

Decision Support in Dermatology and Medicine: History and Recent Developments

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This article is focused on diagnostic decision support tools and will provide a brief history of clinical decision support (CDS), examine the components of CDS and its associated terminology, and discuss recent developments in the use and application of CDS systems, particularly in the field of dermatology. For this article, we use CDS to mean an interactive system allowing input of patient-specific information and providing customized medical knowledge-based results via automated reasoning, for example, a set of rules and/or an underlying logic, and associations.

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As computing evolved, physicians and other researchers began exploring ways in which computer technology could be used to manage medical information and optimize health care delivery. The earliest efforts were focused on hospital information systems for recording and storing medical data and for administrative support, and on decision support tools to assist in patient care decision making.¹⁻¹⁰ This article is focused on decision support tools, specifically diagnostic decision support tools, and will provide a brief history of clinical decision support (CDS), examine the components of CDS and its associated terminology, and discuss recent developments in the use and application of CDS systems, particularly in the field of dermatology.

Diagnostic Decision Support

Much like the term “evidence-based medicine,” the term “clinical decision support” has, to some degree, become a buzzword and an industry cachet used broadly to describe almost any electronic medical information resource. There are many electronic clinical reference tools currently in use that, by the strictest definition, would not fall into the category of decision support systems but do facilitate efficient

access to a wealth of medical knowledge. These tools range from online books with electronic indices and text search functionality to more sophisticated databases with complex mappings of terminology and information. Although a few have broadly defined CDS as computer-based medical information, most in the field would choose a narrower definition suggesting the need to customize information to a specific patient or clinical scenario using > 1 variable.¹¹ For this article, we use CDS to mean an interactive system allowing input of patient-specific information and providing customized medical knowledge-based results via automated reasoning, for example, a set of rules and/or an underlying logic, and associations. In other words, CDS is the physician interacting with the computer source in real time to assist with thinking and decision making on a specific patient case. As in aviation, in medicine, human error can lead to injury and death. Similar to pilot resource management systems used to reduce pilot error,¹² CDS systems have the potential to increase a physician’s cognitive awareness, help them recognize their knowledge limitations, and assist with problem solving and decision making in a specific patient context.

Several notable computerized systems designed to aid clinicians in the diagnosis of disease—“diagnostic expert systems”—have emerged over the past 30 years. Starting in the 1980s, commercially released prototypes were being implemented for medical education and patient care. Although varied in methodology (ie, data organization, logic structure) and in subject matter (ie, specialized vs more general medicine), diagnostic expert systems all generate differential diagnoses by computing associations between patient-specific

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clinical findings (eg, patient signs and symptoms entered by the clinician during the patient encounter) and diseases. Besides generating differential diagnoses, the systems for the most part also provide general information on the diseases covered (etiology, pathology, predominating signs and symptoms, and therapy recommendations). This information is typically available via differential listings or search by disease, allowing for more efficient access to medical data than could be achieved by paging through textbooks or re-searching journal articles.

One of the earliest diagnostic tools developed was Iliad (University of Utah School of Medicine, Dept. of Medical Informatics, Salt Lake City, UT).¹³ It was first created in the 1980s to assist physicians with internal medicine diagnosis. Iliad uses Bayesian reasoning to calculate probabilities of diagnoses in relation to patient findings entered by the physician. DXplain (Massachusetts General Hospital Lab. of Computer Science, Boston, MA), also released in the 1980s, covers general medicine diagnosis.¹⁴ Using a modified form of Bayesian logic, the system ranks diagnostic possibilities from most likely to least likely on the basis of finding frequency and importance in relation to diagnoses. DXplain is presently used primarily as a clinical education tool but can also be used for clinical reference. Quick Medical Reference (University of Pittsburgh, PA; First DataBank, Inc., San Bruno, CA) is another diagnostic program for internal medicine that uses a non-Bayesian algorithm to assess associations between patient findings and individual diseases and produce a list of potential diagnoses.¹⁵ Isabel (Isabel Healthcare, Ltd., Haslemere, UK) is a diagnosis decision support system released in 2002. It was initially designed for pediatric medicine but now covers all age-groups. As with the other systems, it provides a list of possible diagnoses based on physician entry of patient data. It is unique in that it uses natural language processing, as will IBM's (Armonk, NY) soon-to-be-released Watson project in health care. Like other systems, Isabel links to external knowledge sources related to a disease (eg, journal article abstract). However it does not publish its own clinical content.¹⁶ There are others, too, such as PKC Advisor (PKC Corp., Burlington, VT), which uses combinatorial logic to provide differential diagnosis for a variety of problem-based topics, such as "chest pain" or "constipation." However, it does not publish its own clinical content.¹⁶ First introduced in 2001, VisualDx is an image-rich diagnostic CDS system that allows input of visual clues, symptoms, and patient history to assist physicians in diagnosis and management of diseases. A summary of CDS tool characteristics is provided in Table 1.

