Reducing Error in Safety Critical Health Care Delivery

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Abstract. A behavioral goal in the safety critical delivery of health care is minimizing the likelihood of error in the diagnosis and treatment of presenting symptoms. The prevailing belief in the United States is that information technology (IT) can effectively address such health care delivery problems. The veracity of this belief was not upheld by a study of the application of IT to health care (Stead & Lin, 2009). The study found that IT applications introduce problems such as difficult to detect forms of error and provide little support for clinicians' imposing cognitive tasks. This paper presents a model that addresses both of those issues. The model supports the clinicians' cognitive process of knowledge acquisition through differential diagnosis by creating an evidence based construct of the specific patient. The IT implementation of the model based on a systems engineering concept is described and implications considered for reducing the likelihood of error.

Keywords: Error, health care IT, cognitive support.

1 Introduction

More resources are spent on health care in the United States (U.S.) than in any other country yet the U.S. ranks last among the world's 30 industrialized countries. This is because a minority of the population receives excellent care and a somewhat equal minority receives adequate care (National Academies, 2006) a portion of the population that is approaching 50 million people essentially has no health care.

Pending the advent of re-designed health care to attempt to correct this situation, efforts are underway to reduce errors and enhance the quality of care by employing information technology (IT). Computer technology has great potential – it is easy to imagine how that technology can revolutionize the delivery of health care. The extent to which that currently is happening was addressed in a study by the Institute of Medicine (IOM) of the U.S. National Academy of Sciences involving eight medical centers that are exemplary in their application of IT in the delivery of health care (Stead & Lin, 2009).

1.1 The IOM Study of Reality

Based on observations and other data from site visits to the eight medical centers which included a Veterans Administration Center, the study committee reported that the applications of IT in health care did not differ appreciably from “bean counting”

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which has been successful in administrative matters both in and out of health care. The committee also found that despite the potential of the technology, the health care IT in the subject medical centers rarely provided an integrative view of patient data important for avoiding errors in diagnosis and treatment (Stead & Lin, 2009).

Care providers were found to spend a great deal of time in electronically documenting what they did for patients. Clinicians often stated that such information was to comply with regulations or to defend against lawsuits, rather than information that someone could, indeed would use in improving patient care. The study committee found that IT exacerbated frustrations in performing some required tasks to the extent that work to accomplish those tasks increased rather than decreased. Another onerous finding was that often IT applications not only increased the possibility of error but also introduced new forms of error that are difficult to detect (Stead & Lin, 2009).

In summary, data gleaned from the visits to health care facilities considered exemplary in their implementation of IT suggest that if current applications health care IT continues unchanged, the nationwide implementation of IT will be insufficient to achieve the vision of 21st century health care – that health care should be safe, effective, patient-centered, timely, efficient, and equitable. More ominously, the study committee conjectured that the continuation of the current IT applications will set the goals of that vision of health care back to an earlier level (Stead & Lin, 2009).

The central conclusion of the IOM study provides a focus for change from the current unsatisfactory if not destructive course of IT health care applications. That focus is to provide IT support for the cognitive tasks inherent in the delivery of health care regardless of who provides it – family members, patients or professional clinicians. That support is envisioned as a cognitive model of the patient.

2 IT Cognitive Support in Health Care

Consistent with the “bean counting” approach of other aspects of health care IT applications, current IT based cognitive support typically focuses on health care transactions such as admitting a patient, interpreting a report, performing a procedure, (Stead & Lin, 2009). Such transactions involve activity to achieve a set of goals for the patient – goals that should be based on an understanding of the patient, yet raw data that are descriptive of the patient are illusive in current health care IT. Indeed, as previously noted clinicians spend considerable time searching for patient data that are vital to understanding the multiple interacting dimensions of the physiological, psychological and social aspects of the patient that is necessary to provide safe and effective care.

