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THE USE OF CMAPS IN THE DESCRIPTION OF CLINICAL INFORMATION STRUCTURE AND LOGIC

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Abstract. The development and implementation of competent and cost-effective computerized medical records will require the development of a new paradigm for the representation and analysis of medical knowledge and logic. Medical knowledge is acquired inductively by observing, measuring, and eliciting information from patients in a process that is investigational rather than transactional. Most, if not all, current approaches to health information technology (HIT) rely on a logic and data structure that imposes significant limitations on the ability of physicians to adequately and efficiently document and access empiric patient data because the information is almost invariably organized deductively and lexically which presumes, rather than makes explicit, the relationships of concepts and their meaning. Cmapping provides a graphical method of capturing and displaying expert content knowledge which is simple to comprehend and modify, and provides a foundation for a dynamic, inductive, and inclusive method of clinical documentation and research. The basis of medical decision analysis along with representative samples of medical knowledge modeling in the Cmap format is presented.

1 Introduction

The basic science and clinical foundations of modern medicine are evolving so rapidly and broadly that the capture, access and use of this vast amount of data advantageously and efficiently has generated a world-wide challenge to effectively use modern health information technology (HIT) to improve the health of the world's citizens. The United States government has recently embarked on an unprecedented program to convert the current US medical system, in which less than 10% of clinical practices are using electronic medical records, to a universal, interoperable, clinically meaningful electronic system by 2015. This has been mandated in the context of the extremely rapid and virtually universal adoption of computerized practice management systems in the United States in the past two decades.

It has been widely assumed that such systems 1) would be developed as elaborations of currently existing clinical computer technology; 2) could be modeled on current specialized systems, such as radiology and emergency medicine HIT, for other specialties, such as ophthalmology and dermatology; and, 3) that there would be significant improvements in safety, quality, and efficiency, that would rapidly lead to lower healthcare costs. These assumptions have not been scientifically demonstrated, may not be valid, and the failure to take these possibilities into consideration may lead to qualitative and fiscal degradation of healthcare. Despite the obvious incentives and the example of successful implementations in several specialties, there has been widespread reluctance and uncertainty about its general adoption by most medical practitioners, if not by administrators, politicians, public advocates, etc.

Physicians have widely adopted costly and complex new diagnostic and therapeutic instruments. They have been willing to undertake extensive continuing medical education to learn newer and better techniques of patient care. Most physicians will use tools that they find are consistent with or can be adapted to their personal approach to patient care and practice management. It is our premise that the structure of current HIT is inconsistent with the core of clinical medicine and that this inconsistency has motivated the inertia that has resulted in slow and limited adoption of HIT for clinical documentation.

We have experimented with Cmapping and have concluded that it is a useful tool for the capture of expert knowledge in a way that lays the foundation for further advances in the development of information technology that will improve the access, quality, and safety of medical care. We believe that such systems should enhance physician and other provider productivity and effectiveness, in order to lower costs. Such a system should also provide a foundation for new approaches to research of large and diverse populations, across cultural and linguistic boundaries. In addition, the system could also encourage better patient counseling, since many of the Cmaps can be used by patients to better understand their conditions and treatments.

2 Clinical Data Structure and Logic

Cmaps are particularly useful for content experts to collaboratively describe clinical findings to essentially any level of detail. It is possible to annotate concepts with textual and image-based references. It is important in clinical documentation systems based on a detailed clinical knowledge model not to blend empiric evidence with inference or diagnosis, but to express evidence and inferences using a common terminology that is semantically consistent. Physicians may wish to describe the physical findings, capture patient history, and make measurements with instruments that are properly calibrated or standardized. Each observation, measurement, sign or symptom must be captured and described at whatever level of specificity is known or relevant. Evidence must be able to be represented at the desired detail.

Blood pressure measurement seems to be a simple piece of data to capture. In most situations, the patient's identifying information is connected to the diastolic and systolic measurements, as illustrated in Figure 1.

