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<th>Study, Year (Reference), Type of Study (n = 22)</th>
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<th>Dimensions of Care End Points</th>
<th>Effect Evaluated</th>
<th>Type of Institution</th>
<th>Key Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercially developed systems Adherence Rollman et al., 2002 (89), RCT</td>
<td>1997–1998 DS/EHR (Logician, MedicaLogic Corp.)</td>
<td>Outpatient</td>
<td>Three interventions on screening for mood disorders and physician agreement with computer-based diagnosis: 1) computer-generated, paper-based reminders for depression with treatment recommendations; 2) computer-generated, paper-based reminders with diagnosis information; on quality of depression care, and 3) usual care</td>
<td>Effectiveness</td>
<td>Adherence</td>
<td>Academic</td>
<td>No statistically significant difference in depression symptom scores or delivery of recommended processes of depression care for either intervention group when compared with usual care</td>
<td></td>
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<tr>
<td>Utilization of care Garrido et al., 2005 (86), retrospective time-series study</td>
<td>2000–2004 EHR (EpicCare, Epic Systems Corp.)</td>
<td>Outpatient</td>
<td>EHR on adherence to recommended care and efficiency measures</td>
<td>Effectiveness</td>
<td>Adherence</td>
<td>Kaiser Permanente</td>
<td>No statistically significant difference in depression symptom scores or delivery of recommended processes of depression care for either intervention group when compared with usual care</td>
<td></td>
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<tr>
<td>Chin and Wallace, 1999 (85), time-series study</td>
<td>1994–1997 EHR/DS (EpicCare, Epic Systems Corp.)</td>
<td>Outpatient</td>
<td>EHR with CPOE and DS on adherence to guideline-based care for radiology services and medication use</td>
<td>Quality/effectiveness</td>
<td>Utilization of care</td>
<td>Kaiser Permanente</td>
<td>48% relative decrease (from 10.6 tests/1000 to 5.6 tests/1000) for upper gastrointestinal tract radiology studies by year 4 after EHR implementation, with a 33-percentage point absolute increase (from 55% to 88%) in adherence to protocols for test ordering; 20% decrease in chest radiographs ordered (years after implementation and information on relative or absolute decrease not provided); 2.3-percentage point absolute decrease (from 4.7% to 2.4%) in prescribing of a nonformulary antidepressant by year 2 after implementation</td>
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### Appendix Table 2—Continued

<table>
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<tr>
<th>Study, Year (Reference), Type of Study (n = 22)</th>
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<tr>
<td><strong>Surveillance</strong></td>
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<td><strong>Effectiveness Surveillance</strong></td>
<td><strong>Dimensions of Care</strong></td>
<td><strong>End Points</strong></td>
<td><strong>Type of Institution</strong></td>
<td><strong>Key Findings</strong></td>
</tr>
<tr>
<td>Rollman et al., 2001 (88), RCT</td>
<td>1997–1999</td>
<td>DS/EHR (Logician, MedicaLogic Corp.)</td>
<td>Outpatient</td>
<td>Three interventions on quality of depression care: 1) computer-generated, paper-based reminders for depression with treatment recommendations; 2) computer-generated, paper-based reminders with diagnosis information alone; and 3) usual care</td>
<td>Effectiveness</td>
<td>Surveillance</td>
<td>Academic</td>
<td>Three days after computer notification of possible mood disorder, 65% of physicians agreed with computer-screened diagnosis, 13% disagreed, and 23% were uncertain; no differences in treatment provided across guideline-exposure condition</td>
</tr>
<tr>
<td><strong>Time utilization/medication errors</strong></td>
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<td><strong>Safety</strong></td>
<td><strong>Medication errors</strong></td>
<td><strong>Academic</strong></td>
<td><strong>CPOE facilitated 22 types of medication error risks; errors were classified as being due to 1) fragmentation of data and failure to integrate CPOE systems with other hospital systems and 2) flaws in human–machine interface</strong></td>
