
Richard N. Shiffman, MD, MCIS, Yischron Liaw, MD, Cynthia A. Brandt, MD, MPH, Geoffrey J. Corb

Abstract In this systematic review, the authors analyze the functionality provided by recent computer-based guideline implementation systems and characterize the effectiveness of the systems. Twenty-five studies published between 1992 and January 1998 were identified. Articles were included if the authors indicated an intent to implement guideline recommendations for clinicians and if the effectiveness of the system was evaluated. Provision of eight information management services and effects on guideline adherence, documentation, user satisfaction, and patient outcome were noted.

All systems provided patient-specific recommendations. In 19, recommendations were available concurrently with care. Explanation services were described for nine systems. Nine systems allowed interactive documentation, and 17 produced paper-based output. Communication services were present most often in systems integrated with electronic medical records. Registration, calculation, and aggregation services were infrequently reported. There were 10 controlled trials (9 randomized) and 10 time-series correlational studies. Guideline adherence improved in 14 of 18 systems in which it was measured. Documentation improved in 4 of 4 studies.


Despite the considerable effort and resources that have been invested in the development and dissemination of clinical practice guidelines, there continues to be considerable variation in the effectiveness of guidelines to bring about changes in the behavior of clinicians. A number of studies have found that, despite serious initiatives on the part of national organizations to develop and disseminate guidelines, practitioners may still ignore them.1–6

Greco and Eisenberg7 devised a general taxonomy of methods that may be used to influence clinician behavior. These include education, feedback, participation by physicians in efforts to bring about change, administrative rules, financial incentives, and penalties. Several investigators have attempted to identify which factors in guideline implementation strategies are most efficacious. Davis and Taylor-Vaisey8 found that reminder systems, academic detailing, and the use of combined interventions were most effective.

Grimsbaw and Russell9 found that the guideline implementation strategies most likely to be effective were those that delivered patient-specific advice at the time and place of a consultation. Computers can provide, concurrent with care, advice that is tailored to the needs of individual patients. A systematic review by Johnston et al.10 found that computer-based decision support can improve clinician performance.

Any computer-based tool is more likely to work if it is integrated with clinical activities. Elson11 pointed out the critical role of workflow integration for effective guideline implementation. To be accepted, guide-
line implementation applications should give back to
the user something of value to offset the inconven-
ience of using the system.

In the course of developing a computer-based guideline
implementation system to assist in the manage-
ment of childhood asthma and in creating additional
tools, we identified eight information management
services that promote workflow integration—recom-
mendation, documentation, registration, communication,
calculation, explanation, presentation, and aggrega-
tion. Each service adds value to a computer
application that should translate to an increased prob-
ability for success. In addition, the services provide a
structure for comparison and evaluation of dissimilar
implementations.

Because both successful and unsuccessful strategies
have provided many of these services, we sought to
perform a detailed analysis of the functionality deliv-
ered by current computer-based implementation sys-
tems. In this paper, we analyze which information
management services have been delivered by recently
described guideline implementations. We also review
the effectiveness of the computer-based interventions
in influencing clinicians’ behavior and changing pa-
tient outcomes.

**Methods**

Using the OVID search engine, the MEDLINE and CINAHL databases from 1992 through January 1998
were searched. Search terms included the following
MeSH headings—algorithm, computer-assisted deci-
sion making, computer-assisted therapy, consensus
statement, guideline adherence, health planning
guidelines, health services research, medical audit,
practice guideline, process and outcome evaluation,
quality assurance, quality of health care, and reference
standard—and the following text words—remind$,
alert$, guideline$, implement$, and computer$. We
also reviewed books and bibliographies of primary
and review articles.

We selected studies for review if computers were used
as part of an implementation strategy for clinical prac-
tice guidelines; the authors specifically indicated an
intent to implement guideline recommendations—not
simply to provide computer-based decision support;
the implementations were intended to influence
health care providers (thereby excluding systems that
provided recommendations directly to patients); and
the studies included an evaluation component that
objectively studied some aspect of the effectiveness
of the system in a practice setting.

