Dynamic Clinical Pathways–Adaptive Case Management for Medical Professionals

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Abstract

Medical professionals diagnose conditions and prescribe treatments based on a process called a clinical pathway. Yet the criteria within the pathway are largely memory-based. There is a need for a system that manages the process and allows the physician to focus on decision-making and patient care. This paper proposes such a system.

Introduction

The medical industry is undergoing dramatic changes. There is a need to provide quality services while limiting costs, with necessary oversight. Health care workers, ranging from physicians, nurses, therapists and first responders need to make critical decisions based on rapidly changing information (such as evidence-based consensus reports called “clinical practice guidelines” for specific situations). The emerging practice of Adaptive Case Management (ACM) is well equipped to handle this application, in that it assists knowledge workers by providing timely information to make informed decisions in dynamically changing environments.

Medical workers need to keep myriad information about symptoms and possible causes in their heads, and winnow down the possibilities until finally arriving at a diagnosis and treatment plan. Along the way, tests are conducted to validate or invalidate hypotheses. When formalized for a specific symptom or disease, this process is called a clinical protocol. A medical professional can either quickly move to a diagnosis based on an expensive test, or first try a medicinal therapy. The choice depends on the doctor’s judgment and experience. This “experience” aspect is enhanced by accessing large pools of data which are increasingly changing and growing, adding to the body of knowledge on the subject. It is therefore important to employ a system that provides information about different ailments and guides a medical worker down an accepted pathway toward treatment. This should interact with centralized electronic medical records, contributing towards a more efficient pathway. A complete audit trail of all decisions would satisfy regulatory requirements. Ultimately, social business process management (BPM) interactions amongst the users will enhance the process by allowing care to be provided by experts not physically present.

This paper presents a multi-tiered concept regarding the application of ACM and social BPM to medical clinical pathways, and is *not* a description of a commercial software product. It is the stating of a need, anticipating the benefits, and delineating the requirements to solve the problem. We refer to it as a system in the strict sense: a set of interacting activities to solve a particular problem. A systemic approach is needed. Therefore we will continue to refer to this as the "system" without inferring a commercial implementation of the approach presented.

We are calling ACM as applied to clinical protocols with social BPM enhancement: "Dynamic Clinical Pathways." This system will allow medical professionals to focus on using their experience and intuition to make nuanced diagnoses, while letting the system provide the extensive memory needed and structure the process. Severity of the ailment can be aligned with the skill-level of the professional, leaving more complicated cases to scarcer expert physicians. More widely-available and accurate medical treatment at lower costs may result, while also ensuring oversight and transparency.

DIRECTION OF THE MEDICAL PROFESSION

It is obvious that containing costs will become a major objective of the medical profession. Yet, patients demand quality care. The growth of health care costs are rising to an extent that threatens to compromise our economic future and wreck budgets for generations to come, in both the public and private sectors. Regardless of the final outcome of the new health care legislation in the USA, cost containment will be paramount, along with providing care to more than 40 million additional patients with the current amount of resources and providers. However, people are enjoying the benefits of advances in health care. Life expectancies are increasing. The expectation of quality care will not give way to budgetary concerns. Attempts to rein in costs have focused on limiting the reimbursement for health care professionals. Also, hospitals are stretched in that they provide free care for the uninsured when they show up at emergency rooms. The recent health care legislation attempts to bring most of the uninsured into the health care system, and these people will be demanding care at earlier stages of infirmity than the emergency situations. This shifting mission of the healthcare industry is changing traditional relationships, demanding greater value for healthcare dollars spent, and will likely result in a transformation of the healthcare economy [1, 2].

Many in the health care profession agree that as a result of these stressors there will be a shortfall in needed physicians and other professionals to deliver this medical care. Among these reasons are:

1. Lower physician reimbursement and increased malpractice risks resulting in early retirement of existing physicians.
2. Newer emphasis on work-life balance and reduced work-hour habits among younger physicians.
3. Not enough physicians and allied health professionals in the training pipeline to meet the expected needs.
4. An aging population with increased healthcare needs.
5. More than 40 million additional patients to the roles of the insured.
6. Likely increased demand per patient with an increasingly healthcare-savvy population seeking multiple opinions on their care. Although medical school enrollment is up, there is the risk that talent will be drawn to other fields as the economic realities become apparent.

Therein lays the dilemma of the future of health care: how to continue to provide quality care at lower cost in an environment of scarcer health care resources.