The emphasis on developing IT based cognitive support that is usable and useful for patient centered diagnosis and treatment of presents a formidable challenge to the computer science and biomedical informatics communities. That challenge can be met by gleaning insights from the study of human cognition by the discipline of psychology to enable an effective change from current IT applications.

An important insight for the IT support of cognitive tasks in health care is providing that support in a manner that is in harmony with the care providers health care related cognitive processes – processes that incorporate the specific provider’s medical knowledge and experience. This is not as difficult as it may seem because clinicians are trained to acquire patient data by the process of differential diagnosis – a process that is amenable to IT implementation.

3 Differential Diagnosis

The process of differential diagnosis is the systematic acquisition of patient symptoms which often are characteristic of a variety of problems. This process of acquiring symptoms continues until one diagnosis can be differentiated from the various possibilities. Then treatment can be administered that is appropriate for the presenting problem. This differential diagnosis is guided by the knowledge and experience of the care provider. For example, the clinician acquires the datum that a patient is vomiting and also the datum that the patient has diarrhea. These data could lead to the diagnosis of flu or food poisoning. To clarify the issues for diagnosis, the clinician seeks additional data that might point to another source of the presenting symptoms.

Drawing on experience with patients having side effects from medication, the clinician finds that the patient is taking medication Z. That datum doesn't aid the diagnosis unless the care provider can access information concerning the side effects of Z from his or her experience or auxiliary information. Data are acquired that medication Z can have a side effect of vomiting and diarrhea. This additional datum changes the previous information/diagnosis so that rather than providing treatment for flu or food poisoning which would not have relieved the problem and possibly led to the supposition of error, the care provider discontinued medication Z, after which the vomiting and diarrhea stopped.

Although the above example is simple, the same cognitive processes occur in complex cases involving large numbers of variables – the more complex the case, the more important is the availability of support for the cognitive task of differential diagnosis. IT is ideal for this support – not because it is capable of complex, involved calculations which are not appropriate for differential diagnosis but because IT has the capability to support the simple yet challenging process of differentiating a myriad of data.

Thus, IT based support that simply presents data to the clinician in a manner amenable to his or her process of acquiring knowledge for differential diagnosis allows the clinician to form his or her conceptual construct of the specific patient. That construct can be elaborated by the acquisition of additional data to clarify the symptoms for effective diagnosis and subsequent treatment. The search for those additional data might be guided by the clinicians' previous experiences or a serendipitous datum which likely would not be present on a pre-determined patient model as in computer assisted diagnosis.

Because IT can present data so that they can be considered in different constellations the likelihood of an error occurring from not considering a datum relevant to the specific patient is reduced. It might be conjectured that using data to build a model for each patient is not an efficient use of time – an important consideration in this era of reimbursement dictated 12 minute patient encounters. This does not occur because the human mind and its cognitive processes are parsimonious. Representation of such parsimony that can guide the development of IT cognitive support is afforded by the Tien (2003) systems engineering framework of human cognitive structure. That framework supports the development of a patient centered cognitive construct for the integration of raw data into the context of the clinician's medical knowledge and experience that is described later in this paper.

4 A Framework of Human Cognitive Structure

The importance of a cognitive support model being compatible with the acquisition of data is underscored by the reference to cognition as the critical interface of humans interacting with data (Tien, 2003). A systems engineering elaboration of cognition (Tien, 2003; Tien & Goldschmidt, 2009) provides the basis for the ensuing discussion of the implementation of IT. That implementation which is related to the decision making framework in Figure 1 supports the process of differential diagnosis

The components of the framework vary in the dimensions of complexity with data being the least and wisdom the most complex, and time – data are the most transient and wisdom the least. Please note the tactical nature of the aspects of the framework indicated by the Decision Making Range area beneath of triangle in Figure 1 is beyond the scope of this discussion hence will not be addressed.