Building Blocks of CDS

CDS systems require certain foundational building blocks if they are to work safely, be in the workflow, and be interoperable with other systems such as the electronic medical record (EMR). Standardized terminology allows a CDS system to be interoperable with any other system by assuring that medical concepts are nonambiguous, discrete, and nonredundant. It is easy to imagine that different EMR systems

Table 1 Clinical Diagnosis Decision Support Systems

Iliad

Developed in early 1980s at Utah School of Medicine
Uses Bayesian logic to rank diagnostic probability
Covers >1,500 internal medicine diagnoses
No longer commercially available

Quick Medical Reference

Developed at University of Pittsburgh in 1980
Uses non-Bayesian reasoning for internal medicine diagnosis
More than 5,000 clinical findings mapped to >750 diseases
No longer commercially available, last update in 2001

DXplain

Developed in 1984 at Massachusetts General Hospital
Relational database covering >2,400 diseases, with full differentials for >5,000 clinical findings
Currently in use by hospitals and medical schools

PKC Advisor

Developed by Dr. Lawrence Weed at the University of Vermont
Uses combinatorial logic to provide differential diagnosis for a variety of problem-based topics
Commercially available to institutions

Isabel

Launched in 2002 with support from UK National Health Service and UK Department of Health
Search engine allowing natural language processing of patient-specific queries
Licenses/links to 100,000 documents
Commercially available to individuals and institutions

VisualDx

Released through a partnership with the University of Rochester in 2001
First visual diagnostic decision support system
Relational database covering >1,200 disease topics and containing >24,000 images, approximately 36,000 finding–diagnosis relationships, and >5,000 medication–disease relationships
Commercially available to individuals and institutions

might use differing lists of symptoms, signs, diagnoses, and other terms. However, if digital systems are going to communicate accurately, there must be shared standardized terms to ensure reliability and prevent error. In the field of dermatology, one of the first large-scale efforts to standardize terminology was the British Association of Dermatologists (London, UK) lexicon project led by Dr Robert Chalmers. The National Institute of Arthritis and Musculoskeletal and Skin Diseases (Bethesda, MD) also recognized a need to develop a dermatology lexicon and funded the Dermatology Lexicon Project in 2001.¹⁷ The American Academy of Dermatology (Schaumburg, IL) assumed responsibility of the Dermatology Lexicon Project in 2006, renaming it DermLex™. DermLex™ is freely available, and can be viewed and downloaded from <http://www.aad.org/dermlex/>.

Dermatology-specific terminologies must fit into a broader terminological framework, and current efforts are planned to ensure that dermatology-specific vocabularies are tied to na-

tional and international efforts such as the Systemized Nomenclature of Medicine Clinical Terms, or SNOMED CT (IHTSDO, Copenhagen, Denmark). SNOMED CT is the largest, most comprehensive terminology of medicine and can be used to make CDS systems interoperable with electronic records. It should be noted that the International Classification of Diseases (ICD) system (WHO, Geneva, Switzerland) is inadequate for representing medical concepts for clinical information. ICD is not a comprehensive terminology, and its use as a clinical informatics terminology should be discouraged. Other important clinical terminology databases include the Online Mendelian Inheritance in Man (<http://www.ncbi.nlm.nih.gov/omim>) and the Unified Medical Language System (<http://www.nlm.nih.gov/research/umls/>) of the National Library of Medicine (Bethesda, MD), which can be conceptualized as a “warehouse” for the terminologies of medicine.