Health care professionals are human, and humans make omissions and mistakes. However unlike many other professions the consequences of those mistakes can literally be "life and death." Therefore, quality control of decisions is paramount. Yet, to this day, many processes in health care have not been formalized through the use of protocols. Limited access to information through limited time and the hugely-increasing body of knowledge ultimately decreases the chance of favorable heath care outcomes. There is much room in the medical diagnosis and care processes for enhanced efficiencies and oversight. This paper addresses those imperatives.

NEED FOR SOLUTION

Medical professionals, particularly physicians, spend a long time in school honing their skills. A diagnosis and treatment plan requires knowledge, experience and intuition, while rigorously bound to the scientific method. Yet medical diagnosis is still very memory-bound. Physicians must keep myriad symptoms and causes in their heads to find the right solution. It also relies heavily on experience, yet the experience of a single doctor cannot compare with the collective knowledge of the profession. In the popular doctor TV shows, when the hero recognizes the highly unusual ailment when it is missed by everyone else is, in reality, a rarity. Sometimes the unusual pathway is missed because of the limited experience of the doctor.

The other part of being an effective physician is being able to interpret information and make judgments about ordering tests, diagnosing and proposing treatment. Each case has its own unique aspects. Thus the medical worker is the ultimate knowledge worker, in that he must react to his environment and make quick decisions with important consequences. The system presented in this paper seeks to automate the process, while providing access to information stores so that the medical professional can make informed decisions. In essence, it takes over the memory-intensive aspects (which computers do well and humans don't) and administrative tasks in making diagnoses and prescribing treatments. This allows the medical worker to do what humans do best—using their intuition and skill to make decisions that result in positive outcomes for the patient.

THE ROLE OF ADAPTIVE CASE MANAGEMENT

Adaptive Case Management is a practice that strives to provide decision support for the knowledge worker. A knowledge worker is one who does not do repeatable tasks, but who reacts to constantly changing and complex information to use his knowledge and judgment to make decisions. Knowledge workers tend to work on high value activities. The diagnosis and care of a patient is just such a high value activity and a medical worker definitely qualifies as a knowledge worker.

What this system is

Since the problem that this system addresses is not making diagnoses, then what is it? It specifically addresses the pain point that medical professionals feel when doing their jobs—not having access to the information needed *ex-*

actly when it is required. In this sense, it is similar to that of any fast-paced job requiring a broad knowledge on a subject(s).

This system provides information supporting the next decision that a medical professional has to make, and records their decision. The system uses the audit trail of decisions to get better at its support offering capabilities. Currently, medical records only document illnesses and treatments, but not symptoms and factors applied to the decision-making of the diagnosis process. By recording the information, algorithms can be built that offer the professional timely and relevant advice. The system doesn't make any medical decisions but provides the medical professional the information he needs to make the decision, and then records that decision and the outcome to continuously improve its information providing capabilities.

Unlike classical "decision-support" modules for electronic health records software currently in use, the system proposed here facilitates a clinical pathway from a computational standpoint. It also presents an approach at inter-relating many decision points in overlapping clinical care algorithms.

Then what this system is not

This system is *not* a diagnosis system. There are four important reasons for this:

- *Physician autonomy*—and professional autonomy from a system that imposes the diagnosis based on the input information. The system assists the medical professional by providing information, administrative support, and structure to the process, but it is the medical professional who makes the decisions and assumes the ramifications of those decisions.
- *Liability*—the liability of an incorrect diagnosis should not fall on the creators of the system, or the contributors of content. The diagnosis is made by the medical professional.
- *Adoption*—any system is only worthwhile if it is used. There have been attempts at artificial-intelligence driven systems in the past, meant to make diagnoses. These have not been widely adopted. The reason is two-fold: they are not all that accurate, and medical professionals may feel threatened by them. It is important that medical professionals view this type of system as helpful and not threatening nor cumbersome to use.
- *Not artificial intelligence*—this system uses "conventional" technology. It is meant to run on a typical Von Neumann architecture machine[1], without exceptional powerful computing. To contrast, IBM's Watson computer, which recently inked a deal to produce a "physician's assistant" version of the system, is a massively parallel architecture with 28,000 processors. That this system uses conventional technology has a huge impact on cost. The only aspect that could be considered artificial-intelligence like is that the system "learns" from experience, but not in the way that massively parallel architected systems do. More on this in the section describing the technology.