<td></td>
</tr>
<tr>
<td>Koppel et al., 2005 (93), mixed quantitative/qualitative descriptive methods</td>
<td>2002–2004</td>
<td>CPOE (Eclipsys Corp.)</td>
<td>Inpatient</td>
<td>CPOE in facilitating medication prescribing errors</td>
<td>Safety</td>
<td>Medication errors</td>
<td>Academic</td>
<td>CPOE facilitated 22 types of medication error risks; errors were classified as being due to 1) fragmentation of data and failure to integrate CPOE systems with other hospital systems and 2) flaws in human–machine interface</td>
</tr>
<tr>
<td>Mekhjian et al., 2002, pre–post study</td>
<td>2000</td>
<td>CPOE/DS (Invision24, Siemens Corp.)</td>
<td>Inpatient/ICU</td>
<td>CPOE with electronic records for medication administration on care delivery time, workflow process, and costs</td>
<td>Efficiency</td>
<td>Time utilization/medication errors</td>
<td>Academic</td>
<td>64% relative decrease (from 328 to 111 min) in medication turnaround time; 43% relative decrease (from 457 to 261 min) in completion time for radiology procedures; 25% relative decrease (from 31.3 to 23.4 min) in reporting time for laboratory results; 11.3–percentage point absolute decrease (from 11.3% to 0%) in transcription errors; 5% relative decrease (from 3.91 to 3.71 d) in severity-adjusted length of stay; no statistically significant decreases in overall cost</td>
</tr>
<tr>
<td>Study, Year (Reference), Type of Study (n = 22)</td>
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<tr>
<td>Cordero et al., 2004 (91), pre–post study with retrospective review</td>
<td>2002</td>
<td>CPOE/DS (Invision24, Siemens Corp.)</td>
<td>Neonatal ICU</td>
<td>CPOE with DS on medication errors and care delivery time in neonatal ICU</td>
<td>Safety/efficiency</td>
<td>Medication errors/time utilization</td>
<td>Academic</td>
<td>13–percentage point absolute decrease (from 13% to 0%) in medication dosing errors; 73% relative decrease (from 10.5 to 2.8 h) in turnaround time for 1 medication (caffeine); 24% relative decrease (from 42 to 32 min) in radiology response time; physician and staff training started 4 wk before CPOE implementation; nurse leaders received 16 h of training, nurses and clerical staff received 8 h, and physicians received 2–4 h; during implementation, information systems staff provided 24-h support</td>
</tr>
<tr>
<td>Kilgore et al., 1998 (92), pre–post study</td>
<td>1995–1996</td>
<td>EHR (CareVue 9000, Hewlett-Packard Corp.; PIN System, Eclipsys Corp.)</td>
<td>ICU</td>
<td>Two different nursing ICU information systems with CPOE and results reporting on nurse work patterns and costs</td>
<td>Efficiency</td>
<td>Time utilization</td>
<td>Academic</td>
<td>Effect of computer systems on nurse charting time was inconclusive per authors because ICU patient census varied; staff satisfaction was higher with CareVue 9000 than with PIN System because of interface ease and greater support of workflow; expected net annual savings from preferred system were estimated at $320 359</td>
</tr>
<tr>
<td>Krall, 1995 (87), descriptive quantitative study</td>
<td>1994</td>
<td>EHR (EpicCare, Epic Systems Corp.)</td>
<td>Outpatient</td>
<td>EHR use on workflow and attitudes</td>
<td>Efficiency</td>
<td>Implementation cost</td>
<td>Kaiser Permanente</td>
<td>Physicians took 30 d to return to baseline productivity levels (patient visits/d); 2-min increase in physician time per visit; physician satisfaction with system increased over time</td>
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<tr>
<td>Internally developed systems</td>
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<tr>
<td>Adherence</td>
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<tr>
<td>Khoury, 1998 (72), time-series study</td>
<td>1993–1997</td>
<td>EHR/DS</td>
<td>Outpatient</td>
<td>EHR with DS on adherence to guideline-based care</td>
<td>Effectiveness/efficiency</td>
<td>Adherence</td>
<td>Kaiser Permanente</td>
<td>Adherence to guidelines improved for 6 conditions; levels of improvement ranged from 4– to 52–percentage point absolute increases in process of care delivery; estimated annual savings, $2 470 000 (cost of system development not included)</td>