CDS systems use differing logic and functional techniques to deliver patient-conceptualized data to the user. Nonprobabilistic, probabilistic, and rules-based systems, algorithms, and other techniques are used to represent clinical information and suggest diagnoses, proper testing, patient management, therapy, or other guidance. Many systems use standardized terminology and a knowledge engine to construct relationships between findings. The relationships between medical findings, diagnosis, and therapies, as well as accurate representation of the semantic meaning, underpin the development of a quality knowledge database or knowledge engine. Newer techniques in CDS include natural language processing. Whatever the technique, the goal is to represent unique patient data, and to assist the clinician user with more contextualized and organized knowledge to guide care.

History of Dermatology CDS

Differential diagnosis generation in dermatology can be traced back to the 1970s, with the development of a program to diagnose febrile illness with eruption, as reported by Hadley et al.¹⁸ The system used Bayesian reasoning to determine a diagnosis based on entry of findings related to demographic data, recent history, fever history, drug history, lesion types, distribution of lesions, and number of lesions. Several additional efforts were undertaken throughout the next few years to see whether computing could assist diagnosis, including the development of the DERM/DDX expert system by the American Academy of Dermatology, DIAG at the University of Toronto,¹⁹ AI/DERM EXPERT program for diagnosis of skin tumors at the University of Missouri Health Sciences Center, and TEGUMENT at the University of Illinois.²⁰ These early programs used various methods to reach a diagnosis, with some using probabilistic techniques and others using cognitive models. The AI/DERM EXPERT tumor database, developed by Vanker and Van Stoecker,²¹ used visual features to describe and index the tumors, and for each diagnosis, there was a high-quality photograph of the lesion as well as stored expert visual findings from a checklist. Work throughout the late 1980s and early 1990s focused on image analysis of lesions and pattern recognition software, primar-

ily for melanoma identification.²²⁻²⁵ Although these early diagnostic CDS systems laid the foundation for future commercialized diagnostic systems such as VisualDx (Logical Images, Inc, Rochester NY), they remained primarily academic and did not receive widespread adoption.

Adoption/Shifting Paradigms

Expert diagnostic systems have continued to evolve in platform, content, and sophistication, yet they have not been widely adopted in the clinical setting. This is due to multiple factors, including (1) past physician/medical culture, (2) inconsistent adoption of technology by practices and institutions, and (3) workflow integration challenges. The first 2 of these barriers have been diminished significantly because physicians increasingly use and rely on technology to access and manage the flood of medical information available, including guidelines, “best evidence,” and voluminous journals, texts, and online resources.²⁶ In addition, the federal government continues to push for widespread implementation of electronic health resources via the American Recovery and Reinvestment Act stimulus legislation, of which \$19.2 billion was apportioned under the Health Information Technology for Economic and Clinical Health Act for increasing use of electronic health records (EHRs) by physicians and hospitals.

Physician Adoption

As the field of medicine has become ever more complex and specialized, there has been a paradigm shift in medical education and medical practice from an insistence on the memorization of facts and reflexive care to problem solving and memory-assisted care using electronic and Web-based resources. From the 1970s through the 1990s, most physicians who used computers only did so for practice management, such as billing and scheduling. However, by the late 1990s, a new generation of physicians began using inexpensive easy-to-use handheld devices, quickly adopting technology to bolster memory.²⁷ Today, the use of electronic resources is second nature for most medical students and physicians. Many medical schools require third- and fourth-year students to own a mobile device. In addition, according to a 2007 study published in *Family Medicine*, > 87% of all the residents and faculty surveyed used a personal digital assistant.²⁸