[1] The **von Neumann architecture** is a design model for a stored-program digital computer that uses a central processing unit (CPU) and a single separate storage structure ("memory") to hold both instructions and data.
http://en.wikipedia.org/wiki/Von_Neumann_architecture

Why Social BPM

Social BPM recognizes the need for people to collaborate and interact to achieve a goal, enabled by software that accommodates this need. Dynamic Clinical Pathways qualifies as social BPM for the following reasons:

1. *Multiple people in charge of care*—patients are treated by multiple physicians and support staff with overlapping roles.
2. *Integrated practice unit*—the ideal care is provided through an "integrated practice unit" where all specialists have input to the decision process, yet it's impractical to get all specialists in the same room at the same time for most patient encounters.
3. *Standardize decision processes for basic care*—clinical pathways attempt to standardize decision processes for basic care that were otherwise sporadic and anecdotal.
4. *All cases contribute to the body of knowledge*—the recording of data at each step of the process bringing patients to the next step in the pathway results in tacit communication between these specialists.
5. *The process of research*—to clinical practice guidelines, to protocolization, to dynamic assessment (clinical pathways) involves consensus. The collaboration and debate of current standard-of-care amongst users of such a system makes its decision processes "dynamic."

PROTOCOLS, PATHWAYS, AND COMPLEX DISEASE: HOW ACM AND SOCIAL BPM CAN CREATE DYNAMIC CLINICAL PATHWAYS

The concept of *automating* clinical care is fundamentally challenging, sharing the stark contrast between antiseptic business process models, and humanity in the care of patients. While a decision support structure aides clinical decisions, a proper system would actually allow the physician and health care provider to maintain a greater amount of patient interaction. The system should reinforce the provider's fund of knowledge, experience, and ability to keep up-to-date with the latest standards of care. This would enable them to perform more valuable service, such as adding their clinical intuition to the care regimen, getting to know their patients better, and communicating compassion.

It is necessary to take a standardized approach to the development of a decision-support structure to be able to construct such decision-trees systematically for many different diseases. This process is shown in Figure 1.

Clinical Practice Guidelines (CPG) are expert consensus statements derived from the highest levels of scientific research for a specific disease. Assembling these recommendations in a group that reflects a sequence of time and decision processes is called a clinical protocol. Although some clinical protocols are constructed from a single investigator's anecdotal experience (i.e.: low level of scientific evidence), the ideal protocol is based on the latest CPGs, which should be derived from the highest level of scientific evidence (randomized clinical trials and translational science). The construction of the clinical protocol may also include factors such as patient flow and risk assessment, and reflects an attempt at standardization of care across different providers.

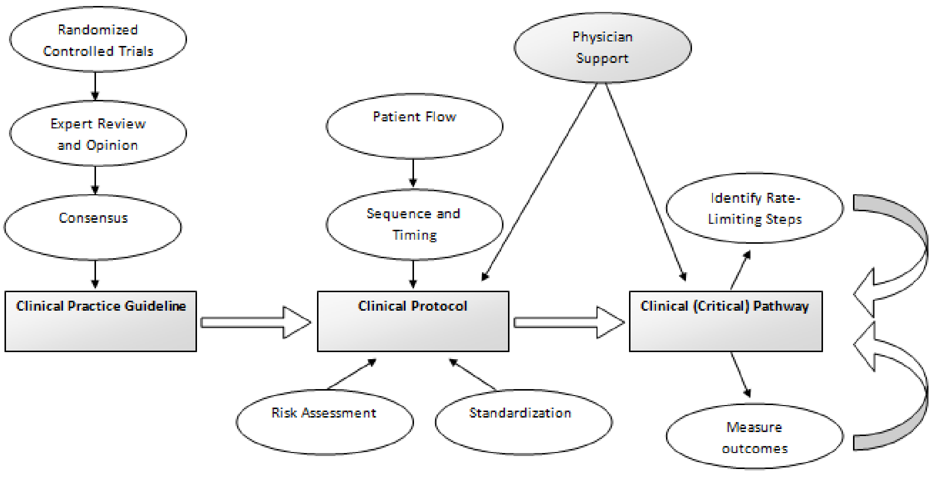

Figure 1: Genesis of a critical (clinical) pathway.

A critical pathway is an industrial process that seeks to maximize efficiency through identifying and improving-upon the rate-limiting step, which is anything that seeks to limit the cost or time of treatment [3]. Our clinical protocol effectively becomes a critical pathway when factors, such as optimal timing for ordering tests, successful medical outcomes, costs, or validity of a medical risk assessment are measured. To emphasize that the critical pathway is for clinical purposes, we will henceforth refer to it as a *clinical pathway*. This clinical pathway is therefore considered an example of adaptive case management by automating processes to improve the effectiveness of knowledge workers. Social BPM comes into play when physicians and others need to collaborate to monitor the outcomes, update the CPG recommendations, and seek to improve upon the clinical pathways.