**Information Management Services Model**

We have devised an information management services
model for the implementation of clinical practice
guidelines. Briefly, the model comprises eight com-
ponents, defined as follows:

- **Recommendation**: the determination of appropri-
ate, guideline-speciﬁed activities that should occur
under speciﬁc clinical circumstances

- **Documentation**: the collection, recording, and stor-
age of observations, assessments, and interventions
related to clinical care

- **Explanation**: the provision of background infor-
mation on decision variables and guideline-speci-
ﬁed actions (e.g., deﬁnitions, measures of quality or
cost) and the rationale that supports guideline rec-
ommendations, including evidence and literature
citations

- **Presentation**: the creation of useful output from in-
ternal data stores

- **Registration**: the recording and storage of admin-
istrative and demographic data to uniquely identify
the patient, provider(s), and encounter

- **Communication**: the transmission and receipt of
electronic messages between the clinician and other
information providers

- **Calculation**: the manipulation of numeric or tem-
poral data, or both, to derive required information

- **Aggregation**: the derivation of population-based in-
formation from individual patient data

A variety of methods may be used to incorporate each
service in a computer-based guideline implementa-
tion. Although their inclusion should result in a more
comprehensive, workflow-integrated system, individ-
ual services may be excluded from any speciﬁc ap-
lication.

Each pertinent article was scrutinized by at least two
of the authors for evidence that the system described
there did or did not provide each information management service. Disagreements between the authors were settled by discussion. In addition, evidence of effectiveness was extracted and summarized. We determined the types of studies that were performed to evaluate each system (using the classification system used by Grimshaw and Russell9) and then ascertained the effectiveness of the system with regard to guideline adherence and other process measures (such as documentation and user satisfaction) and patient outcome measures when available. Because of the wide variety of study types and outcome variables, no quantitative meta-analysis of the results was possible.

### Table 1

<table>
<thead>
<tr>
<th>Study (year)</th>
<th>Domain; System; Site</th>
<th>Source of Guideline</th>
<th>Recommendation</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bouhaddou et al. (1994)</td>
<td>Three procedure preauthorizations (cholecystectomy, cataract extraction, knee arthroscopy); ILIAD; UHC Health Plan and University of Utah Medical Center, Salt Lake City, Utah</td>
<td>Locally developed</td>
<td>Surgical preauthorization; delayed</td>
<td>Logic and deviations from preauthorization criteria</td>
</tr>
<tr>
<td>Burack et al. (1994)</td>
<td>Mammography screening; multiple practice sites in Detroit, Mich.</td>
<td>USPSTF and other authorities</td>
<td>Mammography reminder; concurrent</td>
<td>Breast cancer risk factors</td>
</tr>
<tr>
<td>Day et al. (1995)</td>
<td>Low back pain; Emergency Department Expert Charting System; UCLA Emergency Medicine Center, Los Angeles, Calif.</td>
<td>AHCPR with local adaptation</td>
<td>Advice about appropriate tests, treatment, and disposition; prompts for missing history or physical exam items; concurrent</td>
<td></td>
</tr>
<tr>
<td>Dexter et al. (1998)</td>
<td>Advanced directives; Regenstrief Medical Records System; General Medicine Practice, Indianapolis, Ind.</td>
<td>Nd</td>
<td>Reminders to discuss advanced directives; concurrent</td>
<td>Nd</td>
</tr>
<tr>
<td>Goethe and Bronzino (1995)</td>
<td>Pharmacotherapy in psychiatry; Clinical Evaluation and Monitoring System; Institute of Living, Hartford, Conn.</td>
<td>Locally developed</td>
<td>Alerts for appropriate psychotropic medications based on diagnosis, appropriate baseline and followup laboratory testing and drug monitoring; potential for drug–drug interactions; concurrent</td>
<td>Summary information about medications, potential for drug–drug interactions</td>
</tr>
<tr>
<td>Lobach and Hammond (1997)</td>
<td>Diabetes; CAMP; Duke University Medical Center, Durham, N.C.</td>
<td>American Diabetes Association with local adaptation</td>
<td>Care recommendations regarding which studies or procedures are currently due and due at next visit; concurrent</td>
<td>Nd</td>
</tr>
<tr>
<td>Margolis et al. (1992)</td>
<td>Six common pediatric problems; CHARTS; Community Pediatrics Clinic, Olfaqquem, Israel</td>
<td>Nd</td>
<td>Advice from clinical management algorithms; concurrent</td>
<td>Nd</td>
</tr>
</tbody>
</table>

**NOTE:** ACQUIP indicates Ambulatory Care Quality Improvement Program; AHCPR, Agency for Health Care Policy and Research; CAMP, computer-assisted management protocol; COSTAR, Computer-stored Ambulatory Record; DHCP, decentralized hospital computer system; EMR, electronic medical record; JNC V, Joint National Committee on Detection, Evaluation and Treatment of High Blood Pressure; Nd, not discussed; USPSTF, U.S. Preventive Services Task Force; VA, Veterans Administration.

