Appendix B: Literature Review Methods

Literature Tables

TABLE B-1
Systematic Reviews

Study	Health IT Component	Study Purpose	Time Frame	Sample Size	Outcome Measures	Relevant Findings
Black, A. D., J. Car, C Pagliari, C. Anandan, K. Cresswell, T. Bokun, B. McKinstry, R. Procter, A. Majeed, A. Sheikh. 2011. The impact of eHealth on the quality and safety of health care: A systematic overview. *Public Library of Science Med* 8(1): e1000387.	Overview	To determine the impact of eHealth on the quality and safety of health care by conducting a systematic review of current systematic reviews	1997 to 2010	53 systematic reviews	Benefits and risks associated with various eHealth systems (i.e., legibility, accessibility, efficiency, patient disengagement, and increased costs)	– There is insufficient empirical evidence in the literature to establish the impact of eHealth on the quality and safety of health care – Evidence supporting eHealth is weak and inconsistent – The presence of negative consequences cited in the literature indicates a need to further evaluate the risks associated with eHealth

Harrington, L., D. Kennerly, and C. Johnson. 2011. Safety issues related to the electronic medical record (EMR): Synthesis of the literature from the last decade, 2000–2009. *Journal of Health Care Management* 56(1):31-43.	Overview	Identify problems associated with health IT that health care leaders need to be aware of when implementing health IT systems	2000 to 2009	24 studies	Rates of potential adverse drug events (ADEs)	– Although health IT can be associated with greater patient safety (e.g., resolve legibility problems), it can lead to unintended consequences such as
						  • Increases in coordination load for clinicians resulting in new opportunities for error
						  • Overdependence on health IT, particularly when incorrect information is entered into the system, and making errors
						  • Alert fatigue
						– When implementing health IT systems, health care leaders must be aware of potential problems and be prepared to address them

Pearson, S.-A., A. Moxey, J. Robertson, I. Hains, M. Williamson, J. Reeve, and D. Newby. 2009. Do computerised clinical decision support systems for prescribing change practice? A systematic review of the literature (1990-2007). *Health Services Research* 9:154.	Clinical decision support (CDS)	To determine CDS systems' impact on specific aspects of prescribing	1990 to 2007	56 studies	Effectiveness of CDS systems in supporting prescribing during the following:
					– Initiation of treatment
					– Before drug selection
					– After drug selection
						– CDS systems were more effective after drug selection in
						  • Flagging key safety issues (e.g., drug–drug interaction (DDI) alerts and warnings against prescribing potentially inappropriate medications for the elderly)
						  • Medication messages, such as suggesting alternative drug treatments

Shamliyan, T. A., S. Duval, J. Du, and R. L. Kane. 2008. Just what the doctor ordered. Review of the evidence of the impact of computerized physician order entry system on medication errors. *Health Services Research* 43(1 Pt 1):32-53.	CDS	To determine if electronic ordering with CDS lowers medication errors (MEs) as compared to handwritten orders	1990 to 2005	12 studies	Rate of MEs	– Computerized physician order entry (CPOE) can be associated with a reduction in MEs, particularly when used with a CDS
						– CPOE use is associated with
						  • 66 percent reduction in total prescribing errors in adults (odds ratio [OR] 0.34; 95 percent confidence interval [CI] 0.22 to 0.52)
						  • A positive tendency in children, but not statistically significant (OR .31; 95 percent CI 0.09 to 1.02)

Tan, K., P. R. F. Dear, and S. J. Newell. 2005. Clinical decision support systems for neonatal care. *Cochrane Database of Systematic Reviews* (2):CD004211.	CDS	To assess how newborn mobility and mortality is affected by the use of CDS in CPOE, computerized physiological monitoring, diagnostic, and prognostic systems	1966 to 2007	3 studies – 2 randomized control trials – 1 randomized crossover trial	– Mortality within first 28 days of life – Mortality within the first year of life – Effects on physician or nursing staff performance – Staff satisfaction or compliance – Costs	There are too few randomized trials and data to determine the benefits or harms of CDS systems in neonatal care
Wolfstadt, J. I., J. H. Gurwitz, T. S. Field, M. Lee, S. Kalkar, Wei Wu, and P. A. Rochon. 2008 The effect of computerized physician order entry with clinical decision support on the rates of adverse drug events: A systematic review. *Journal of General Internal Medicine* 23(4):451-458.	CDS	To determine how CPOE systems with CDS components impact the rate of ADEs	1994 to 2007	10 studies	Rate of ADEs	– More research is needed to determine the impact of CPOE systems with CDS components – 5 of 10 studies focusing on CDS systems' impact on ADE rates found a significant reduction in the number of ADEs