The sequence of developing a clinical pathway is effectively demonstrated in two recent papers. For the example of gastroesophageal reflux disease (GERD), we performed a systematic review of the literature that critically analyzed CPGs and their recommendations [4]. Principles of constructing a clinical protocol were then summarized. These principles were used to guide a comparison of existing protocols, and a new protocol was constructed as a synthesis of those reviewed [5]. Since measuring outcomes of various metrics was built into the design, we present this as a clinical pathway for reflux disease as shown in Figure 2. This particular pathway introduced medical risk assessment as an initial step, and shows decision branching points based on response to empiric medication, and on results from screening tests. The pathway for GERD was chosen for development as it is a fairly linear decision process.

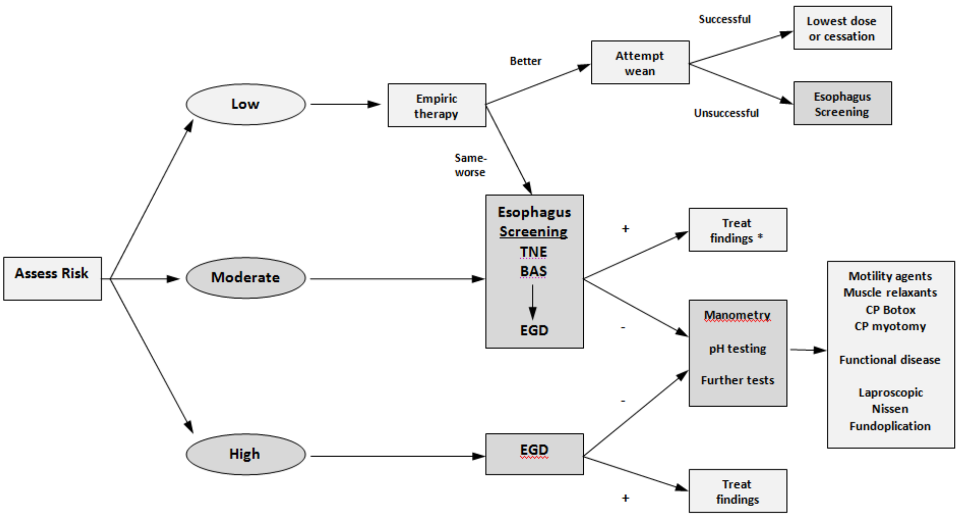

Figure 2: Clinical pathway for evaluation and management of gastroesophageal reflux (GERD), reprinted with permission from [5]. Description of medical decision-making and explanation of technical terms are beyond the scope of this paper. This is a clinical pathway because the decision points and lines connecting them are all measureable. (TNE—transnasal esophagoscopy, BAS—Barium esophagohram, EGD—esophagogastroduodenoscopy, CP—cricopharyngeus).

Chronic cough is a far more complex example, based on the many contributing factors that can cause cough with overlapping physiologic processes that form synergistic effects (Figure 3). In this example, rhinologic diseases are a common cause (such as post-nasal drip from allergy or sinusitis). These diseases can cause a cough directly by irritating the vocal folds, or indirectly by aggravating lung disease (such as bronchitis or asthma). Lung disease can also directly cause a cough. GERD is another common cause of cough, and can cause it by directly stimulating nerve endings in the esophagus or larynx, can cause aspiration to the lung which results in a cough, and can itself be caused by the act of coughing. Since there are many overlapping and complicating factors here, the clinical work-up may be inconsistent.

One major difference in the approach to a clinical work-up is between *serial* evaluation and treatment (one trial or test at a time), and *parallel* evaluation and treatment (where more than one contributing disease may be addressed at the same time). While the computational demands for guiding the linear GERD pathway of Figure 2 may be straightforward, the ability to construct a computational model for the care pathways needed for cough (seen in Figure 3) would be far more daunting.