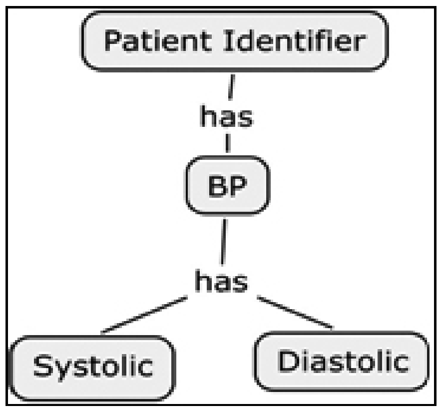

Figure 1. Simple Blood Pressure Description Model

There are times that such a representation of blood pressure is incomplete and insufficient, particularly in critical clinical situations, such as in intensive care or surgery. Although not exhaustive, Figure 2 illustrates a greater level of complexity that may be required to document a not-so-simple blood pressure.

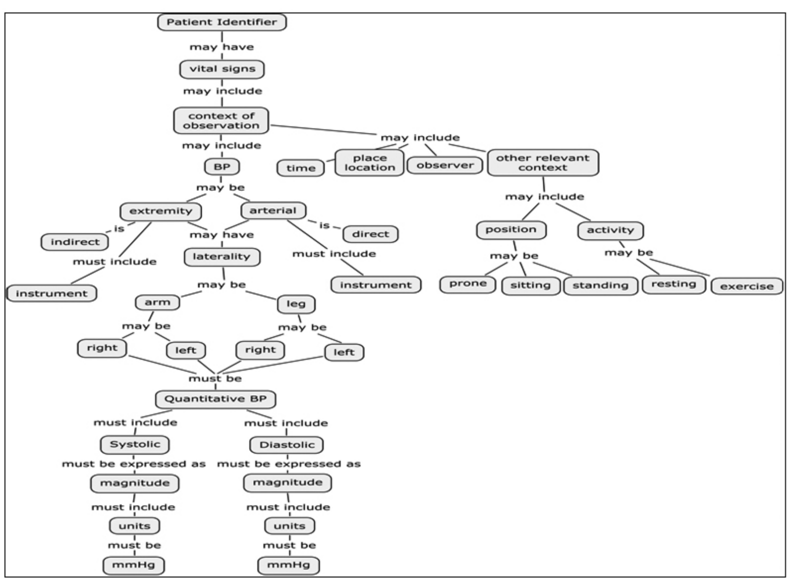

Figure 2. Complex Blood Pressure Description Model

In the context of a paper record, one would record the particular details that modify and contextualize the finding. In an electronic medical record, however, the functionality to capture that detail must pre-exist or the data may be recorded without the requisite modifiers.

Clinical findings may require reinterpretation over months to years by the same or new providers. Descriptive functions have historically tended to be idiosyncratic and personal because they represented notes intended to jog memory at a future time. These personalized documentation systems may not be easily interpreted by others. It is often unfamiliarity with the descriptive meaning that prevents rapid interpretation of older or unfamiliar records rather than the infamous “bad handwriting” of doctors. Having practiced medicine for 30+ years, the author has learned to decipher clinical notes from the past. The major barrier to understanding the implications or meaning of a predecessor’s clinical note is much less the decryption of the words themselves – the lexical content – but rather the difficulty is interpreting, accurately, the clinical intent or the semantics of the record.

The traditional medical decision cycle is a specific example of a general decision cycle description as formulated by Boyd in the 1960s and 1970s, which is known as the Boyd Cycle or OODA Loop. (Figure 3) The relevance of Boyd’s Observation-Orientation-Decision-Action cycle to medicine is easier to understand when applied to every aspect of medical decision making – from the slow-motion management of neuro-degenerative disease to intra-ocular microsurgery. Cycle time can be a critical element in medical outcomes, particularly if physician decision making lags behind the disease process or anatomical complexity of the surgical field.