Software such as Epocrates (Epocrates, Inc., San Mateo, CA) can be accessed on a personal digital assistant, supplying information on diseases, drug interactions, pricing, dosing, ICD-9 codes, and continuing medical education, as well as a medical dictionary. Physicians now routinely use medical information references, such as eMedicine (Medscape, LLC, New York, NY), UpToDate (UpToDate, Inc., Wolters Kluwer Health, Philadelphia, PA), Clin-eGuide (Wolters Kluwer Health, Conshohocken, PA), MD Consult (Elsevier, Inc., Maryland Heights, MO), and even Google (Google, Inc., Mountainview, CA), to address clinical questions at the point of care. In the past, physicians questioned whether they

would use these tools (or for that matter, even open a medical book) in front of the patient, concerned that the patient might think the doctor was admitting a lack of knowledge. Now with patients persistently using the Internet for health information before and after their visits, patients expect to see the doctors using professional tools on computers and mobile devices to fact-check as they go.

Arguably, just as important has been the body of research examining how doctors think and investigating potential cognitive biases that can lead to error and patient harm, summarized in Groopman's book, *How Doctors Think*.²⁹ Groopman looked at the work of Croskerry and other researchers studying cognitive bias. In one study of 100 cases of diagnostic error (90 injuries, including 33 deaths), 74% were attributed to errors in cognitive reasoning, with the most common cause of misdiagnosis being the failure to consider reasonable alternatives after early possible diagnosis.³⁰ Other common cognitive causes of diagnostic error include physician overconfidence,³¹ faulty context generation, misjudging findings, faulty perception, and errors connected with the use of shortcuts (heuristics).³² Thus, today's physicians possess an increased cognitive awareness and a willingness to examine potential cognitive biases in their own decision-making processes, as nearly 70% of health care providers are looking for ways to improve diagnostic accuracy.³³

Federal Health Information Technology Measures

The ARRA stimulus legislation, with 2 stages of meaningful use criteria defined, has created powerful financial incentives, as well as penalties, to implement EHRs, clinical references, and CDS tools. Dermatologists, like other physicians, are now on the steep adoption curve for EMRs. With electronic records installed, new opportunities to embed intelli-

gent algorithms and thus CDS into the dermatology workflow now exist.

To conceptualize the potential benefits of CDS in dermatology, it is best to think of the continuum of care beginning with the very first interaction of the patient with the dermatologist and consider how CDS might impact care from that first interaction all the way through to the completion of the patient encounter and/or subsequent follow-up. Consider this flow:

1. Gathering of past medical history and present history, representation of historical data, and presentation of data to physician.
2. Differential diagnosis generation.
3. Testing recommendations (if needed).
4. Pattern analysis (if needed).
5. Management and therapeutic recommendations.
6. Disease state monitoring.

Systems to gather pertinent patient data and thereby replace the paper clipboard in the waiting room already exist. More than a decade ago, CDS systems such as PKC and medicalhistory.com suggested that computer-based history acquisition could not only be more efficient, but also develop a more accurate and detailed history in advance of the patient entering the examination room.³⁴ Certainly, within the field of dermatology, new tablet-, mobile-, and home-based history input will evolve quickly as the EMR evolves.

Interoperability and Integration of CDS with the EHRs

Driving "intelligence" into the digital workflow is the goal of interoperability. At the highest level, there are 2 different approaches to CDS integration, a "push" approach and a "pull" approach. A "push" approach means that the user is

Figure 1 Interoperability between an electronic health record (EHR) and a clinical decision support (CDS) system (VisualDx) using the Health Level Seven International (HL7) Infobutton standard. The user selects "terbinafine" from the patient medication list by clicking the infobutton icon, and the CDS system produces a corresponding set of results.

receiving an alert, reminder, or any data without requesting it. The system is designed to anticipate an information need and automatically pushes that reminder or alert to the user. “Pop-up” windows and other automated “flags” guide and instruct, but they come with a price: alert fatigue. Usability research shows that if there are too many alerts in any system, then almost all alerts will eventually be ignored. “Pull” CDS, in contrast, means that the user must request the contextualized information. The most widely used technique to represent available CDS information is the “infobutton.”³⁵ A number of EHRs and CDS systems have adopted the Health Level Seven International (HL7) Infobutton standard facilitating interoperability between systems (Fig. 1). The infobutton strategy eases user input: instead of retyping your search in the CDS system, standard terms are interchanged from the electronic record to the CDS system with just a click of the infobutton.