### Results

A total of 25 papers that described 20 discrete systems were identified. We included more than one report on a single system if descriptions and evaluations of a single system were segregated into more than one report or if the authors investigated more than one guideline implementation strategy on the same system. Features of the guideline implementation systems are summarized in Table 1.

Eleven systems were based on national guidelines, including those published by AHCPR; the American Di-
abetes Association; the National Cholesterol Education Program; the Joint National Committee on Detection, Evaluation, and Treatment of High Blood Pressure (JNC V); and the U.S. Preventative Services Task Force (USPSTF). In several cases, the authors commented on the need for local modifications of the guidelines. Four systems implemented locally developed guidelines. In five systems, the guideline source was not described.

Thirteen of the guideline implementations addressed patient management issues and therapy, including one system that provided pre-authorization for surgical procedures\(^\text{12}\) and another system that was intended to improve discussion of advance directives.\(^\text{16}\) The other seven systems provided guidance with screening and health maintenance activities.

**Services**

All systems provided patient-specific recommendations. The scope of the recommendations encompassed a broad range of clinical activities, including appropriate tests and treatments, alerts about at-risk states, and reminders of appropriate physical assessments and screening activities. With one exception, all systems provided recommendations concurrently with

<table>
<thead>
<tr>
<th>Documentation</th>
<th>Registration</th>
<th>Communication</th>
<th>Calculation</th>
<th>Presentation</th>
<th>Aggregation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgical indications documented on paper and phoned or faxed to central office; prompted, noninteractive</td>
<td>Nd</td>
<td>None</td>
<td>Nd</td>
<td>Paper: status of preauthorization; full report of guideline compliance/deviations</td>
<td>Nd</td>
</tr>
<tr>
<td>Procedure indication (screening or diagnostic) initiator; patient response to referral; prompted, noninteractive</td>
<td>Yes</td>
<td>Nd</td>
<td>Age</td>
<td>Paper: reminder form, previous mammography results, appointment postcard</td>
<td>Nd</td>
</tr>
<tr>
<td>Core history and physical examination items; clinician’s rationale for deviation from recommendations; prompted, interactive</td>
<td>Nd</td>
<td>None</td>
<td>Nd</td>
<td>Paper: after-care instructions for patients, laboratory and treatment orders, prescriptions On-screen: color-coded suggestion prompts and order screens</td>
<td>Nd</td>
</tr>
<tr>
<td>Paper-based encounter sheet allows choice of discussed, deferred, or rationale for deviation; prompted, noninteractive</td>
<td>EMR</td>
<td>EMR (Regenstrief system)</td>
<td>Age</td>
<td>Paper: reminders on encounter forms</td>
<td>Nd</td>
</tr>
<tr>
<td>Documentation checklists for key symptoms and behavioral issues; rationale for deviation; prompted, interactive</td>
<td>Nd</td>
<td>Laboratory, pharmacy, and diagnostic data</td>
<td>Nd</td>
<td>On-screen: alerts, historical laboratory values, medications, medical problems</td>
<td>Nd</td>
</tr>
<tr>
<td>Clinic visit notes handwritten on encounter forms; rationale for deviation; prompted, noninteractive</td>
<td>EMR</td>
<td>EMR (Regenstrief system)</td>
<td>Age</td>
<td>Paper: indicated tests on the encounter form, reminder report</td>
<td>Nd</td>
</tr>
<tr>
<td>Handwritten documentation that a recommended action was performed, declined, or never to be done; data entry by clinic personnel; prompted, noninteractive</td>
<td>EMR</td>
<td>EMR, scheduling, accounting, laboratory orders, results (TMR system)</td>
<td>Age, intervals</td>
<td>Paper: recommendations on encounter form, prescriptions, orders</td>
<td>Nd</td>
</tr>
<tr>
<td>Clinical observations recorded on clinical algorithm serve as visit form; prompted, interactive</td>
<td>Nd</td>
<td>Nd</td>
<td>Nd</td>
<td>On-screen: clinical algorithm Paper: record of the visit</td>
<td>Nd</td>
</tr>
</tbody>
</table>