Fig. 1. Decision-Making Framework (Tien & Goldschmidt, 2008)

The components of the framework are not static or tightly compartmentalized. Rather their boundaries are permeable with elements moving within and across components. Each of the components of categories of elements in the framework is discussed in some detail to emphasize inter-relatedness among them. Such relatedness is relevant to the development of IT support for the process of differential diagnosis described later in the paper.

4.1 Data

Data, the basic elements of the decision framework, are obtained by observation, measurement, and verbal report such as a patient reporting a symptom. Data can be qualitative as well as quantitative. The patient's temperature and each aspect of the results from a laboratory test are examples of basic elements as are the symptoms of diarrhea and vomiting in the previous example.

Because humans are parsimonious, the individual datum is not absorbed by contributing to an information unit but continues as an element to be associated with other data to form other information units. It is emphasized that each datum is a single simple measure obtained at a given point in time – presenting compound material as data limits the clinician's ability to consider independently the elements that comprise the material for possible processing unless the clinician takes the time to decompose the material into its elements.

Each of multiple data elements of symptoms can be envisioned as cognitive elements that when acquired by the process of differential diagnosis and associated as in the previous example of diarrhea, vomiting, and use of medication Z are processed as a unit of information in the clinician's diagnostic cognitive structure.

4.2 Information

For each patient, data can be processed by linking each datum about that patient to an appropriate other – each elaborating the other. This continues until the data are processed by the clinician into information about the specific patient. Units of information can be characterized by patterns and groupings. Although the data elements become information about patient A each datum is not absorbed by the processes but continues as an element in the care provider's cognitive structure being associated with other data elements to form information about a specific patient B or additional information about patient A.

Information includes groupings, and patterns, hence is more complex than data. Because the data comprising information were obtained at different times and the information is a part of the clinician's cognitive patient construct that might be used for future cases, it is considered analogous to short term memory in time (Wickens, et al, 2004)..

The process of data points becoming information continues in accordance with the education and experience of the clinician. The units of information may or may not be related in the clinician's cognitive structure. As more data points are obtained to elaborate the information or additional information is formed, appropriate and sufficient units of information coalesce to become knowledge.

4.3 Knowledge

The information units are not absorbed when they are inter-related and processed as knowledge – rather they are readily accessible so that other knowledge units might be formed by coalescing with different yet appropriate information units. Each data element that ties in to the information unit elaborates it and to the extent the information is an aspect of a knowledge, that knowledge is elaborated and can be accessible for the consideration of data points – the utility of data is multi-faceted.

The data points that lead to the decision then become information about the specific patient, which upon the existence of additional information about that patient can be processed when other conditions are met to become knowledge about the patient. The information components in a specific unit of knowledge are not absorbed in the knowledge but are available to consolidate as knowledge with other information units formed by the processing of when additional constellation of data points.

Because the data points for the specific patient have become information about that patient their usefulness as individual datum for that patient is diminished, hence their utility in the diagnostic process is transitory. This process occurs again for each specific patient often involving a number of considerations through differential diagnosis of data elements that provides more information for the clinician's cognitive construct of the specific patient.

Knowledge is more complex than the two previously noted aspects of the framework because it consists of synthesized information integrated with experiences, beliefs, values, attitudes, culture. Knowledge exists over time; it is analogous to long term memory (Wickens, et al, 2004).

4.4 Wisdom

Wisdom is synthesized knowledge plus insight often gleaned from multiple experiences and assessment of aspects of patient care over time. Units of knowledge regarding certain aspects of specific patients would be processed together with related experience based knowledge from a variety of sources. Wisdom is the most complex of the aspects of the cognitive framework, the most integral to the person, and not an aspect of every clinician's cognitive structure. Ideally a wise clinician would be encouraged to share to the extent possible the process by which the wisdom was acquired either verbally to the extent that one can articulate wisdom or by allowing unobtrusive observation of the application of that wisdom in patient care as in teaching.