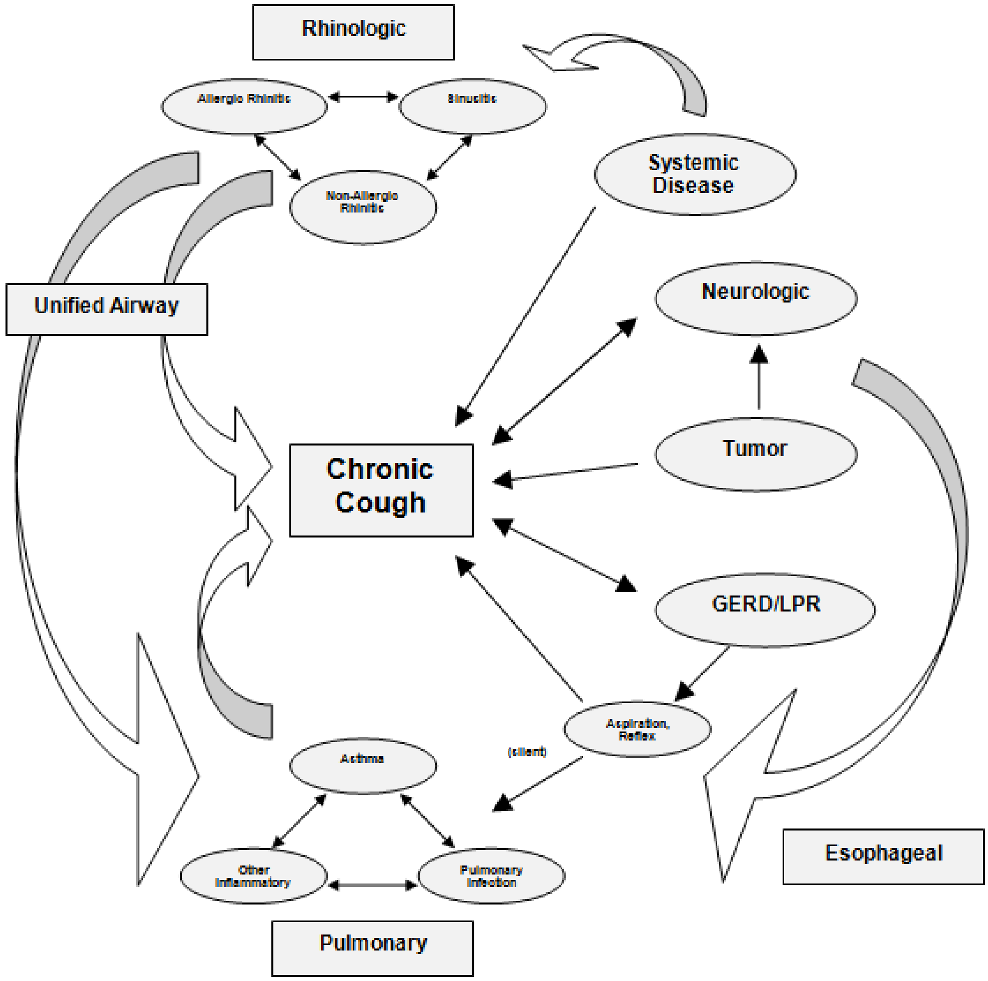

Figure 3: A complex disease such as cough may have many physiologic causes and inter-relationships, as well as overlapping contributions from different diseases. Reprinted with permission from [6].

To demonstrate the approach to computational structure, Figure 4 shows a schematic representation of the linear GERD pathway from Figure 2. The diagram for GERD (seen at the top of the figure) is displayed using *nodes* to represent points in time during the patient observation and medical decision-making process. Two additional pathway schematics are also shown in this figure. In the case of cough, these three pathways may represent rhinologic disease (such as post-nasal drip), and pulmonary disease (such as asthma or bronchitis). Since these three disease processes may exacerbate each other for many reasons, they become inter-related at different nodes. Relationships between these nodes may be based on timing, common physiology, synergistic effects, and prioritizing testing between two competing diseases diagnoses (shown in dashed lines connecting the three pathways). A mathematical representation of these relationships connecting the pathways in a computational model would facilitate a parallel work-up and treatment of a complex disease.