Ammenwerth, E., P. Schnell-Inderst, C. Machan, and U. Siebert. 2008. The effect of electronic prescribing on medication errors and adverse drug events: A systematic review. *Journal of the American Medical Informatics Association* 15:585-600.	CDS e-prescribing	To determine the effects of CPOE on the relative risk reduction of MEs and ADEs	1992 to 2004	27 controlled field and pretest-post-test studies	Relative risk of
					– MEs and
					– ADEs
						– Studies show that the implementation of CPOE, especially those with CDS, can reduce the relative risk of MEs and ADEs
						– However, these studies
						  • Differ substantially in setting and design
						  • Were often weak, with many before–after trials and insufficient descriptions to assess the comparability of the study and control groups
						– 23 studies showed a 13-99 percent relative risk reduction for MEs
						– 4 studies showed a 30-84 percent relative risk reduction for ADEs
						– 6 studies showed a 35-98 percent relative risk reduction for potential ADEs

Conroy, S., D. Sweis, C. Planner, V. Yeung, J. Collier, L. Haines, and I. C. K. Wong. 2007. Interventions to reduce dosing errors in children: A systematic review of the literature. *Drug Safety* 30(12):1111-1125.	CDS e-prescribing	To determine the effect of CPOE systems, with and without CDS, on the risk of dose calculation errors in pediatric medicine	– Pre August 2004; – September 2004 to October 2006	28 studies	Medication error rate	– In most studies, CPOE with CDS was associated with a large reduction in medication error rate – Some studies showed a medication error rate of zero after the implementation of CPOE with CDS – One study showed a significant increase in mortality after the implementation of CPOE

Durieux, P., L. Trinquart, I. Colombet, J. Nies, R. T. Walton, A. Rajeswaran, M. Rège-Walther, E. Harvey, and B. Burnand. 2008. Computerized advice on drug dosage to improve prescribing practice. *Cochrane Database of Systematic Reviews* (3):CD002894.	CDS e-prescribing	To determine impact of computerized advice on drug dosage	1966 to 2007	23 studies	– Change in the behavior of the health care provider (e.g., changes in the dose of drug used)
					– Change in the health of patients resulting from computerized advice (e.g., ADEs)
						– Use of computerized advice had no effect on adverse reactions
						– Computerized advice for drug dosage resulted in the following benefits:
						  • Increasing
						    – Initial dose (SMD 1.12, 95 percent CI 0.33 to 1.92)
						    – Serum concentrations (SMD 1.12, 95 percent CI 0.43 to 1.82)
						  • Reducing
						    – Time to therapeutic stabilization (SMD _0.55, 95 percent CI _1.03 to _0.08)
						    – Risk of toxic drug level (rate ratio 0.45, 95 percent CI 0.30 to 0.70)
						    – Length of hospital stay (SMD _0.35, 95 percent CI _0.52 to _0.17)

George, J., and P. S. Bernstein. 2009. Using electronic medical records to reduce errors and risks in a prenatal network. *Current Opinion in Obstetrics & Gynecology* 21(6):527-531.	EHR	To review the impact of implementing EMRs on quality of obstetrics care	1999 to 2009	n/a	– Improvement in the delivery of patient care – Complete documentation of a patient's history – Reduction in medication errors	– It is not clear how EMRs affect patient outcomes – EMR implementation is associated with high costs; however, EMRs can provide for better quality of care because • Benefits can outweigh the use over the long term – EMRs allow for more complete, accurate, and rapid access to data