The magnitude of each aspect of the framework is represented by the size of the triangle in Figure 1– the plethora of data being consolidated into a smaller quantity of information which in turn is synthesized to become a smaller quantity of knowledge, which is consolidated into wisdom.

5 IT Support for Cognitive Tasks

The previously discussed components of the human cognitive framework provide the operational concept for IT support for the cognitive tasks of health care diagnoses and treatment decisions. For ease of reference this IT cognitive support tool is referred to as Differential Diagnosis Cognitive Support (DDCS). It is to be noted that this is not an aid for diagnosing a specific health problem but support in diagnosing and treating the range of health problems. Neither is DDCS in any sense a computerized diagnosis. Rather DDCS serves as an extension of the care provider's patient specific cognitive processes – an extension that provides the raw material upon which the clinician can exercise his or her skills and knowledge to provide safe and effective patient centered health care.

The DDCS IT support is in the form of tree structure. The data and information the clinician enters is compared with data and information from the appropriate counterpart described in the discussion of the human cognitive structure. The clinician can select data or information at each level from one or more of three sources: that which the clinician previously entered that automatically entered the tree library, information from a data bank (from unidentified colleagues) or from the medical literature.

5.1 Data Entry

DDCS provides a diagnostic tree structure on which each datum of reported symptoms, observations and measurements for a specific patient would be entered individually. The clinician can prompt DDCS for an information tree with the same data elements together with unit(s) of information from those elements. That would appear on the screen. The clinician then can prompt for a tree with suggested additional categories of data elements that would aide in the process determining information to be used in considering the diagnosis for the specific patient.

If the clinician wishes guidance for gathering additional data for the specific patient, he or she can request that the DDCS data tree receive a thesaurus of DDCS data trees developed from the specific clinician's experience, or experiences of other unidentified clinicians for patients with demographic and health data comparable to those of the specific patient, or from the medical literature. Data for the specific patient would be entered which would trigger the presentation of several trees each with the entered data, suggestions for additional data to be acquired and the unit of information for each of those constellations of data. It may be necessary to enter more than one set of data trees depending on values entered for certain symptoms or results of tests.

When these data elements support information that the clinician considers sufficient for diagnosis, he or she might perform the differential diagnosis without IT assistance or request diagnosis trees tailored to the characteristics of the specific patient together with the medical information from the directory of diagnostic trees.

After forming a diagnosis appropriate for the specific patient, the clinician could request treatment trees from the directory of treatment trees. With the entry of appropriate patient characteristic data such trees could be tailored not only to the diagnosis but also to the extent possible to the personal characteristics of the specific patient to reduce the likelihood of error in treatment. Alternative trees can be requested

For those specific cases for which the treatment and its outcome potentially are problematic, the treatment trees for the specific patient can be submitted to the wisdom encyclopedia of outcomes.

6 Conclusion

The potency of this approach lies in data presentation that is driven not by what is technologically possible or by what researchers or theorists advocate rather by how the actual health care provider acquires and assimilates data. DDCS by incorporating information from actual clinical settings can provide insights gained from the real world experiences of clinicians. In addition the DDCS support of clinician's cognitive processes is dynamic. This is in contrast to the IOM study committee's vision of patient-centered cognitive support in which the clinician interacts with a static virtual patient comprised of raw data synthesized with medical knowledge in ways that make clinical sense for that patient.

The DDCS utilizes the capabilities of IT beyond "bean counting", but is DDCS feasible? That is an empirical question. Beyond a doubt there is a crying need for a

technology such as DDCS that can reduce the likelihood of error by supporting the cognitive processing of the tsunamis of data for any given patient not only by clinicians but also by lay family care givers and patients involved in self care.

This need becomes critical when the stress of workload, production pressure, and fatigue compromise the cognitive functioning of the health care provider, hence increase the occurrence of errors. This need isn't unique to the U.S. – other countries have a similar issues perhaps to a lesser extent. Health is a precious commodity. It is time to realize the potential of IT to provide safe and effective patient centered care.

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