medical health records and decision support system for a specific task of diagnosis. The potential impact of health information technology is arising along with the wave of artificial technology. It is meaningful to apply the advanced computer technology to healthcare in time.

A. Pain management in medicine

The treatments for chronic pain are as diverse as the causes. The most appropriate pain management method for a patient depends on several factors: pain level, how it affects your life, treatment goals, overall health condition, and the actual cause of your pain [15]. The method mainly include medications to manage pain (e.g., analgesics and opioids), physical therapy and psychological therapies. Medications have long been the main approach to cope with chronic pain. The dose of medicine may depend on individuals. While chronic pain medication can be effective and important for pain management for many people, it is not the only option available for pain treatment and may potentially raise side effects [16]. There are no good studies on using medications for long periods of time for the treatment of chronic pain yet. Physical therapy is a very important part of any pain management program and can be highly effective for all types of chronic musculoskeletal and neuropathic types of pain [18]. Pain can be worsened by exercise that is not done correctly (or interpreted incorrectly as pain rather than overuse), and a physical therapist can tailor the right exercise regimen for you. People who are fearful of pain, depressed, or anxious may experience pain differently, and perhaps more severely, than someone who has pain but is not experiencing other emotions. Therefore psychologists come to help patients cope with those thoughts, feelings and behaviors that accompany chronic pain [17].

However, no single technique is guaranteed to produce complete pain relief. Relief may be found by using a combination of treatment options to resolve chronic pain. This is widely known as multidisciplinary pain programs. A recent review of medical studies found that multidisciplinary pain programs are far superior to standard medical treatment [19]. Evidence is building that patients with fibromyalgia or chronic back pain in particular benefited greatly from a multidisciplinary approach [19].

Members of a multidisciplinary chronic pain management team often include: primary care physician; physician pain-management specialists such as neurologists, rheumatologists, orthopaedists, physiatrists, anaesthesiologists, and psychiatrists; physical and occupational therapists who can help guide your recovery and rehabilitation; psychologists who can help you deal with the emotional and mental aspects of pain management; registered nurses who can aid your day-to-day pain treatment; case managers who can help keep all the different pain management efforts organized and coordinated. These pain management specialists work together to coordinate patient care. Each reviews patient progress and communicates with others on the team on a scheduled basis about individual patients and their pain management.

B. Health information technology and applications

Health information technology (health IT) is the application of information technology to healthcare in the broadest sense. A 2008 study about the adoption of technology in the United States, Furukawa, and colleagues classified applications for prescribing to include electronic medical records (EMR), clinical decision support (CDS), and computerized physician order entry (CPOE) [23]. Health IT systems are not absolutely implemented from scratch. In fact, they can involve both computer hardware and software that deal with the storage, retrieval, sharing, and use of health care information, health data, and knowledge for communication and decision making [24].

Electronic medical record (EMR) systems are to create and manage the database that digitalizes patient ‘s histories, diagnoses, treatments, medications and more. These systems can

also alert you when patients are due for preventive procedures and screenings. In addition, EMRs help physicians treat patients by looking at their history and comparing their health data against past entries. Examples are using a touchscreen EMR system to record data in the processes of patient care [22] and combining different clinical EMR systems to identify a specific type of diabetes [23]. A study on how electronic medical systems transform health care reported that such applications eventually saved more than $81 billion annually by improving health care efficiency and safety [20].

Clinical decision support systems are designed to provide physicians and other health professionals with assistance on clinical decision-making tasks at the point of care. Since they mainly deal with clinical diagnoses, event reminding, care planning etc., they are the major branch of health IT that are combined with artificial intelligence. CDSSs were expected to make decision for clinicians in the early days. However, the effectiveness was evaluated to be varied from task to task and still remains plenty of room for improvement [25]. This can be achieved through either completing the knowledge base that guide the formulation of diagnoses results [26] or optimizing the machine learning algorithms that conclude patterns from clinical datasets [27]. Both approaches have advantages and disadvantages. The former knowledge based CDSSs are able to explain on decision results with prior rules but can easily fall into the bias of human knowledge. The later non-knowledge based CDSSs, in contrast, eliminate the need for inputting rules but rely on big dataset to make data-driven decisions and they also cannot explain on their decision results due to the limitations of machine learning algorithms. It finally comes that choosing which type of CDSS mainly depends on what clinical resource you have before designing a suitable one for practical use. For example, when the dataset is sufficient and the task requires preliminary exploration, then the machine learning approach is advanced for that. If the dataset is small while the task requires explicit disambiguation, then following the expert rules are practical.