continued
<table>
<thead>
<tr>
<th>Study (year)</th>
<th>Domain; System; Site</th>
<th>Source of Guideline</th>
<th>Recommendation</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nilasena et al.\textsuperscript{22} (1994) Nilasena and Lincoln\textsuperscript{23} (1995)</td>
<td>Diabetes; University of Utah Medical Center and the VA Medical Center; Salt Lake City, Utah</td>
<td>American Diabetes Association with local adaptation</td>
<td>Alerts about high-risk aspects of clinical profile; concurrent</td>
<td>Nd</td>
</tr>
<tr>
<td>Ornstein et al.\textsuperscript{24} (1993) Ornstein et al.\textsuperscript{25} (1995)</td>
<td>13 preventive services; Division of Family Medicine, Medical University of South Carolina, Charleston, S.C.</td>
<td>USPSTF</td>
<td>Reminders of deficient preventive services, e.g., dental, diet, injury prevention counseling, immunizations, screening of blood pressure, fecal occult blood, Pap smears, mammograms; concurrent</td>
<td>Explanation and citations for each preventive service tracked</td>
</tr>
<tr>
<td>Overhage et al.\textsuperscript{26} (1996)</td>
<td>22 adult preventive care in hospitalized patients; Regenstrief Medical Record System; Wishard Memorial Hospital, Indianapolis, Ind.</td>
<td>USPSTF</td>
<td>Preventive care reminders, suggested orders; concurrent</td>
<td>Citations of literature to support recommendations</td>
</tr>
<tr>
<td>Robbins et al.\textsuperscript{27} (1993)</td>
<td>Lipid Management Program; private practice, Norfolk, Va.</td>
<td>National Cholesterol Education guidelines with local adaptation</td>
<td>Reminders about patients for whom laboratory data are due; concurrent</td>
<td>Nd</td>
</tr>
<tr>
<td>Rossi and Every\textsuperscript{28} (1997)</td>
<td>Pharmacotherapy with calcium channel blockers in hypertension; DHCP and ACQUIP; Seattle VA Medical Center, Seattle, Wash.</td>
<td>JNC V</td>
<td>Advice regarding use of diuretic and beta blocker for at-risk patients; concurrent</td>
<td>Cardiovascular risk associated with calcium channel blockers</td>
</tr>
<tr>
<td>Safran et al.\textsuperscript{29} (1995)</td>
<td>HIV management; Center for Clinical Computing, Beth Israel Hospital, Boston, Mass.</td>
<td>Locally developed</td>
<td>Alerts and reminders regarding HIV patients, including laboratory results, recommended medications and dosages, referrals, immunizations; concurrent</td>
<td>Nd</td>
</tr>
<tr>
<td>Schriger et al.\textsuperscript{30} (1997)</td>
<td>Occupational exposure; Emergency Department Expert Charting System; UCLA Emergency Medicine Center, Los Angeles, Calif.</td>
<td>Locally developed</td>
<td>Tests and treatments recommended, optional, not recommended; concurrent</td>
<td>Computer’s reasoning for each recommendation</td>
</tr>
<tr>
<td>Tape and Campbell\textsuperscript{31} (1993)</td>
<td>Health maintenance; COSTAR medical record system; University of Nebraska Internal Medicine Clinic, Omaha, Neb.</td>
<td>Nd</td>
<td>Reminders about health maintenance deficiencies based on age, sex, chronic disease, and past health maintenance records; concurrent</td>
<td>Nd</td>
</tr>
<tr>
<td>Turner et al.\textsuperscript{32} (1994)</td>
<td>Preventive care; private practices in eastern North Carolina</td>
<td>Nd</td>
<td>Reminders about influenza vaccine, Pap smears, breast exams, and mammography; concurrent</td>
<td>Nd</td>
</tr>
<tr>
<td>Vincent et al.\textsuperscript{33} (1995)</td>
<td>Disease prevention, cancer detection, immunization; Quality Care Program; Swedish Hospital, Seattle, Wash.</td>
<td>Nd</td>
<td>Recommended health maintenance procedures based on individual risk factors; concurrent</td>
<td>Nd</td>
</tr>
<tr>
<td>Willson et al.\textsuperscript{34} (1995)</td>
<td>Pressure ulcer prevention and treatment; LDS Hospital, Salt Lake City, Utah</td>
<td>AHCPR</td>
<td>Reminders to nurses to perform Braden assessments; stage appropriate treatment recommendations; concurrent</td>
<td>Nd</td>
</tr>
<tr>
<td>Zielstorff et al.\textsuperscript{35} (1996) Zielstorff et al.\textsuperscript{36} (1997)</td>
<td>Pressure Ulcers; Pressure Ulcer Prevention &amp; Management System; Massachusetts General Hospital, Boston, Mass.</td>
<td>AHCPR</td>
<td>Treatment plan, risk status; concurrent</td>
<td>Definitions of individual data items</td>
</tr>
</tbody>
</table>