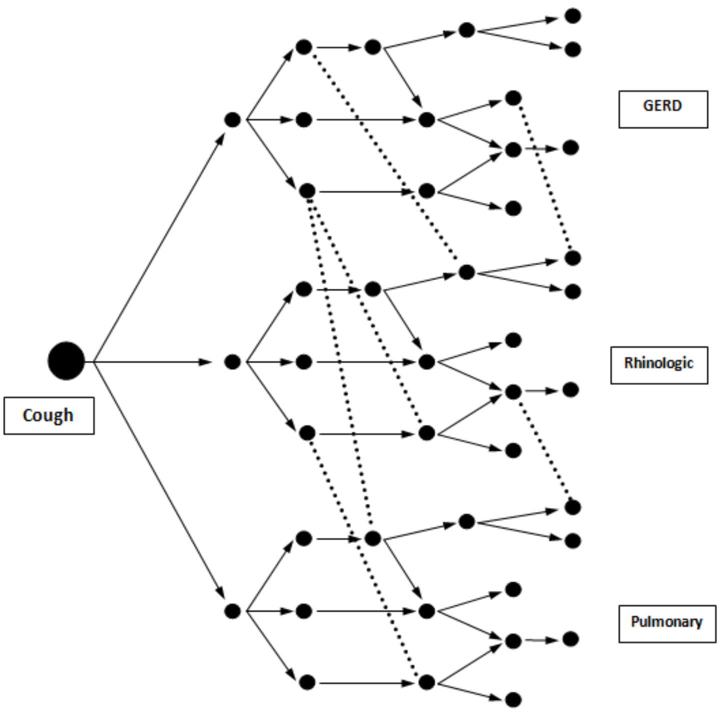

Figure 4: Nodal schematic diagram of the pathway shown in Figure 2 (top), and two additional pathways for other diseases. Interconnections between nodes (points of time with patient observation or medical decision-making) are shown with dashed lines.

The relationship between this computer-based clinical pathway and the electronic medical record (or EHR—Electronic Health Record) is beyond the scope of this paper. There are essentially three possible scenarios that can be considered:

1. The clinical pathway is completely independent of the EHR and only guides the clinician on the next step which they document independently.
2. The clinical pathway is "called-up" by the EHR during the course of documentation via keywords, tabs or smart-text currently in use today by some EHR systems.
3. Or, the clinical pathway itself is used to generate an EHR document.

Nevertheless, documentation of the decision process, test results and patient outcome are vital to successful patient care and communication among physicians and other healthcare providers.

TECHNICAL SOLUTION FOR DYNAMIC CLINICAL PATHWAYS

To automate Clinical Pathways, the solution needs the following characteristics:

- Ability to group entities in sets based on common characteristics
- Ability to flexibly define and encode the criteria for set inclusion
- Ability to explode to sub-structures and implode to super-structures, with no limit on depth of nesting of structures

- Ability to traverse multi-dimensional networks and manage the complexities of that navigation
- Ability to self-modify based on feedback mechanisms

Figures 1-4 indicate the pathways that diagnosis and treatment can take. There are many interacting variables. This application defies traditional BPM, which is only able to represent fairly rigid logic paths. Set theory applies because it manages the interactions of variables that constitute inclusion in the set to determine the next step in the process. Think of it as a traversal of a complex network. However the connections are determined by stochastic criteria. Thus medical professionals must use their judgment in determining the next step. Previous rule-based artificial intelligence (AI) attempts at medical diagnosis use weightings to determine the probability of an outcome. In this implementation, the weighting-based probability determines the order that the system would serve up the information to the user. The weightings are the result of observation recorded in the system, so the outcomes influence the system behavior the next instance given the same conditions. The content for clinical pathways would initially be seeded by expert specialists, but evolves and morphs over time into more refined criteria.

The set theory/structure nesting/network traversal-based processing system was first proposed in the paper on People Relationship Management published in the 2009 BPM Workflow Handbook [7]. The original premise was to map the relationships between people in an organization so a workflow system would know the right person to whom to route a transaction. This was initially geared toward transaction-based processes which are the traditional premise of BPM systems. Examples would be Human Resource Management transactions such as processing promotions, benefits changes, and time tracking, among others.

However, it was stated in the paper that the underlying technology was capable of tracking relationships between any type of entity. In addition, it has a very rich rule-based engine for inclusion in sets (spheres) based on the relevant meta-data. The discipline of tracking relationships between any type of entity is called *Extended Relationship Management*, or XRM. The term Extended Relationship Management grew out of Customer Relationship Management (CRM) by extending the capabilities to include relationships between people other than customers. Although the proposed system discussed in this paper is not similar to CRM, the acronym fits.