Reckmann, M. H., J. I. Westbrook, Y. Koh, C. Lo, R, and O. Day. 2009. Does computerized provider order entry reduce prescribing errors for hospital inpatients? A systematic review. *Journal of the American Medical Informatics Association* 16(5):613-623.	e-prescribing	To evaluate the evidence regarding whether CPOE systems reduce prescribing errors among hospital inpatients	1998 to 2007	13 studies	Rate of prescription errors	– Little to no evidence to supports the hypothesis that CPOE systems reduce prescription errors
						– Studies supporting the link between CPOE use and a reduction in errors are limited by modest study sample sizes and designs:
						  • Data collections were usually limited to no more than two wards
						  • Control groups were generally not used
						  • Severity of data was generally not reported

Coiera, E., J. I. Westbrook, and J. C. Wyatt. 2006. The safety and quality of decision support systems. *Methods of Information in Medicine* 45:20-25.	CDS e-prescribing	To identify and determine the frequency of errors associated with CDS systems	n/a	n/a	– Error rates	– Poorly designed, implemented, and used CDS systems can lead to harm – The level of CDS performance is dependent on complex sociotechnical interactions within the system – Understanding the safety issues surrounding CDS can lead to more safely designed systems and contribute to safer outcomes delivered by busy or poorly resourced clinicians