\textbf{NOTE:} ACQUIP indicates Ambulatory Care Quality Improvement Program; AHCPR, Agency for Health Care Policy and Research; CAMP, computer-assisted management protocol; COSTAR, Computer-stored Ambulatory Record; DHCP, decentralized hospital computer system; EMR, electronic medical record; JNC V, Joint National Committee on Detection, Evaluation and Treatment of High Blood Pressure; Nd, not discussed; USPSTF, U.S. Preventive Services Task Force; VA, Veterans Administration.
<table>
<thead>
<tr>
<th>Documentation</th>
<th>Registration</th>
<th>Communication</th>
<th>Calculation</th>
<th>Presentation</th>
<th>Aggregation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seven data entry forms, self-contained database; data entry by clerical personnel from paper forms; prompted, noninteractive</td>
<td>Demo-graphics</td>
<td>None</td>
<td>Nd</td>
<td>Paper: health maintenance report with demographics, preventive health status, schedule of upcoming and past-due preventive activities</td>
<td>Nd</td>
</tr>
<tr>
<td>Integrated with EMR (problem lists, progress notes, social history); tracks preventive services; some notes dictated and transcribed; prompted, interactive</td>
<td>EMR</td>
<td>EMR, laboratory results</td>
<td>Age, intervals</td>
<td>Paper: reminders to physicians, annual letters to patients to alert them about preventive services</td>
<td>Nd</td>
</tr>
<tr>
<td>Integrated with Regenstrief inpatient and outpatient EMR; prompted, interactive</td>
<td>EMR</td>
<td>Order entry for laboratory and pharmacy; EMR (Regenstrief system)</td>
<td>Age, creatinine clearance</td>
<td>On-screen: reminders displayed during order entry</td>
<td>Nd</td>
</tr>
<tr>
<td>Lipid results and current therapy; prompted, noninteractive</td>
<td>Nd</td>
<td>Nd</td>
<td>Nd</td>
<td>Paper: reminders of laboratory tests due; results sent to patients and referring physicians</td>
<td>Nd</td>
</tr>
<tr>
<td>Paper-based form documents appropriate indications for calcium channel blocker therapy; data entry by clerical personnel; prompted, noninteractive</td>
<td>EMR</td>
<td>EMR (DHCP, ACQUIP systems)</td>
<td>None</td>
<td>Paper: reminder attached to prescription refill form</td>
<td>Nd</td>
</tr>
<tr>
<td>Integrated with EMR that includes problems, medications, preventive screenings, progress notes; prompted, interactive</td>
<td>EMR</td>
<td>EMR, scheduling, test ordering (Clinical Computing System)</td>
<td>Nd</td>
<td>On-screen: alerts, reminders (appear only when patient record is accessed)</td>
<td>Laboratory, scheduling, demographics, dates of admission and discharge and alerts triggered</td>
</tr>
<tr>
<td>History of exposure event, exposed worker, and source; rationale for deviation; prompted, interactive</td>
<td>Nd</td>
<td>Nd</td>
<td>Nd</td>
<td>Paper: after-care instructions for patients (modifiable by clinician), prescriptions</td>
<td>Deviation rates by decision</td>
</tr>
<tr>
<td>Paper-based document; prompted, noninteractive</td>
<td>EMR</td>
<td>EMR (COSTAR system)</td>
<td>Age, intervals</td>
<td>Paper: problem list, medication list, and most recent progress note</td>
<td>Nd</td>
</tr>
<tr>
<td>Nd</td>
<td>Nd</td>
<td>Nd</td>
<td>Age</td>
<td>Paper: reminder</td>
<td>Nd</td>
</tr>
<tr>
<td>Paper-based worksheet completed at encounter and entered into system by clerical staff; prompted, noninteractive</td>
<td>Yes</td>
<td>Nd</td>
<td>Age, intervals</td>
<td>Paper: worksheet attached to medical record; health maintenance reminder letters for patients</td>
<td>Nd</td>
</tr>
<tr>
<td>General screening and Braden scale; prompted, interactive</td>
<td>EMR</td>
<td>EMR (HELP system)</td>
<td>Nd</td>
<td>On-screen: alerts</td>
<td>Nd</td>
</tr>
<tr>
<td>Data entry screens provide explicit cues for assessment data; prompted, interactive</td>
<td>Nd</td>
<td>Nd</td>
<td>Nd</td>
<td>Paper: patient-specific treatment plan</td>
<td>Nd</td>
</tr>
</tbody>
</table>
A variable number of factors were evaluated by the systems to determine appropriate intervention recommendations.

Nine reports documented that some explanation functionality was provided. These services provided background information, definitions, and risks as well as the rationale that supported specific recommendations. One system offered literature citations.