As initially discussed in the paper on People Relationship Management in this series, a sphere is a collection of entities (initially people). Inclusion in a sphere is defined by business rules. Every entity is considered a *sphere*, whether it is a collection of entities (it can be a collection of different type entities) or a single one. A sphere which cannot be subdivided further is called an elemental sphere. Spheres can be nested any number of times. Spheres can have attributes assigned to them. A business rule can test an elemental's spheres attributes to determine inclusion in a larger sphere. Spheres are connected together in a context, meaning they are related to each other in some way. Putting it all together it is called a relationship: a group of spheres, defined by business rules, related in a context. Since spheres can represent anything, a sphere can be defined to represent a full pathway, and nested in another sphere. That way the system can represent explosion to another pathway at a node. Essentially the system allows dynamic criteria for set inclusion, and the ability to manage and navigate very complex network structures with no limitations. In the realm of a transactional BPM system, People Relationship Management can be used to define the relationships between people in an organization, in very complex ways that accurately represent the relationships. Applying this technology to Dynamic Clinical Pathways (DCP) is almost a natural fit. The model needs to be extended to weight the set inclusion criteria based on feedback loops. Also, unlike a workflow system, where traversal to the next node is sent automatically based on business rules, in DCP the worker explicitly chooses which node to move to next. The system makes "suggestions" based on the rules (initially seeded as clinical practice guidelines) and modified by the "experience" of the system. Using XRM for DCP, the context would be analogous to the pathway, for instance: diagnosing a cough, or diagnosing chest pain. Each sphere represents a potential diagnosis, or more refined categorization of the condition. The business rules associated with the sphere are the symptoms or test results that indicate inclusion in that diagnosis.

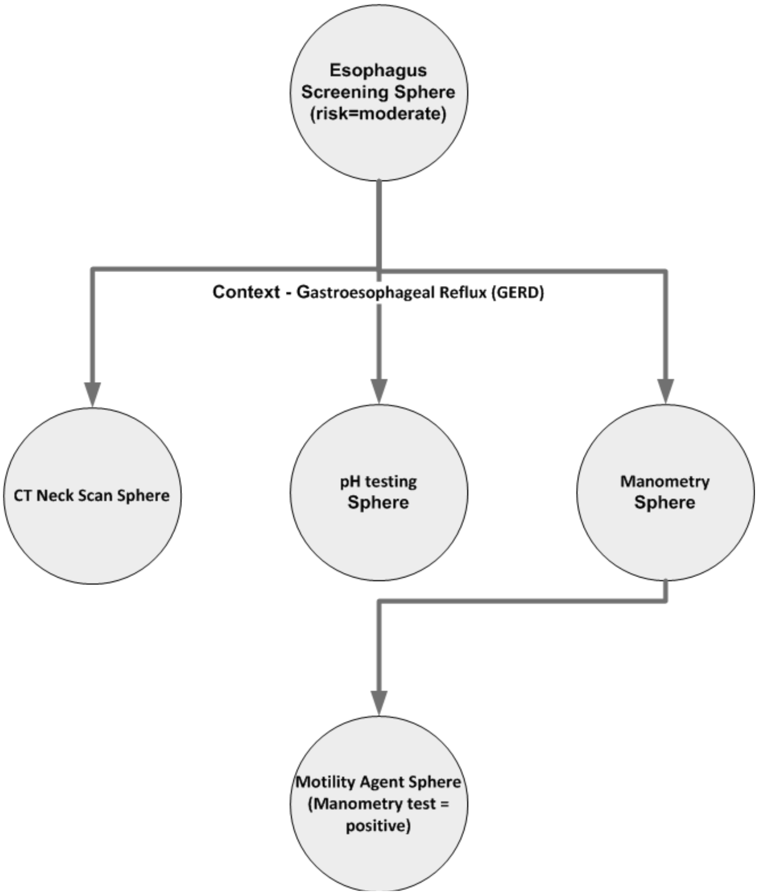

Figure 5: Part of the clinical pathway for GERD is mapped to an XRM schema. Inclusion business rules are indicated within the spheres.

PROCESSING EXAMPLE

Jim makes an appointment with Dr. Sarah, a primary care physician, complaining of heartburn and a sense of a "lump" in the throat. Sarah brings her tablet computer with her to the initial consultation. After taking a proper clinical history and examining the patient, Dr. Sarah indicates on the tablet that Jim is at moderate risk for having medical complications from his disease and initiates the Gastroesophageal Reflux (GERD) pathway. The system suggests that Dr. Sarah instructs the patient on diet and lifestyle changes, starts the patient on medication to treat GERD, and sends the patient for esophageal screening to be sure that there are no obvious tumors or precancerous changes to the esophagus.