Unique Needs of Dermatology and Other Visual Specialties

Dermatologists are generally expert diagnosticians; however, infrequently, patients do present with skin findings that are ambiguous and do not instantly suggest the correct diagnosis. Areas of diagnostic CDS opportunities in dermatology lie in assistance for memory-intensive areas such as medication reactions, geographic relationships, and diagnoses where a rich history is necessary, such as an urticarial or allergic contact dermatitis.

Medication Reactions

Medication reactions have differing severity and effect. All too often, clinicians fail to promptly identify, classify, and diagnose medication reactions, or discontinue a medication, believing a reaction is present when it is not. Existing widely-used medication databases include some adverse event information but are not optimized to assist clinicians in identifying and visually recognizing medication reactions with precision, timeliness, and accuracy. Most available resources supply adverse event data from original drug trials, inadequately reflecting the true prevalence of actual reactions. The skin and mucosa is often the first site of a reaction, including life-threatening disease reactions. Existing medication reaction resources will list “rash” and perhaps the life-threatening Stevens–Johnson syndrome and TEN reactions but fail to include guidance on the full set of possible reactions. Of these, 2 CDS systems that provide fuller differentials for the possible adverse reactions for each drug are Litt’s DERM database (Informa Healthcare, London, UK) and the Drug Eruption module in VisualDx.

Litt’s DERM database, built from the Litt’s Drug Eruptions Reference Manual textbook, is a comprehensive database indicating adverse reactions and drug–drug interactions.³⁶ The system is searchable by both reaction and medication and provides link-outs to PubMed citations supporting each medication–reaction relationship. The VisualDx Drug Eruptions module is part of a CDS database that is searchable by

medication, skin or mucosal reaction patterns, or other symptomatology. The database covers > 100 medication reactions, each with handbook-length text, images of the reaction, and associated medications and findings. Each medication–reaction relationship is hyperlinked to PubMed evidence. Within VisualDx, > 700 medications are searchable. Each search by medication provides an adverse event result ordered by the highest number of PubMed references to the reactions with the fewest references. As an example, terbinafine is associated with 21 cutaneous adverse reactions (Fig. 1).

Geographic Relationships

Recalling the relationships between foreign travel or infectious disease exposure in an immigrant and the diseases found within a particular geographic area is almost impossible, particularly during the patient visit. Two CDS systems that are designed to search by state or country for infectious disease relationships are Global Infectious Diseases and Epidemiology Online Network (GIDEON [GIDEON Informatics, Inc., Los Angeles, CA]) and VisualDx. First launched in 1992, GIDEON is a diagnostic Web application covering the relationships of > 340 infectious diseases and 231 countries. The database is searchable by country, symptom, exposure, or medication.³⁷ With similar capabilities to GIDEON, VisualDx covers infectious diseases that present with cutaneous findings and allows users to additionally search by lesion type, endemic country, exposures, medications, laboratory findings, and body location.

Allergic Contact Dermatitis

The evaluation of the patient with possible allergic contact dermatitis can involve a lengthy investigation for occult allergens. CDS has great potential to guide the patient history, assessment, and eventual patient recommendations. Complex and almost-impossible-to-memorize relationships between occupations and related workplace allergens have typically only been discoverable in books. Embedding occupation-to-allergen relationships in a relational CDS structure can bring a more complete contact dermatitis evaluation to the point of care. A unique and successful effort supported by the North American Contact Dermatitis Society also brings CDS to patient recommendations.³⁸ Once the patient allergen(s) is identified, patients want to know which products they can use safely. The Contact Allergen Replacement Database, now part of the American Contact Dermatitis Society Contact Allergen Management Program database, is an available resource found online.³⁹

Other Uses of CDS in Dermatology

Testing Recommendations (Case Example 1)

Your patient, 62 years old with lymphoma, recently received a bone marrow transplant and now appears to have quickly developed palpable purpura. What is the most appropriate workup? Ideally, CDS will guide you, recommending the

most appropriate tests as you consider your patient assessment.