Study	Health IT Component	Study Purpose	Method	Time Frame	Sample Size	Outcome Measures	Relevant Findings
Amarasingham, R., L. Plantinga, M. Diener-West, M. J. Gaskin, and N. R. Powe. 2009. Clinical information technologies and inpatient outcomes. *Archives of Internal Medicine* 169(2):108–114.	Overview	To determine the relationship of cost and rate of incidence with the increase use of health IT	Cross-sectional study	December 2005 to May 2006	41 hospitals	– Use of health IT as measured by the Clinical Information Technology Assessment Tool (CITAT) – Mortality – Complications – Costs – Length of stay	– Higher health IT usage was associated with lower complications – A 10-point increase (using the CITAT scoring system) in the automation of notes and records was associated with a 15 percent decrease in the adjusted odds of fatal hospitalizations (OR 0.85; 95 percent CI 0.74 to 0.97) – Increased use of CPOE was associated with a decrease of deaths by • Myocardial infarction, 9 percent • Coronary artery bypass graft procedures, 55 percent – Increased use of CPOE and CDS systems was associated with a 16 percent decrease in complications (OR 0.84; 95 percent CI 0.79 to 0.90) – Use of CPOE and CDS systems resulted in lower admission costs: • Test results, –$110 • Order entry, –$132 • Decision support, –$538 (p < 0.05)
Culler, S. D., J. N. Hawley, V. Naylor, and K. J. Rask. 2007. Is the availability of hospital IT applications associated with a hospital's risk adjusted incidence rate for patient safety indicators: Results from 66 Georgia hospitals. *Journal of Medical Systems* 31(5):319–327.	Overview	To determine how the availability of health IT components affects the risk adjusted incidence rate for Patient Safety Indicators (PSIs)	Observational study	August to December 2003	66 acute care community hospitals	The availability of IT applications compared with a hospital's risk adjusted incidence rate per 1,000 hospitalizations for anesthesia complications, death in low-mortality DRGs, decubitus ulcers, failure to rescue, foreign body left during procedure, iatrogenic Pneumothorax, infection due to medical care, postoperative hip fracture, postoperative hemorrhage or hematoma, postoperative physiologic and metabolic derangement, postoperative respiratory failure, postoperative pulmonary embolism or deep vein thrombosis, postoperative sepsis, postoperative wound dehiscence, accidental puncture or laceration	Very little statistically significant correlation between the availability of health IT applications and PSIs – Greater availability of health IT was associated with significantly lower rates of postoperative hemorrhage or hematoma – All other PSIs were not significantly affected or had significantly increased rates
Johnson, K., D. Chark, Q. X. Chen, A. Broussard, and S. T. Rosenbloom. 2008. Performing without a net: Transitioning away from a health information technology-rich training environment. *Academic Medicine* 83(12):1179–1186.	Overview	To determine how transferring from a health IT–rich environment to a health IT–poor environment affects practitioners' self-perceptions of competence, practice efficiency, and patient safety	Cross-sectional survey	2004 to 2005	– 255 practitioners who transferred from health IT–rich to health IT–poor environments – 73 practitioners who transferred to an equally health IT–rich environment	The self-reported impact on perception of health IT on – Safety – Evidence-based practice – Efficiency – Communication	Transition from a health IT–rich to a health IT–poor environment is associated with a perception of decreased – Safety (p < 0.02) – Efficiency (p < 0.0001)
Magrabi, F., M. Ong, W. Runciman, and E. Coiera. 2009. An analysis of computer-related patient safety incidents to inform the development of a classification. *Journal of the American Medical Informatics Association* 17:663–670.	Overview	To determine the frequency and type of patient safety incidents that are associated with computer use problems	Retrospective analysis	July 2003 to June 2005	42,616 incidents	Rate and type of computer related incidents	– Of all reported incidences, the rate of computer-related incidents was 0.2 percent, of which • 55 percent were machine related (software and hardware related) • 45 percent were caused by human–computer interaction problems – Consequences of computer-related incidents: • 3 percent of incidents resulted in harm • 34 percent resulted in no noticeable consequences • 38 percent resulted in noticeable consequences, but no harm
Agostini, J. V., J. Concato, and S. K. Inouye. 2007. Use of a computer-based reminder to improve sedative-hypnotic prescribing in older hospitalized patients. *Journal of the American Geriatrics Society* 55(1):43–48.	Alerts	To determine whether a computerized reminder system improves sedative-hypnotic prescribing in hospitalized older people	Prospective pre- and postintervention	N/A	– Preimplementation: 12,356 patients – Postimplementation: 12,153 patients	Frequency of prescription of four sedative-hypnotic drugs: – Diphenhydramine – Diazepam – Lorazepam – Trazodone	– Implementation of computerized reminder system improved sedative-hypnotic prescribing for older persons in acute care – 95 percent of patients were successfully directed to a safer sedative-hypnotic drug or a nonpharmacological sleep protocol
van der Sijs, H., L. Lammers, A. van den Tweel, J. Aarts, M. Berg, A. Vulto, and T. van Gelder. 2009. Time-dependent drug–drug interaction alerts in care provider order entry: Software may inhibit medication error reductions. *Journal of the American Medical Informatics Association* 16(6):864–868.	Alerts	To determine the effect of alerts on the rate of errors caused by time-dependent drug–drug interactions (TDDIs)	Retrospective analysis	October 2004 to July 2007	– Study 1: 8 internal medicine wards – Study 2: 28 internal medicine wards	Significant drug administration error rates	– Significant drug administration errors were insufficiently reduced – Significant drug administration error rates were reduced in the first study by 20.2 percent (p < 0.05) – Second study found a reduction of 1.5 percent of significant drug administration errors (p > 0.05)
Isaac, T., J. S. Weissman, R. B. Davis, M. Massagli, A. Cyrulik, D. Z. Sands, and S. N. Weingart. 2009. Overrides of medication alerts in ambulatory care. *Archives of Internal Medicine* 169(3):305–311.	Alerts	To determine the acceptance rate of medication alerts and whether the type and severity of alert affects acceptance rates	Retrospective study	January to September 2006	– 233,537 medication safety alerts – 2,872 clinicians	Acceptance rates of alerts	– Clinicians override most medication alerts – 61.6 percent of generated alerts were high-severity alerts – Clinicians accepted • 9.2 percent of drug interaction alerts • 23.0 percent of allergy alerts • 10.4 percent of high-severity interaction alerts • 7.3 percent of moderate-severity interaction alerts • 7.1 percent of low-severity interaction alerts
Lin, C. P., T. H. Payne, W. P. Nichol, P. J. Hoey, C. L. Anderson, and J. H. Gennari. 2008. Evaluating clinical decision support systems: Monitoring CPOE order check override rates in the Department of Veterans Affairs' computerized patient record system. *Journal of the American Medical Informatics Association* 15(5):620–626.	Alerts	To compare the 2001 and 2006 override rates of critical order checks (computer-generated recommendation and alerts for potential medication allergies, interactions or overdosing)	Retrospective analysis	– Period 1: January 4, 2006, to January 6, 2006 – Period 2: January 9, 2006, January 11, 2006	908 critical order checks	– Frequency of order check types – Frequency of order check overrides by order check type	– Clinicians override critical drug–drug and drug-allergy order checks at a high rate – Critical override rate for January 2006 and 2001 (2001 data taken from a previous study): • DDIs: – 2006, 87 percent – 2001, 88 percent (p = 0.85) • Drug-allergy – 2006, 81 percent – 2001, 69 percent (p = 0.005)
Raebel, M. A., J. Charles, J. Dugan, N. M. Carroll, E. J. Korner, D. W. Brand, and D. J. Magid. 2007. Randomized trial to improve prescribing safety in ambulatory elderly patients. *Journal of the American Geriatrics Society* 55(7):977–985.	Alerts	To evaluate the effectiveness of a computerized system designed to alert pharmacists when patients aged 65 and older were newly prescribed potentially inappropriate medications	Prospective, randomized trial	May 2005 to May 2006	59,680 patients age 65 and older	Rate at which inappropriate medications were dispensed	– Alerts can decrease the dispensing rate of potentially inappropriate medication prescribed – Percentage of patients prescribed inappropriate medication: • Control group, 2.2 percent • Intervention group, 1.8 percent (p = 0.002)