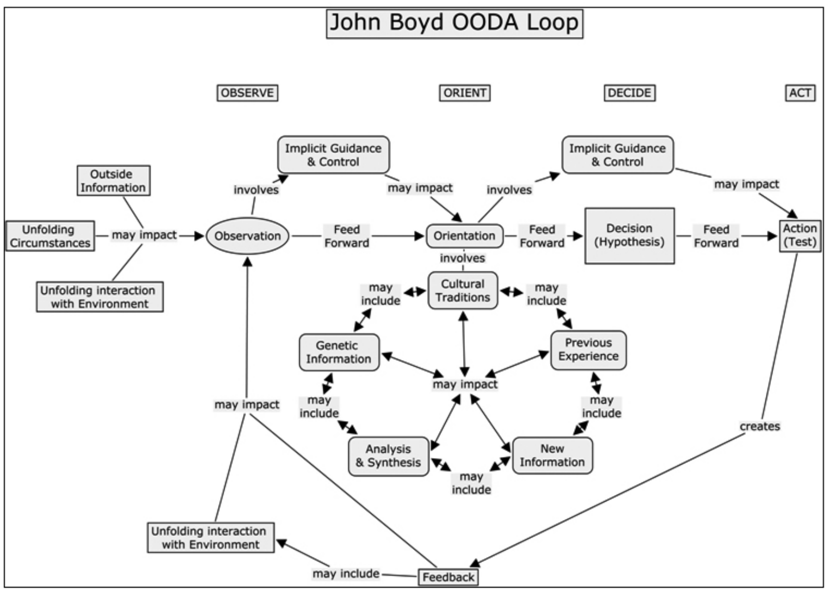

Figure 3. OODA Loop

The fundamental requirement of any clinical documentation system, written or electronic, is preservation for subsequent use of information that informs the evolution of the clinical decision cycle. This cycle is characterized by a process of examination, diagnosis, prognosis, and treatment. (See Figure 4) Examination is composed of the collection of empiric data in a process that is affected by cultural, environmental, scientific and other factors.

Then, considering such elements as the training and experience of the physician, the availability of particular diagnostic modalities, etc., a diagnosis is arrived at, which is a provisional explanation of the empiric findings. A prognosis is the element of the medical decision cycle that represents the clinician’s expectations for the on-going health state of the patient. Temporal, symptomatic, physiologic, etc. hypotheses may be articulated at this time. Therapy is the action that may be taken to intervene in the progress of the patient’s condition. The cycle continuously repeats until some conclusive endpoint is reached.

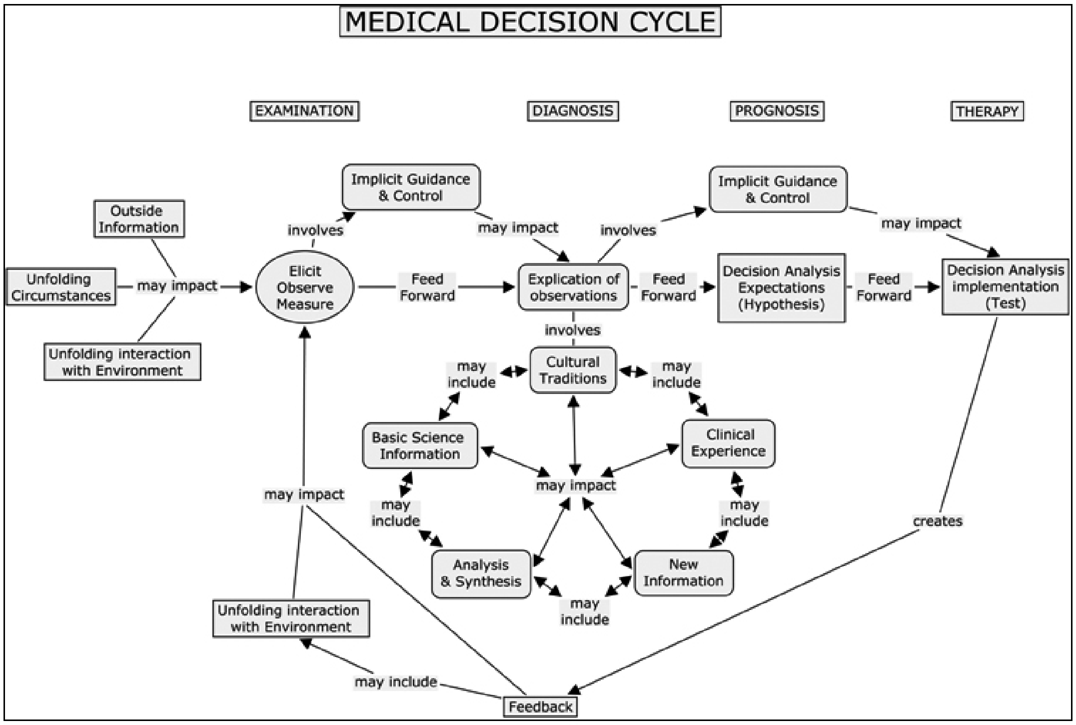

Figure 4. Medical Decision Cycle

The Boyd Cycle, which was first developed to describe the interactions of fighter pilots in aerial combat in the Korean War, is clearly instructive in showing the importance both of making the right decision and making it in the right time frame in the physician's fight for the patient's well-being (Figure 5).