Management and Therapeutic Recommendations (Case Example 2)

Your patient is on thalidomide and hydroxychloroquine for discoid lupus erythematosus. Your electronic record automatically monitors the laboratory follow-up and ensures patient compliance with automated e-mails and telephone calls. Your CDS system ensures laboratory studies are obtained at recommended intervals and results are forwarded to you.

Disease Monitoring Over Time

Providing excellent care over time for chronic diseases such as wound care, acne, and atypical nevi is now achievable with digital imaging, electronic records, and CDS. Automated methods to track nevi for change, such as MelaFind⁴⁰ and MoleMax,⁴¹ and programs to monitor acne are evolving quickly to replace text-based charting with visual CDS.

Conclusions

The medical profession is just now beginning to take advantage of interactive computing to enhance medical knowledge and care. Although visionary attempts in computerized CDS for dermatology first occurred > 30 years ago, it is only now that practical digital tools for dermatology are becoming widely used. These tools are designed to improve care throughout the patient encounter, from assisting with pertinent history acquisition to differential diagnosis generation and all the way through to patient management, therapy, and monitoring. As we are still at the beginning of this digital revolution in health care, a future with further innovation is certain. This future will certainly lead to new approaches and care delivery methods that will make our dermatology practices safer, more reliable, and consistent in care delivery. Our patients will wonder what took us so long.