Most systems provided prompts for documentation of relevant findings that served a reminder function for the clinician-user. In many cases, these data were supplemented by complete medical record capabilities. Documentation services were provided in a variety of ways. Several systems relied on paper-based recording of clinician observations, which were later entered into the computer by clerical personnel. Others made use of online data entry, particularly those that were part of larger electronic medical record (EMR) systems. In nine systems the documentation process was interactive.

Several of the reports described systems that were integrated with institutional EMR systems. Documentation services for these systems tended to make use of the functionality of the EMR. Other systems were essentially stand-alone systems and not integrated with an EMR.

Like the data entry services, presentation services also varied considerably. Presentation modalities included paper-based display of reminders that were attached to patient charts, on-screen reminders and alerts, on-screen display of algorithms, patient summaries, customizable after-care instructions, and annual birthday letters to patients regarding appropriate preventive services. Seventeen of the systems made use of paper-based output of some kind.

Electronic communication services most frequently provided interfaces to the EMR and to order-entry functions. Interfaces existed in some systems to pharmacy, scheduling, and laboratory results reporting. Stand-alone systems, by definition, offered no electronic communication services.

None of the reports on stand-alone systems described provision of registration processes. Some mechanism for identification of patient demographics, provider, and the encounter was assumed to have been present in all cases, but specific mechanisms were not described. The EMR-related systems presumably have the capability to integrate demographic and administrative data.

Calculation services were used to calculate patient ages and intervals between tests and to trigger rules related to preventive services. The Lipid Management Program calculated lipid fractions.

Aggregation services were described for only a few systems. In many cases, it is clear that database capabilities would allow aggregation of individual patient data, but only two reports explicitly described aggregation services. Schriger et al. noted that the database could be used to calculate deviation (non-adherence) rates by physicians. The Beth Israel Clinical Care System captured data about laboratory tests, demographics, dates of admission and discharge, and response to alerts that were used to generate aggregate reports.

Evaluations

The methodologies used to evaluate the effectiveness of the 20 guideline implementations included ten controlled trials (nine of which were randomized) and ten time-series studies (none of which incorporated external controls; one applied a switchback design). The outcome variables that were measured also varied considerably and are summarized in Table 2.

Four studies looked at documentation and found improvement in each case. The average number of relevant data items for surgical pre-authorization increased from 4.0 to 28.8; the mean percentage increase for documentation of common pediatric problems was 58 percent, for management of back pain 30.2 percent, and for management of exposure to body fluids 42 percent.

Eighteen of the 20 studies evaluated provider adherence to the guidelines. In 14 of the 18, some level of improved adherence was described. In several reports, adherence improvements occurred for some of the measured outcomes but not for all.

Failure to improve adherence using computer-based strategies was reported in four studies. An attempt to improve preventive care guideline adherence for hospitalized patients failed because of functional and systemic barriers that interfered with providing preventive care to inpatients. One study of prevention and management of pressure ulcers was unable to show any effect of the computer-based intervention on nursing decision making. In that case, the authors concluded that there was not enough gain for the effort of data entry. A system designed to influence decision making in emergency room patients with back pain failed because of general confusion regarding the utility of plain x-rays in these patients and the fact that recommendations were not enforced. Finally, in a study of diabetes management guidelines, compliance improved to the same degree in both control and
intervention groups; the authors questioned study design issues.\textsuperscript{23} Clinician satisfaction was addressed in four studies. Two investigators found that users were satisfied with computer-based guideline interventions.\textsuperscript{12,36} On the other hand, physician-users of a clinical algorithm system found data entry so tedious that they refused to continue,\textsuperscript{21} and Nilasena et al.\textsuperscript{22} found that 70 percent of users complained that data entry forms were difficult to use and inefficient.

Eight studies examined patient outcomes. A study of an intervention for low-back pain found no effect on cost,\textsuperscript{15} whereas costs increased in both a system for management of health care workers exposed to body fluids and another that pre-authorized surgery.\textsuperscript{12,30} Use of a lipid tracking system was associated with improvements in patients’ cholesterol and lipid fractions.\textsuperscript{27} A system for prevention of pressure ulcers was associated with a decreased incidence of decubiti,\textsuperscript{24} and Dexter et al.\textsuperscript{18} reported a significant improvement in the completion of advance directives (15 percent vs 4 percent for a control group) using a computer-based reminder system. An intervention to substitute appropriate antihypertensives for calcium channel blockers did not have any effect on patients’ blood pressure,\textsuperscript{29} and alerts about appropriate HIV management did not change admission rates, emergency department visits, survival, or pneumocystis admissions.\textsuperscript{30}

**Discussion**

To better understand the design factors responsible for the success or failure of computer-based guideline intervention strategies, we analyzed reports on 20 systems that were intended to implement guideline recommendations in clinical practice. Specifically, we assessed the use of eight information management services, which we believe may be useful in integrating computerized systems into clinical workflow. Many reports failed to describe the systems in sufficient detail to ascertain the presence or absence of some of these services. Therefore, we were unable to create meaningful summary ratings of individual systems that might correlate with the outcomes described. However, we were able to describe qualitatively many aspects of the reported design of current computer applications used as guideline intervention tools and to summarize measures of their effectiveness.