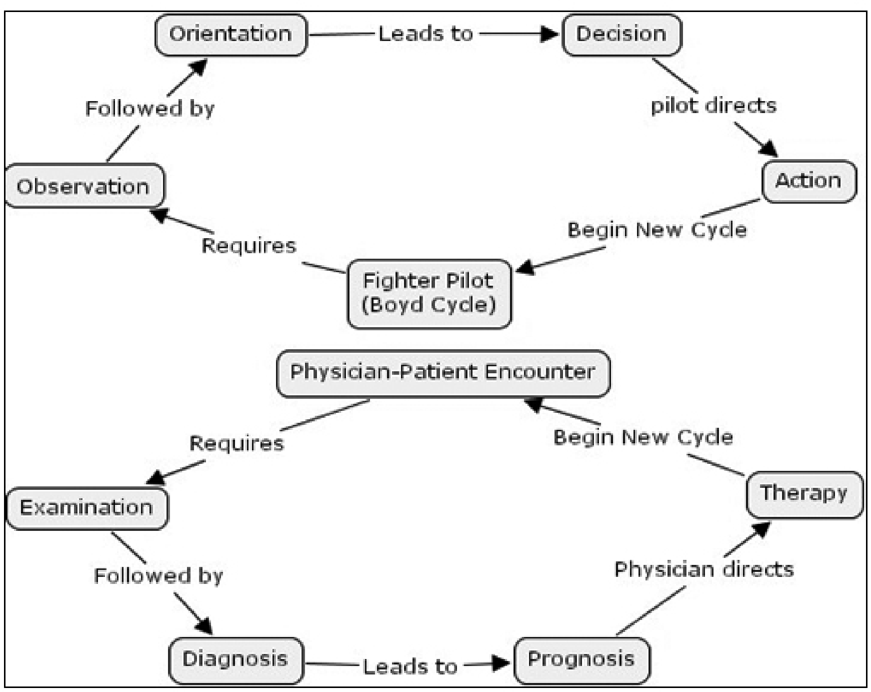

Figure 5. OODA Loop – Medical Decision Cycle

The other critical use of clinical documentation is to facilitate learning and discovery to improve the understanding and treatment of disease. The earliest uses of such documentation go back to the earliest written records of ancient civilizations where written and oral transmission of medical knowledge was used. The formal case study and the earliest epidemiologic research relied on careful observation and documentation that were supported by the evolution of the scientific method that began in the late Renaissance. Research of this type has continued to this day, with many modifications and refinements of design, interpretation, and mathematical analysis. The Double Blind Controlled Clinical Trial has been the Gold Standard of research for almost 50 years, with many successes to its credit. These studies have become increasingly complex, costly, and, in many cases, have outcomes where the difference between the successful and the unsuccessful may be statistically, but not particularly clinically, significant. There may be so many years between the beginning of these studies and their availability for evaluation, discussion, and incorporation into clinical practice that they may become obsolete by the time they are finished. The fundamental element of any clinical trial is the study protocol. A protocol standardizes not just the words of a study, such as a description of pain, but standardizes the meaning of the words, i.e., the semantics. This allows for the combination of standardized elements in order to perform comparisons and contrasts between populations. Standardization also brings the ability to extract, or factor, recurring or unique elements in the study population. The challenge of 21st century medical science is to develop the tools that are necessary to deal with the superficial, or phenotypic, human heterogeneity in the context of explosive discoveries in the underlying standardization, or genetics, of the human species.

The True Electronic Research Library (True ERL) initiative of the Washington National Eye Center has begun the development of tools to capture the detailed empiric descriptive knowledge that is necessary to completely, correctly, and continuously model one specialty area of clinical medicine, ophthalmology. We have been developing Cmaps with high complexities that capture clinical concepts that can be observed, measured, or elicited. Examples of such Cmaps are clinical descriptive models of the iris (Figure 6), and of the macula lutea of the retina (Figure 8).