References

- Barrett JP, Barnum RA, Gordon BB, et al: Evaluation of a Medical Information System in a Community Hospital. Columbus, OH, Battelle Columbus Laboratories, 1975. Report No. NTIS PB 248 340.
- Staggers N, Thompson CB, Snyder-Halpern R: History and trends in clinical information systems in the United States. *J Nurs Scholarsh* 33:75-81, 2001
- Kuperman GJ, Gardner RM, Help PTA: *A Dynamic Hospital Information System*. New York, NY, Springer-Verlag, 1991
- McDonald CJ, Overhage JM, Tierney WM, et al: The Regenstrief medical record system: A quarter century experience. *Int J Med Inform* 54:225-253, 1999
- Wiederhold G, Perreault L: Hospital information systems, in Shortliffe EH, Perreault LE, eds. *Medical Informatics: Computer Applications in Healthcare*. Reading, MA, Addison-Wesley, 1990, pp 219-242
- Barnett GO: The computer and clinical judgment. *N Engl J Med* 307:493-494, 1982
- Berner ES, Webster GD, Shugerman AA, et al: Performance of four computer-based diagnostic systems. *N Engl J Med* 330:1792-1796, 1994
- de Dombal FT: Computer-aided decision support in clinical medicine. *Int J Biomed Comput* 24:9-16, 1989
- Miller RA: Medical diagnostic decision support systems—Past, present, and future: A threaded bibliography and brief commentary. *J Am Med Inform Assoc* 1:8-27, 1994
- Shortliffe EH: Computer programs to support clinical decision making. *JAMA* 258:61-66, 1987
- Richardson JE, Ash JS, Sittig DF, et al: Multiple perspectives on the meaning of clinical decision support. *AMIA Annu Symp Proc* 2010:1427-1431, 2010
- Wiener EL, Nagel DC: *Human Factors in Aviation (Cognition and Perception)*. San Diego, CA, Academic Press, 1988
- Warner HR Jr: Iliad: Moving medical decision-making into new frontiers. *Methods Inf Med* 28:370-372, 1989
- Barnett GO, Cimino JJ, Hupp JA, et al: DXplain: An evolving diagnostic decision-support system. *JAMA* 258:67-74, 1987
- Miller R, Masarie FE, Myers JD: Quick medical reference (QMR) for diagnostic assistance. *MD Comput* 3:34-48, 1986
- Ramnarayan P, Tomlinson A, Kulkarni G, et al: A novel diagnostic aid (ISABEL): Development and preliminary evaluation of clinical performance. *Stud Health Technol Inform* 107:1091-1095, 2004
- Papier A, Chalmers RJ, Byrnes JA, et al: Framework for improved communication: The dermatology lexicon project. *J Am Acad Dermatol* 50:630-634, 2004
- Hadley TP, Geer DE, Bleich HL, et al: The use of digital computers in dermatologic diagnosis: Computer-aided diagnosis of febrile illness with eruption. *J Invest Dermatol* 62:467-472, 1974
- Haberman HF, Norwich KH, Diehl DL, et al: DIAG: A computer-assisted dermatologic diagnostic system—Clinical experience and insight. *J Am Acad Dermatol* 12:132-143, 1985
- Stoecker WV: Computer-aided diagnosis of dermatologic disorders. *Dermatol Clin* 4:607-625, 1986
- Vanker AD, Van Stoecker W: An expert diagnostic program for dermatology. *Comput Biomed Res* 17:241-247, 1984
- White R, Rigel DS, Friedman RJ: Computer applications in the diagnosis and prognosis of malignant melanoma. *Dermatol Clin* 9:695-702, 1991
- Rajpara SM, Botello AP, Townend J, et al: Systematic review of dermoscopy and digital dermoscopy/artificial intelligence for the diagnosis of melanoma. *Br J Dermatol* 161:591-604, 2009
- Chen J, Stanley RJ, Moss RH, et al: Colour analysis of skin lesion regions for melanoma discrimination in clinical images. *Skin Res Technol* 9:94-104, 2003
- Cascinelli N, Ferrario M, Bufalino R, et al: Results obtained by using a computerized image analysis system designed as an aid to diagnosis of cutaneous melanoma. *Melanoma Res* 2:163-170, 1992
- Custers EJ: Long-term retention of basic science knowledge: A review study. *Adv Health Sci Educ Theory Pract* 15:109-128, 2010
- Yu F, Houston TK, Ray MN, et al: Patterns of use of handheld clinical decision support tools in the clinical setting. *Med Decis Making* 27:744-753, 2007
- Morris CG, Church L, Vincent C, et al: PDA usage and training: Targeting curriculum for residents and faculty. *Fam Med* 39:419-424, 2007
- Groopman J: *How Doctors Think*. New York, NY: Houghton Mifflin, 2007
- Graber ML, Franklin N, Gordon R: Diagnostic error in internal medicine. *Arch Intern Med* 165:1493-1499, 2005
- Berner ES, Graber ML: Overconfidence as a cause of diagnostic error in medicine. *Am J Med* 121(suppl 5):S2-S23, 2008
- Croskerry P: The importance of cognitive errors in diagnosis and strategies to minimize them. *Acad Med* 78:775-780, 2003
- Medical Records Institute. Seventh Annual Survey of Electronic Health Record Trends and Usage for 2005. Available at: <http://www.ehto.org/2006/US%20Medical%20Records%20Institute%20-%20Results%20of%20the%20EHR%20global%20survey%20in%202005.pdf>. Accessed March 1, 2012
- Apkon M, Matterna JA, Lin Z, et al: A randomized outpatient trial of a decision-support information technology tool. *Arch Intern Med* 165:2388-2394, 2005
- Infobuttons CJ: Anticipatory passive decision support. *AMIA Annu Symp Proc* 1203-1204, 2008

36. Available at: <http://www.drugeruptiondata.com/>. Accessed March 1, 2012
37. Available at: <http://www.gideononline.com/>. Accessed March 1, 2012
38. El-Azhary RA, Yiannias JA: A new patient education approach in contact allergic dermatitis: The contact allergen replacement database (CARD). *Int J Dermatol* 43:278-280, 2004
39. Available at: <http://www.contactderm.org/i4a/pages/index.cfm?pageID=3489>. Accessed March 1, 2012
40. Monheit G, Cognetta AB, Ferris L, et al: The performance of MelaFind: A prospective multicenter study. *Arch Dermatol* 147:188-194, 2011
41. Patel JK, Konda S, Perez OA, et al: Newer technologies/techniques and tools in the diagnosis of melanoma. *Eur J Dermatol* 18:617-631, 2008