The system orders the medication and the test through the order entry system on the back-end via web-services, transparent to the users. One month later the patient returns to see Dr. Sarah. The results of the test indicate a relatively normal esophagus, although the severity of the patient's initial symptoms and poor response to medication suggests the need for further testing. The pathway recommends that the patient undergo manometry (testing the pressure of the upper esophagus sphincter muscle), which reveals the pressure is unusually high in Jim's case (and noted in the system). As a result, the pathway suggests that Dr. Sarah treat Jim with muscle relaxants, and consider sending him to a specialist to inject botulinum toxin to his cricopharyngeus muscle. Had this test been uninformative, Dr. Sarah would have been instructed to backtrack to "further tests," such as a CT-scan of the neck. If the botulinum toxin injection is successful, the pathway leading to that treatment would be strengthened.

DISCUSSION

There can be process efficiencies gleaned from the medical profession. To use a well-worn metaphor, automating the administrative tasks is like "picking the low-hanging fruit." Yet the low-hanging fruit is ripe for the picking in the medical industry, as it is notoriously under-automated. Providing automated support for the knowledge-worker (ACM) is analogous to harvesting the middle of the tree, because it's addressing more complex problems using more sophisticated tools.

Once the administration is fully automated and DCP alleviates the need for memorizing large amounts of information, the nature of health care will inevitably change. Medical professionals will be able to focus on care of the patient rather than memorization. Training will be more specific because there will be instantaneous access to experts in nuanced areas of medicine. Students will spend more time working with patients and less time in the classroom or library. Costs associated with health care will decrease as care for standard ailments can be managed by less costly resources, unnecessary tests and treatments avoided, and audit trails lessen the risk of malpractice litigation.

The immediate consequences of this system will be more cost-effective care for minor ailments. Nurse practitioners can establish pathways along practice guidelines and prescribe treatments. A physician will be brought in only if the condition is serious. Practice guidelines and audit trail will allow medical professionals to make sound decisions rather than practice defensive medicine. Medical students will focus on complex diagnoses, rather than memorization of that which will be systematized. Therefore, each physician will have more depth and/or breadth of knowledge in their specialty. Ultimately, care of the patient will be paramount, enhanced because burdensome processes and information failures will be abated.

What would the upper branches yield? Is there a compelling case to pursue them? Earlier in this paper we asserted that this system is neither an example of artificial intelligence nor a diagnosis system. Yet inevitably it will evolve into just that. As computing power increases and costs decrease, there will be a shift from rule-based systems (as proposed in this paper) to pattern-recognition software which can approach semantic understanding which is similar to the way humans think. To achieve this requires massively parallel system architecture, as opposed to the "one instruction at a time" architecture predominantly in use today.

One cannot deny that social networks seem to have "touched a nerve" in the human psyche. The ability to achieve synergies by working on problems collaboratively is a fundamental aspect of human nature. ACM is by nature social BPM in that it supports the collaborative nature of knowledge work. This has been a basic aspect of humanity since its inception. But with "groupthink" naturally comes a surrender of privacy to some extent. This has become apparent with the advent of the Web and social networking. Throughout history, people have sacrificed privacy in exchange for inclusion is societies and the ensuing advantages. Digital natives know this intuitively, although older people might be more wary. These are issues that people must come to grips with, and make conscious decisions as to what privacies are to be sacrificed for what benefits.

The medical profession is continually improving care through advances in knowledge and technology. Yet the cost of medical care is rising exponentially, which, if unchanged, will significantly impact our standard of living in a very short time. Why is it growing so much? The desire to continue living is as innate as life itself. But should we allow our quest for life to kill civilization? It is a moral imperative to find a way to provide quality care at a cost that we can live with as a society.

Yet the inevitable conclusion is that technology is forcing us to evolve more quickly and we're faced with important problems. With greater longevity population will grow. We will need to plan for the resource issues that will result. Throughout time, populations have been self-regulating to some extent. Therefore, we will have fewer offspring and the gene pool will be replaced slower. Our lives are merging with digital technology more each day. As technology advances this will accelerate and our personas in the cloud will take on more of what we define as "us."

In addressing any problem, it's best to plan a long-term strategy and determine shorter term tactics that achieve mileposts along the strategic plan. Dynamic Clinical Pathways is just that. The advent of Adaptive Case Management and Extended Relationship Management are well suited frameworks within which to solve this problem, and see us down the pathway toward healthy lives without compromising our financial future.

CONCLUSION

A system to manage clinical pathways using conventional technology is feasible. Through careful analysis of the process, and leveraging and extending existing technologies, a system can be devised that will assist medical professionals in diagnosing and treating conditions. This is an application of Adaptive Case Management, in that it will provide decision support for knowledge workers.

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