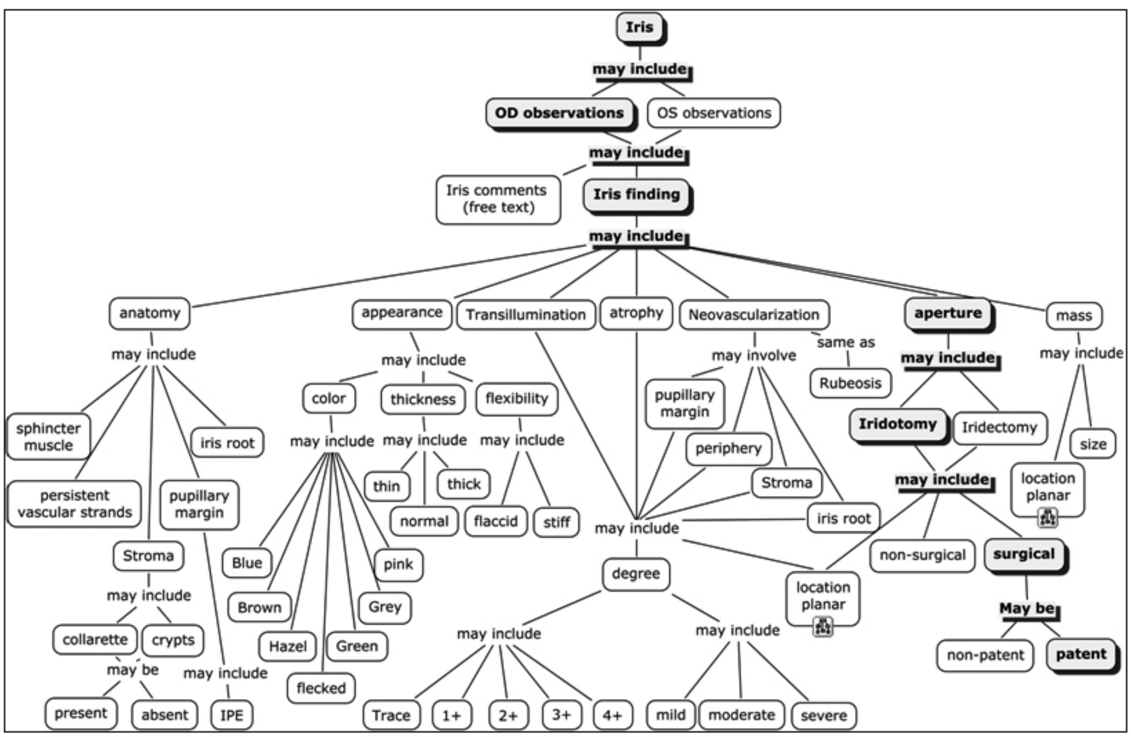

Figure 6. Iris Description Model

The highlighted propositional chain in Figure 6 may be considered as the foundation of a discrete, complete, and unique clinical statement. This clinical statement can be extracted as a linear Cmap (Figure 7) to clarify how this approach can be used to capture and store empiric data in a new and revolutionary way.

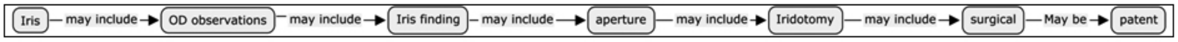

Figure 7. Iris Clinical Statement.

Figure 7 may be interpreted, in English, as:

The right (OD) iris has a finding which is an aperture which did not involve removal of iris tissue (which would be an iridectomy) by surgical means and which iridotomy is through-and-through the iris.

The Cmap of macular observations (Figure 8) with the linked sub-Cmaps (Figures 9 & 10) is a highly complex representation of what a comprehensive ophthalmologist may wish to describe on a clinical examination. It is almost certainly incomplete from the perspective of a retinal specialist. It is the power of the Cmap graphical and logical structure that easily permits additions and alterations in a knowledge model. Such knowledge models may, in turn, be used to construct a clinically useful electronic medical record (EMR).