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<tr>
<td>Ornstein et al., 1995, pre–post study</td>
<td>NS</td>
<td>EHR/DS</td>
<td>Outpatient</td>
<td>EHR with computerized reminders on delivery of preventive care</td>
<td>Effectiveness</td>
<td>Adherence</td>
<td>Academic</td>
<td>7 of 7 counseling measures improved: absolute increase in adherence ranging from 13 to 16 percentage points; 10 of 15 screening processes improved: absolute increase approximately ranging from 3 to 20 percentage points</td>
</tr>
<tr>
<td>Garr et al., 1993, pre–post study</td>
<td>DS/EHR</td>
<td>Outpatient</td>
<td>EHR with computerized reminders on delivery of preventive care</td>
<td>Effectiveness</td>
<td>Adherence</td>
<td>Academic</td>
<td>Absolute increases in delivery of preventive care, 1–8 percentage points; all 5 services included</td>
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<tr>
<td>Safran et al., 1992–1993, CCT</td>
<td>EHR/DS</td>
<td>Outpatient</td>
<td>Computerized reminders and alerts on delivery of HIV care</td>
<td>Effectiveness</td>
<td>Adherence</td>
<td>Academic</td>
<td>Approximate 22–percentage point absolute increase (from 46% to 68%) in adherence to recommended process of care at 1 y after occurrence of clinical event warranting reminder; 29–percentage point absolute increase (from 38% to 67%) in physician responses 1 mo after clinical event warranting alert</td>
<td></td>
</tr>
<tr>
<td>Schriger et al., 1997, CCT</td>
<td>DS/EHR</td>
<td>Emergency department</td>
<td>Computerized guidelines embedded in computerized charting system designed to track 5 conditions on processes of care for exposure of health care workers to bodily fluids</td>
<td>Effectiveness/efficiency</td>
<td>Adherence</td>
<td>Academic</td>
<td>12–percentage point absolute increase (from 83% to 96%) in adherence to 5 treatment guidelines; 20–percentage point absolute increase (from 63% to 83%) in adherence to 4 guidelines on laboratory test use; 62–percentage point absolute increase (from 31% to 93%) in documented adherence to aftercare guidelines; 42–percentage point absolute increase (from 57% to 98%) in adherence to guidelines for documentation of patient history; all measures decreased toward baseline rates when computer system was turned off; 23% relative decrease (from $520 to $401) in total per-patient costs</td>
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<tr>
<td>Schriger et al., 2000 (76), CCT</td>
<td>1992–1995</td>
<td>DS/EHR</td>
<td>Emergency department</td>
<td>Computerized guidelines embedded in computerized charting system designed to track 5 conditions on processes of care for evaluation of febrile children &lt; age 3 y presenting to emergency department</td>
<td>Effectiveness/efficiency</td>
<td>Adherence</td>
<td>Academic</td>
<td>Per authors' report, 13–percentage point absolute increase (from 80% to 92%) in documented adherence to guidelines for medical history and physical examination; 33–percentage point absolute increase (from 48% to 81%) in documented adherence to guidelines for aftercare instruction; all rates returned to baseline when computer system was turned off; no statistically significant differences in appropriateness of treatment, appropriateness or utilization rates of diagnostic tests, or test charges per patient</td>
</tr>
<tr>
<td>Day et al., 1995 (78), pre–post study</td>
<td>1992–1993</td>
<td>DS/EHR</td>
<td>Emergency department</td>
<td>Computerized guidelines embedded in computerized charting system designed to track 5 conditions on processes of care for lower back pain</td>
<td>Effectiveness/efficiency</td>
<td>Adherence</td>
<td>Academic</td>
<td>No statistically significant differences in appropriateness of diagnostic testing or treatment; no statistically significant decrease in costs; 12– to 51–percentage point absolute increase in documentation of 6 medical history items; 13– to 70–percentage point absolute increase in documentation of 6 aftercare counseling items</td>
</tr>
<tr>
<td>Simon et al., 2000 (79), RCT</td>
<td>NS</td>
<td>EHR/data summary/DS</td>
<td>Outpatient</td>
<td>Three interventions: 1) feedback to physicians of computerized data summaries with treatment recommendations for depression care, 2) computerized feedback plus telephone follow-up, and 3) usual care</td>