All systems delivered patient-specific recommendations, and in most cases the advice was made available concurrently with care, thus meeting Grimshaw and Russell’s criteria for implementations with a high probability of success.\textsuperscript{9} However, providing recommendations in this manner was neither necessary nor sufficient to ensure adherence. Several authors were unable to influence guideline adherence with concurrent reminders. Even providing delayed feedback was associated in one case with increased procedure authorization rates, although this system’s influence may have been related to financial incentives and disincentives.\textsuperscript{12}

The level of specificity of the advice varied considerably, as evidenced by the number of factors that were weighed by the programs to trigger relevant recommendations. Some systems simply checked a patient’s age and gender to discern appropriate preventive interventions, whereas others monitored ongoing clinical transactions and considered multiple factors (e.g., diagnoses, laboratory results, and medications) in arriving at recommendations for changing medications or dosages and for planning treatment.

Somewhat surprisingly, fewer than half the reports documented provision of explanation services. More than 15 years ago, Teach and Shortliffe\textsuperscript{37} showed the importance of providing explanation for computer-based advisories.\textsuperscript{35} One noteworthy benefit of the use of computers for implementation of guideline recommendations is their capability to link recommendations dynamically to the evidence that supports them.

Most reports described the use of on-screen and paper-based prompts to remind users of critical information that should be documented. Clinicians entered data into computers directly and interactively in fewer than half the systems. Even some long-established EMR systems depended on completion of paper forms with subsequent data entry by clerical personnel. Likewise, paper-based output was described for 17 of the 20 systems. It seems clear that the paperless office remains a vision of the future.

Registration, calculation, communication, and aggregation services were infrequently described. These components offer tremendous potential benefit for well-designed computer-based guideline implementation. Providing communication services requires networked systems. Registration services may seem mundane, but an interface to an administrative database that contains this information may be vital to the success of a computer-based initiative by diminishing the clerical workload for clinicians. Calculation and aggregation services are basic functions of many computer systems that were rarely reported in these guideline implementation systems.