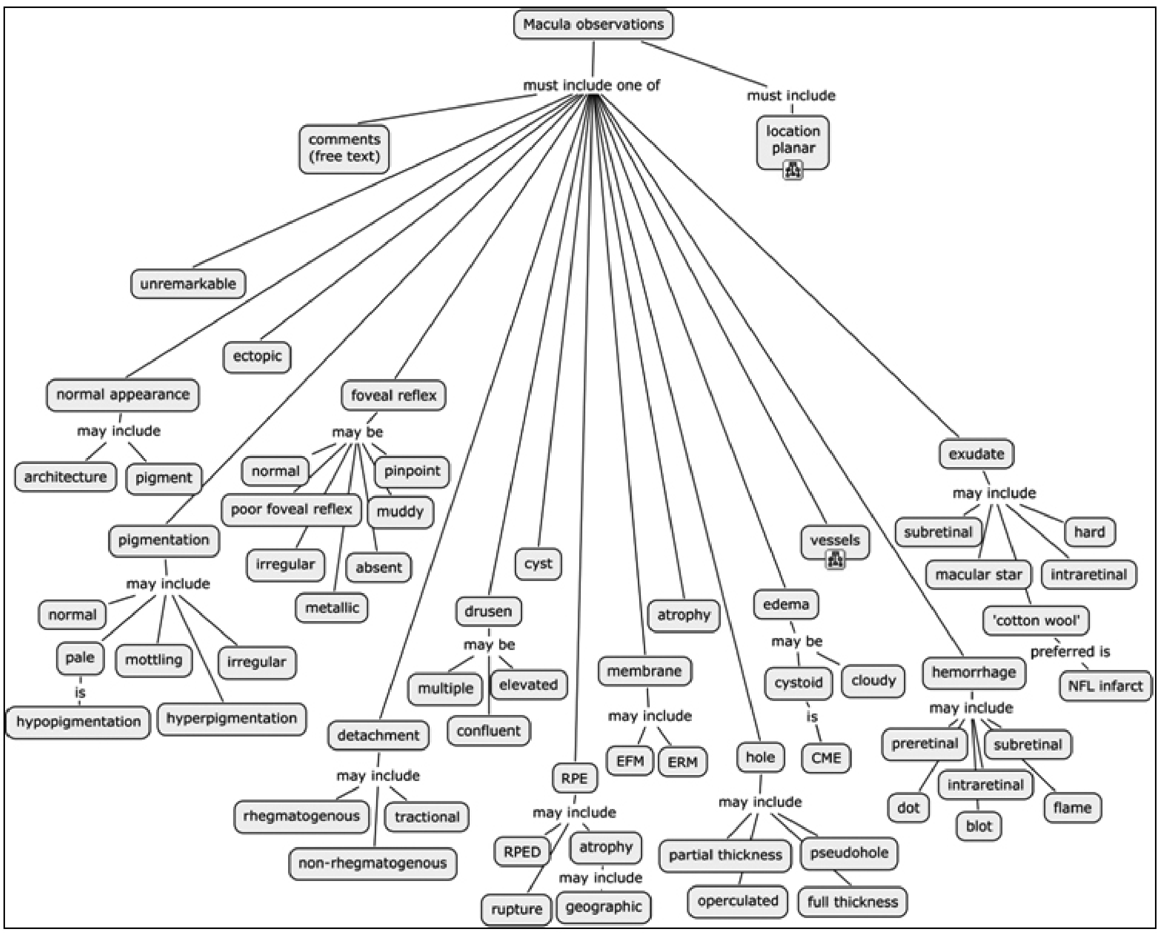

Figure 8. Macula lutea Description Model

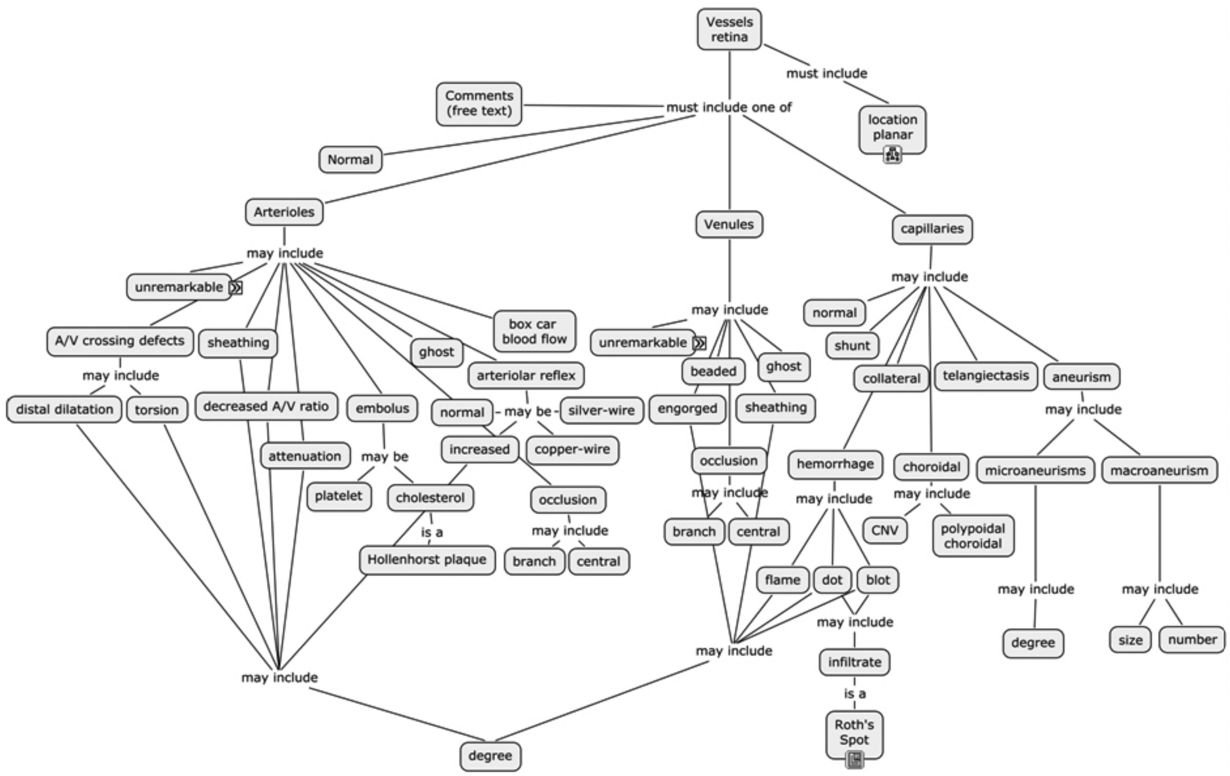

Figure 9. Vessels Retina linked Cmap from Fig. 8

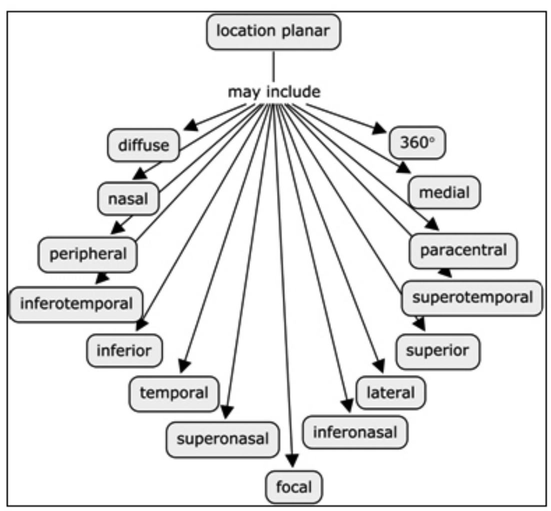

Figure 10. Location Planar linked Cmap from Figs. 6, 8, & 9

We intend to continue to elaborate these representations with the help of our specialty and sub-specialty colleagues. MedTrak Systems, an EMR and practice management systems developer and vendor, in collaboration with the True ERL, has developed software that can automatically convert Cmaps into EMR templates, checklists, etc. We believe that the tools and processes that the True ERL is developing for ophthalmology can be used to model the rest of medical knowledge. It is the purpose of this paper to introduce the use of concept mapping as a powerful tool in the continuous development and management of 21st century medical knowledge.

3 Summary

Medical knowledge structure and logic are highly complex. Simple hierarchical transactional and lexical models are not suitable to accurately reflect the practice of medicine as exemplified in clinical documentation and decision cycle analysis. Cmapping provides a tool that can significantly contribute to building a foundation for a dynamic, inclusive, collaborative, and cost-effective process of medical documentation that can meet the challenges of 21st century medicine.

4 Acknowledgements

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