Clinical Decision Support Systems (CDSSs)—at least those whose effectiveness has been evaluated—perform one or more of the following functions: diagnosis, drug dose determination, preventive care reminders, and active (diagnostic or therapeutic) care advice.¹ These applications and some recent examples—including ones whose effectiveness has not been evaluated—are discussed in the following sections. With most of these systems, clinicians do not interact directly with the computer; rather, staff personnel input the needed data on the patient and provide the clinician with computer-printed reports.²

**COMPUTER-AIDED DIAGNOSIS**

These systems are designed to assist the clinician in determining the patient’s exact diagnosis or the condition underlying his/her presenting health problem. The systems take as input the patient’s signs and symptoms, physical findings, test results, and background information, and then report one or more possible diagnoses that match that combination of characteristics. The patient data must ordinarily be manually key-entered in a particular format required by the system. Rather than attempting to cover all diagnoses, most systems focus on specific health problems.

¹ Johnston et al., op. cit., footnote 1. Connelly and Bennett propose a similar scheme for classifying the functions of knowledge-based systems that have clinical laboratory applications: classify (e.g., diagnosis), predict (e.g., adverse events), plan (i.e., recommend specific actions), monitor (including alerts, reminders, and process control/scheduling), facilitate (make a human task easier), and convey (present data, conclusions, etc.). D.P. Connelly and S.T. Bennett, “Expert Systems and the Clinical Laboratory Information System,” *Clinics in Laboratory Medicine*, vol. 11, No. 1, March 1991, pp. 136-138.

² Johnston et al., op. cit., footnote 1, p. 137.
However, several systems, including Dxplain, Iliad, Meditel, and QMR, are designed to address the entire field of internal medicine. They employ either deterministic or probabilistic/adaptive algorithms to produce a list of possible diagnoses, ranked in order of likelihood.

**DRUG DOSE DETERMINATION**

These systems are designed to assist the clinician in determining the proper dosage of a specific drug for a particular kind of patient. Some evidence suggests that clinicians have a particularly difficult time calculating drug dosages. Again, data on the patient is usually entered manually in a format required by the system. (The patient’s diagnosis is usually assumed by the system, based on the drug being used.) The algorithms in the knowledge base then ascertain the proper dosage of the drug in question, either as an exact quantity or as a permissible range. One example of such a system generates estimates for dosing of aminophylline for acute asthma cases presenting in the emergency room. Commercial programs have also been developed for dosing of selected drugs based on patient-specific characteristics and measured drug concentrations.

**PREVENTIVE CARE REMINDERS**

These systems are designed to remind the clinician to administer a particular preventive service when the patient reaches a certain stage in the process of care for a given health problem (e.g., retinal examination for diabetics), or simply a certain stage of life (e.g., immunization). Unlike computer-aided diagnosis and drug-dose determination, which are usually designed to provide a single report in response to a specific set of data on a given patient, a preventive care reminder system requires repeated input of data on the patient over time. This includes not only the patient’s diagnoses and other clinical characteristics, but also the treatments and tests administered and when they were administered. To the extent that the set of rules for generating reminders represents a model of the disease process for which a preventive service is to be administered, they constitute a type of formal clinical protocol.

The protocol specifies exactly what preventive treatments should be performed at each stage in the process of care for the health problem at hand, based either on the amount of time that has elapsed since the previous stage (e.g., a previous treatment or test) or on data values measuring the patient’s

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3 Massachusetts General Hospital, Boston, MA.
4 Applied Informatics, Salt Lake City, UT.
5 Meditel, Devon, PA.
6 CAMDAT, Pittsburgh, PA.
11 Dasta et al., op. cit., footnote 1.
condition at that point in time. The Regenstrief Medical Record System at Indiana University\textsuperscript{12} was apparently the first CDSS to develop a comprehensive set of preventive care reminders, for example, to administer influenza vaccinations.\textsuperscript{13} More specialized examples include two systems that provide reminders to perform blood pressure measurement and cervical cancer screening, respectively.\textsuperscript{14} The HealthQuiz program elicits background information and risk factors from patients, then compares their answers to detailed preventive care guidelines, flags problems, and recommends appropriate interventions.\textsuperscript{15}

**ACTIVE-CARE ADVICE**

These systems are designed to assist the clinician in performing diagnostic or therapeutic procedures (including pharmaceutical treatments) when the patient reaches certain stages in the process of care for a given health problem, again often modeled in a formal clinical protocol. An active-care advisory system requires repeated input of data on the patient’s health problems, tests, and treatments over time. The protocol specifies exactly what diagnostic and therapeutic procedures should be performed at each stage in the process of care for the health problem at hand. This type of computer-based clinical advice can take six basic forms:

1. **Treatment recommendations** (including pharmaceuticals) appropriate for the health problem at hand, for example, the MYCIN program that provides diagnostic and treatment advice for patients with meningitis,\textsuperscript{16} and the antibiotic consultant component of the Health Evaluation through Logical Processing (HELP) system at LDS Hospital in Salt Lake City, Utah, that recommends appropriate antibiotics in light of the patient’s characteristics and specific infection, drawn from an electronic medical record.\textsuperscript{17}

2. **Reminders** to the clinician to perform specific diagnostic or therapeutic procedures at certain stages in the process of caring for the health problem at hand, such as adult respiratory distress syndrome in the HELP system.\textsuperscript{18}

3. **Alerts** to the clinician regarding potential adverse events, for example, worsening of the patient’s condition, based on feedback of abnormal test results.\textsuperscript{19}

4. **Feedback** (including alerts) regarding orders that the clinician entered for the patient, including:
   - possibly inappropriate treatments, given the patient’s complicating health problems and/or

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background characteristics (even if the treatment would otherwise be appropriate for the health problem at hand), for example, alerts regarding drug allergies in the order-entry system at Brigham and Women’s Hospital in Boston;20

- possibly inappropriate treatments regardless of the patient’s health problems or characteristics, for example, commercial programs to detect drug-drug and drug-nutrient interactions;21
- likely conflict or redundancy between a chosen test and others already ordered for the patient;22
- likely results of a test ordered for the patient; if the probability of an abnormal result is low, the clinician can reconsider whether the test is really worth performing;23
- results of previous tests on the patient that are like the one being ordered, so the clinician may reconsider whether the test really needs to be repeated;24
- the cost of a test or treatment ordered for the patient, so the clinician can reconsider whether it is really worth performing;25 and
- tests or treatments that would be less costly than the one ordered, but equally effective in treating the health problem at hand.26

5. Prompts to the clinician for decisions regarding testing or treatment options, or for entry of information on the patient’s health problems or background, as in the drug order-entry system at Brigham and Women’s Hospital.27

6. Prognoses of intensive care unit patients based on such predictors as severity of illness (using vital signs and other physical measures) and physiological reserve (age and complicating health problems) in the Acute Physiology and Comprehensive Health Evaluation (APACHE) system.28 APACHE is also used as a method of measuring severity of illness and risk-adjusting outcome measures.29 An expanded prognostic model known as SUPPORT (Study to Understand Prognoses and Preferences for Outcomes and Risks of Treatments) is designed to predict survival to 180 days (rather than to discharge) and includes patients who are not severely ill.30

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22 Connelly and Bennett, op. cit., footnote 2.