Computerized physician order entry (CPOE) is a process of electronic entry of medical practitioner instructions for the treatment of patients (particularly hospitalized patients) under his or her care. It basically serves for orders transferring across departments to improve the efficiency of medication process. CPOE used to be sold as stand-alone products but now mostly are equipped with EHR. However, implementing a CPOE system costs a lot of money and maintaining it requires a lot more [29].

There have been many applications developed for medical practice use. Unfortunately, poor clinician usability has proven to be a barrier in the uptake and success of many health information technologies, including CDSSs [3]. This usability is commonly verified from learnability, efficiency, effectiveness, usefulness, accessibility and user satisfaction. Poor usability and high complexity can be quite a big gap in primary care settings as most care providers lack a professional knowledge system with respect to the pain causes and/or appropriate therapies.

In summary, health information technology have been implemented as a variety of applications and systems to help doctors and institutions manage laborious work and improve efficiency [4]. However, none of them have the ability to transfer across medical disciplinaries and many are difficult to integrate with each other due to their stand-alone operations. This especially poses a challenge when deploying a healthcare system in the chronic pain management where multidisciplinary treatments are employed. For example, research on health IT for chronic pain tends to focus on specific body regions, among which low back pain received the most attention. These separate machines are hard to integrate together for the use in primary care because they require different inputs and operations which are quite time-consuming and difficult for training. This doesn’t mean that every medical system should start from scratch. Instead, we should adopt the successful ideas, employ the advanced technology and especially pay attention to the practical needs of doctors and hospitals. A successful CDSS and EHR integration will allow the provision of best practice, high quality care to the patient, which is the ultimate goal of healthcare. Dealing with chronic diseases like chronic pain

needs repeated cooperation between departments and the diversity of decision support in case of the individual characteristics. Finally, the user-friendliness should be considered to ensure the system is accessible and convenient for practical use.

III. Building a Smart Pain Assistant in Primary Care

The challenges in clinical healthcare applications are known to be not reliable enough for the diagnostic results and in some situations the implemented systems are not easy to use. What's more, the limitations of deployment and scope make it difficult to integrate those systems to form a whole fluid workflow. Therefore care must be taken by the institutions equipped with health IT supported systems to ensure that these systems have become a fluid and integral part of the clinical workflow [26]. Although there have been much research work done for EHRs, CDSSs and CPOE respectively, few are able to be incorporated into an entire system due to their ignorance of other parts of the workflow during implementation. There lacks such a system that can provide holistic assistance instead of switching between stand-alone applications for clinical physicians without disrupting the workflow. In addition, when it comes to dealing with chronic diseases like chronic pain, a slightly different consideration should be taken about the gap between health IT functionality and the practical needs of chronic disease providers [28].

Following the usability criteria and pain management guidelines, our smart assistant is designed and implemented with the participation of pain specialists and potential end users. It involves the necessary functionalities in primary care settings to support primary care physicians to manage chronic pain more easily and safely. We designed the informatics module using a relatively flat EHR structure to facilitate full adoption of informatics for primary care physicians. As many healthcare systems have re-examined to be poorly reliable due to variations of patients and irrelevant information [4], our assistant tries to provide a diverse range of recommendations with underlying explanations to enrich the choice of chronic pain treatments and facilitate their adoptions. It utilizes

expert knowledge to assist primary care clinicians in a user-friendly and accessible way and enable them to deliver better quality care to patients at the point-of-care.

In the following subsections, we describe in detail about the designed modules of the smart assistant for chronic pain in primary care from bottom to up.

A. Smart Documentation

Electronic health records are the way of the future for healthcare industry. They are a way to capture and utilize patient health information to provide high-quality patient care, ensuring efficiency and effective use of time and resources.The smart documentation module allows information transfer and merge across multiple departments to form the EHR of chronic pain. It builds an information bridge for a team of chronic pain management to enable maintaining the EHR efficiently in an organized way. A clinical decision may utilize an enormous range of potentially relevant data. For example, an electronic evidence-based medicine system may potentially consider a patient's symptoms, medical history, family history and genetics, as well as historical and geographical trends of disease occurrence, and published clinical data on medicinal effectiveness when recommending a patient's course of treatment.

Information asymmetry is ensured by allowing care providers and physicians to either record or retrieve patient data via this interface. This means that they can focus on their own work without making extra efforts for information integration. Considering the longitudinal care on chronic pain will highly depend on patients’ histories, the smart documentation also allows tracking their past medications or therapies taken. These characteristics cater to the practical needs exist in the chronic pain management and also pave the way for longitudinal clinical research.