<td>Effectiveness/efficiency</td>
<td>Adherence</td>
<td>Nonacademic (Group Health Cooperative of Puget Sound)</td>
<td>No statistically significant difference in computerized DS group compared with usual care; 15% relative improvement (from 0.83 vs. 0.98) in depression scores in computerized DS with telephone follow-up group, with associated increase in likelihood of receiving antidepressant therapy; $80 increase in costs in telephone follow-up group</td>
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</tbody>
</table>

**Utilization of care**

<table>
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<tr>
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<tbody>
<tr>
<td>Baird et al., 1984 (80), RCT</td>
<td>NS</td>
<td>DS/electronic prescribing</td>
<td>Outpatient</td>
<td>Computer-generated, paper-based pharmacy reminders from hospital mainframe-based information system on prescription refill rates</td>
<td>Access</td>
<td>Utilization of care</td>
<td>Academic</td>
<td>No statistically significant difference in refill rates; initial development of software program, $200; cost per day to generate reminders, $14</td>
</tr>
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<tr>
<td>Sanders and Miller, 2001 (81), pre–post study</td>
<td>2000–2001 DS/CPOE</td>
<td>Inpatient</td>
<td>Computerized guidelines integrated into a CPOE system on utilization of CT and MRI</td>
<td>Efficiency</td>
<td>Utilization of care</td>
<td>Academic</td>
<td>5% relative decrease in neuroradiology CT and MRI diagnostic testing; 40% of users receiving computerized guideline ordered a nonrecommended test</td>
<td></td>
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<tr>
<td>Wells et al., 2003 (83), pre–post study</td>
<td>2001–2002 DS/EHR</td>
<td>Outpatient</td>
<td>EHR on identifying patients taking 2 drugs for which a combination pill is available and then generating computerized reminders to promote combination therapy</td>
<td>Effectiveness</td>
<td>Surveillance/adherence</td>
<td>Academic</td>
<td>27% of patients eligible were switched to combination therapy; cost savings related to combined therapy totaled $6159 per year; 241 patients were screened as eligible for combination therapy; total number of unique patients seen during study not given</td>
<td></td>
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<tr>
<td>Potts et al., 2004 (82), pre–post study</td>
<td>2001–2002 CPOE/DS</td>
<td>ICU</td>
<td>CPOE with DS on medication errors in pediatric ICU</td>
<td>Efficiency</td>
<td>Medication errors</td>
<td>Academic</td>
<td>41% relative decrease (from 2.2 errors/100 orders to 1.3 errors/100 orders) in medication errors categorized as potential adverse drug events; 96% relative decrease (from 30 errors/100 orders to 0.2 error/100 orders) in medication prescribing orders; decreases occurred in all categories of medication errors</td>
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<tr>
<td>Khoury, 1997 (84), time-series study</td>
<td>1989–NS EHR</td>
<td>Outpatient</td>
<td>Long-term costs and benefits of implemented EHR</td>
<td>Efficiency</td>
<td>Implementation cost</td>
<td>Kaiser Permanente</td>
<td>Cost of development estimated at $10 million; project took 8 y from beginning of development to full implementation; total ongoing annual expenses estimated to be $1.1 million per year; expected savings per year estimated as $3.7 million, with greatest savings from reduction in medical record room staff; system predicted to pay for itself in year 13</td>
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* City and state locations of manufacturers are as follows: MedicaLogic Corp., Beaverton, Oregon; Epic Systems Corp., Verona, Wisconsin; Eclipsys Corp., Boca Raton, Florida; Siemens Corp., New York, New York; Hewlett-Packard Corp., Palo Alto, California. CCT = controlled clinical trial; CPOE = computerized provider order entry; CT = computed tomography; DS = decision support; EHR = electronic health record; HIT = health information technology; ICU = intensive care unit; MRI = magnetic resonance imaging; NS = not specified; RCT = randomized, controlled trial.