The evaluations of system effectiveness varied markedly in design, implementation, and level of descrip-
<table>
<thead>
<tr>
<th>Study</th>
<th>Methodology</th>
<th>Documentation</th>
<th>Adherence</th>
<th>Satisfaction</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bouhaddou et al. 12</td>
<td>Time series without external control</td>
<td>Improved; indication of surgery</td>
<td>Improved; rate of request for surgery, mixed; increased pre-authorization approval rate</td>
<td>Improved</td>
<td>Cost increased</td>
</tr>
<tr>
<td>Burack et al. 13</td>
<td>Burack and Gimotty 14</td>
<td>Time series without external control</td>
<td>Increased use of mammography in health department setting, but not in HMO setting</td>
<td>Nd</td>
<td>Nd</td>
</tr>
<tr>
<td>Day et al. 15</td>
<td>Time series without external control</td>
<td>Improved after-care instructions</td>
<td>No effect</td>
<td>Nd</td>
<td>No effect on cost</td>
</tr>
<tr>
<td>Dexter et al. 16</td>
<td>RCT by provider team</td>
<td>Nd</td>
<td>Increased discussion with intervention (24% vs. 4% without)</td>
<td>Nd</td>
<td>Improved rate of advance directive completion, 4% vs. 15%</td>
</tr>
<tr>
<td>Goethe et al. 18</td>
<td>Time series without external control</td>
<td>Nd</td>
<td>Improved response to alerts</td>
<td>Nd</td>
<td>Nd</td>
</tr>
<tr>
<td>Litzelman et al. 19</td>
<td>RCT by provider team</td>
<td>Nd</td>
<td>Improved mammography and fecal occult blood testing; no effect on Pap testing</td>
<td>Nd</td>
<td>Nd</td>
</tr>
<tr>
<td>Lobach and Hammond 20</td>
<td>RCT by clinician</td>
<td>Nd</td>
<td>Two-fold increase in compliance with guidelines for 3 of 8 standards; failure for 5 of 8 diseases</td>
<td>Nd</td>
<td>Nd</td>
</tr>
<tr>
<td>Margolis et al. 21</td>
<td>Time series without external control</td>
<td>Improved; 3 of 6 diseases</td>
<td>Improved for 2 of 6 diseases; decreased inappropriate use of antibiotics for 2 diseases</td>
<td>Too tedious, physicians refused to continue</td>
<td>Nd</td>
</tr>
<tr>
<td>Nilasena et al. 22</td>
<td>RCT by physician</td>
<td>Nd</td>
<td>Improved average total compliance score for both control and intervention</td>
<td>70% found forms difficult to use and did not reduce time to provide care</td>
<td>Nd</td>
</tr>
<tr>
<td>Orrstein et al. 25</td>
<td>Time series without external control</td>
<td>Nd</td>
<td>Improved compliance with counseling, screening tests, breast exams, and thyroid function tests; no change for immunizations, fecal occult blood, Pap smear, mammography,</td>
<td>No improvement in patient’s perceived preventive services delivery</td>
<td>Nd</td>
</tr>
<tr>
<td>Overhage et al. 26</td>
<td>RCT by provider team</td>
<td>Nd</td>
<td>No effect: control, 24% compliance rate; intervention, 23%</td>
<td>Nd</td>
<td>Nd</td>
</tr>
<tr>
<td>Robbins et al. 27</td>
<td>Time series without external control</td>
<td>Nd</td>
<td>Nd</td>
<td>Nd</td>
<td>Cholesterol, LDL, and triglycerides levels decreased; HDL increased</td>
</tr>
<tr>
<td>Rossi and Every 28</td>
<td>RCT by provider</td>
<td>Nd</td>
<td>Improved: 11.3% of patients changed to first line antihypertensive drugs</td>
<td>Nd</td>
<td>No significant change in BP</td>
</tr>
<tr>
<td>Safran et al. 29</td>
<td>RCT by site</td>
<td>Nd</td>
<td>Improved: response time to alerts, 52 vs. 11 days</td>
<td>Nd</td>
<td>No change in admission rates, ER visits, survival or pneumocystis admissions</td>
</tr>
</tbody>
</table>
### Table: Time Series Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Effectiveness</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schriger et al.</td>
<td>Time series with switchback</td>
<td>Improved for 6 of 7 history items</td>
<td>Nd</td>
</tr>
<tr>
<td>Tape and Campbell</td>
<td>Nonrandomized controlled trial by provider team</td>
<td>Nd</td>
<td>Nd</td>
</tr>
<tr>
<td>Turner et al.</td>
<td>RCT by physician</td>
<td>Nd</td>
<td>Nd</td>
</tr>
<tr>
<td>Vincent et al.</td>
<td>Time series without external control</td>
<td>Nd</td>
<td>Nd</td>
</tr>
<tr>
<td>Willson et al.</td>
<td>Time series without external control</td>
<td>Nd</td>
<td>Decrease in incidence of pressure ulcers</td>
</tr>
<tr>
<td>Zielstorff et al.</td>
<td>Time series with control</td>
<td>Nd</td>
<td>Nd</td>
</tr>
</tbody>
</table>

**Note:** BP indicates blood pressure; Nd, not discussed; HDL, high-density lipoprotein; LDL, low-density lipoprotein; RCT, randomized controlled trial.

---

**Conclusions**

Many factors influence the success or failure of guideline implementation systems. While provision of a wide array of information management services may be important, it may not be sufficient to ensure adherence to guideline recommendations and outcomes difficult to control. In the studies described here, different types of guidelines, different settings, and different system implementations make conclusions about the relationship between different types of guidelines and different settings difficult. In addition, a component of publication bias is likely to represent an effect that may not be detected because the guidelines and outcomes of interest may not be directly comparable. In addition, a component of publication bias is likely to represent an effect that may not be detected because the guidelines and outcomes of interest may not be directly comparable. In addition, a component of publication bias is likely to represent an effect that may not be detected because the guidelines and outcomes of interest may not be directly comparable.

In many, the evaluations of effectiveness were methodologically weak. In addition, the guidelines that were implemented differed considerably in content, from health maintenance reminders to alerts for active management of specific disease states. There were also notable variations in clinical settings—primary care office, and public health department—and in evaluation methodology.

Fourteen studies reported some improvement in adherence to guidelines, seemingly independent of the use of computer-based interventions. Clearly, documentation is regularly assisted with tedious data entry requirements in clinical settings. There is also a need to evaluate the effectiveness of the systems in terms of patient outcomes. Future system developers should learn from the successes and failures of past systems.
References