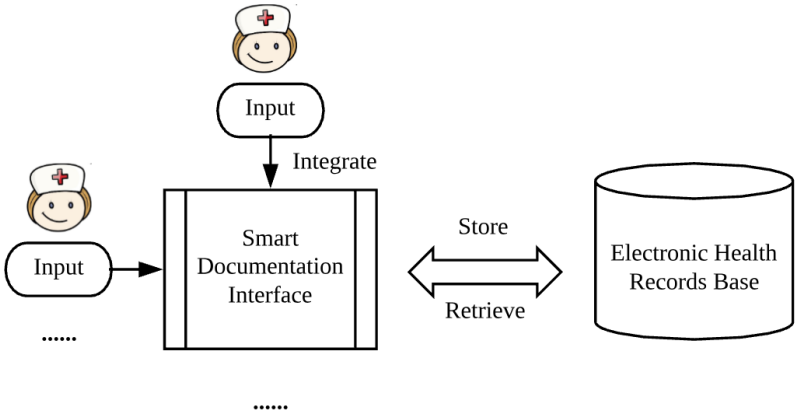

Figure 1 Smart Documentation Interface Design

B. Preliminary diagnosis

The preliminary diagnosis upon the patient health records is achieved based on an expert knowledge base that contains guideline practices. The knowledge base is arranged by a set of IF-THEN rules. The diagnosis tasks involved in chronic pain management differ from those discriminating positive from negative such as cancer diagnosis. In fact, treatments on chronic pain take an overall consideration on a list of diagnostic results. For example, a psychologist will pay attention to patient education, pain interferences on life, patient acceptance on pain, their depression symptoms and more. Such practical needs inspired us to create a dashboard of different diagnostic results for each pain specialist. Each diagnostic result is listed on a panel with its quantitative scales on the back, creating better understanding for primary care physicians. Allowing physicians seeing what is happening behind these data will facilitate better adoption of the recommendations.

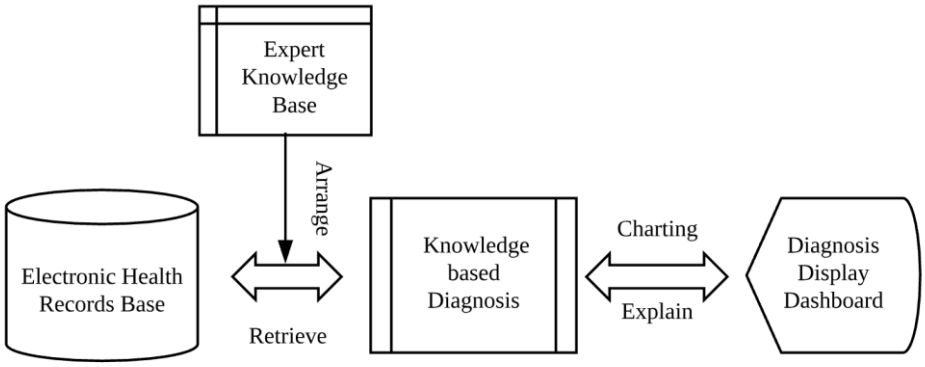

Figure 2 Diagnosis Flowchart

C. Clinical Decision Support

A lot of CDSSs have been implemented for event-driven alerts or reminders though many of them fell into low credibility due to high-frequency errors made. In pain management practice, things are a bit different. Patients who come to seek help have caught up with pain aches. The thing that doctors can do is to relieve their pain safely and guide them to kill chronic pain as soon as possible and avoid relapse. Therefore, the big task of decision support for clinical pain physicians is to draw up treatments from relevant cases for them to refer to. Another roadblock in pain management decision support is that the treatment strategy highly depends on patient's physiological and psychological conditions. That means patients under different health conditions may receive the same prescriptions. This makes it difficult for a machine to make decisions in the most time. One way to resolve this problem is using machine learning model to train out the effective representations that contain the similarity and dissimilarity information from EHR features.

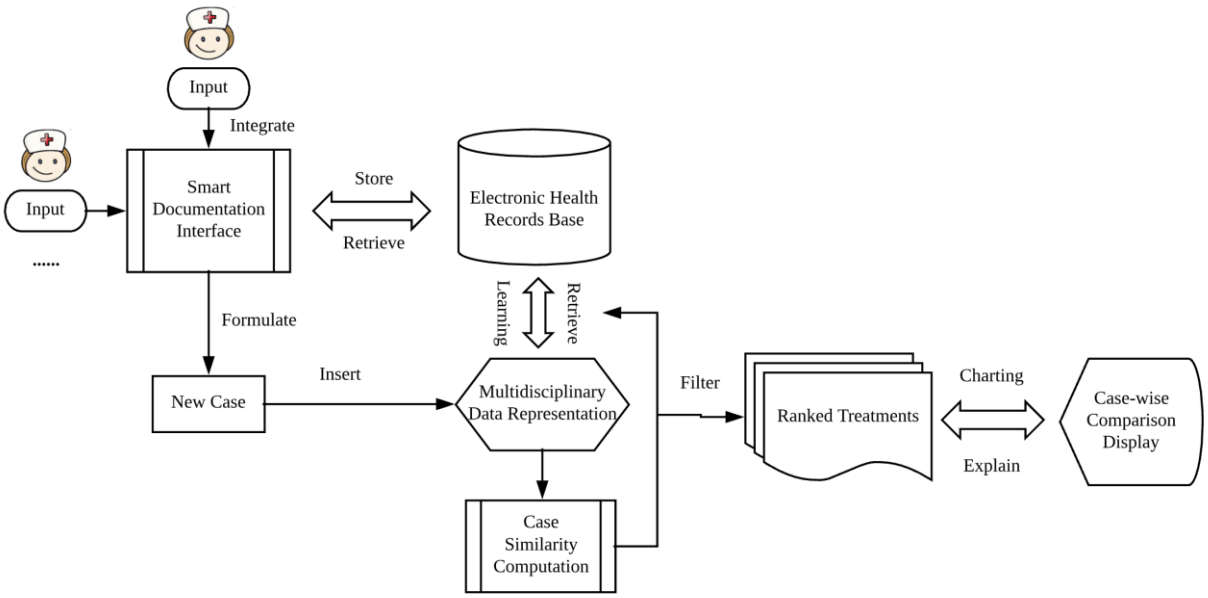

Figure 3 Clinical Decision Support Flowchart

Our clinical decision support module comes after the understanding of the preliminary diagnosis on the chronic pain conditions. The inference engine behind this module is a

machine learning model, which produces a vector representation of the EHR data as well as the preliminary diagnosis and output a table of recommendations about how to manage the chronic pain patients. It composes two parts: 1) a table displaying the relevant treatments from EHR ranked by the similarity between the new patient and those patients on record and 2) a pair-wise comparison panel displaying where the similarity is and how they were managed. This explores a way for primary care providers to learn from pain specialists based on case analytics. What's more, their understanding of the case analytics help to better adopt and combine the recommended chronic pain treatment to make their own prescriptions. Apart from the recommendations based on a whole perspective on the pain indicators, the module also allows the primary care providers selectively rank the EHR in cases when they only need to focus on specific symptom and manage it.

D. Flexible Scheduling

Scheduling an appoint with pain specialists is also an inevitable task for primary care physicians. In the past, pain physicians tend to make appointment for every patient as they are unable to deliver expert care to them. As a result, the waiting list for a pain specialist is always very long though many patients may actually only need minimal care. With the impact of the decision support functionality, the scheduling can be flexible based on how confident the physicians are about their first care treatments. This releases the stress of pain specialists and leaves room for quality improvement on primary care.

IV. Future Work

There are lots of needs exist in medical community where the efficiency and safety are the two main concerns. Although there have been many research done for improving the quality of care by utilizing a wide range of advanced computer and information technology, it is still a long way before reaching the ultimate goal of healthcare. We have proposed a solution and a system design for

resolving a practical need in the primary care for chronic pain. However, it also raised many challenges of critical research and some of them have not achieved satisfied solutions hitherto.

A. Data representation research

While typical numerical fields such as demographics, vitals, lab measurements, diagnoses and procedures, are natural to use in machine learning models, there is no consensus yet on how to use the free-text clinical notes. Clinical text dataset contains valuable expert knowledge which enables computer to make prescriptions. Embeddings that learn from clinical notes are trained by neural and sequence models. Yet the existing embedding techniques on text notes are difficult to transfer to clinical settings because of the dependence on large dataset and the unique forms of medical words. We need to build up a text processing tool for clinical notes to enable following embedding research. In addition, the structure of clinical notes should also be taken into consideration. On the other hand, data representation for medical records involves different forms of data including image, numerical value and text notes. It is meaningful to find out an effective way to represent a heterogeneous medical data network for the integration of medical system.

B. Iterative learning and Evaluation

Combining health IT with medicine is more than an implementation work. The impact of the assistant system depends on both effectiveness and user-friendliness in the long term practice. Because unexpected variations among patients and regular changes of the practical needs will affect how the systems are used and the meaning of the diagnostic results. Therefore, we should be prepared to evaluate the system design and module functionality to adapt to the practical needs continuously. In addition, existing assessment criteria cannot satisfy the iterative effectiveness of an assistant system. There is a need for equitable and comprehensive assessment measure to guarantee the usability of such an multidisciplinary assistant system for primary care settings.

Acknowledgements

This research is supported by Nanyang Technological University, Nanyang Assistant Professorship (NAP) and the Singapore Ministry of Education Academic Research Fund Tier 1 (Grant No. 2017-T1-001-270).

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