Study	Health IT Component	Study Purpose	Method	Time Frame	Sample Size	Outcome Measures	Relevant Findings
Sellier, E., I. Colombet, B. Sabatier, G. Breton, J. Nies, E. Zapletal, J. B. Arlet, D. Somme, and P. Durieux. 2009. Effect of alerts for drug dosage adjustment in inpatients with renal insufficiency. *Journal of the American Medical Informatics Association* 16(2):203–210.	Alerts	To determine the impact of CPOE alerts at the time of ordering medication on the rate of inappropriate medication prescribed	Controlled trial	August 2006 to August 2007	– 603 patients – 38 physicians – 2 medical departments within one hospital	Proportion of inappropriate first prescriptions, according to recommendation	– Alerts did not significantly impact the rate of inappropriate first prescriptions (19.9 vs. 21.3 percent [p = 0.63]) – Residents made fewer errors with alert system (OR 0.69; 95 percent CI 0.41 to 1.15) – Senior physicians made more inappropriate prescriptions with alert system (OR 1.88; 95 percent CI 0.91 to 3.89)
Shah, N. R., A. C. Seger, D. L. Seger, J. M. Fiskio, G. J. Kuperman, B. Blumenfeld, E. G. Recklet, D. W. Bates, and T. K. Gandhi. 2006. Improving acceptance of computerized prescribing alerts in ambulatory care. *Journal of the American Medical Informatics Association* 13(1):5–11.	Alerts	To determine whether a tiered alert system, one which assigned alerts of less serious magnitude to a non-interruptive display, would increase clinical acceptance of more serious interruptive drug alerts	Observational study	2004 to January 2005	– 701 clinicians – 31 adult primary care practices	– The extent an alert design minimizes workflow interruptions – Clinician acceptance rates of selective alerts – The specific types of alerts clinicians accepted most frequently – The reasons clinicians gave for overriding alerts	– The implementation of tiered alerts successfully raised clinician acceptance of more selective interruptive alerts, as compared to acceptance rates of previous studies – Total number of drug alerts under tiered system: 18,115 • 71 percent were noninterruptive, less serious alerts • 29 percent were interruptive, more serious alerts – Acceptance of interruptive alert under tiered system: 67 percent
Singh, H., E. J. Thomas, D. F. Sittig, L. Wilson, D. Espadas, M. M. Khan, and L. A. Petersen. 2010. Notification of abnormal lab test results in an electronic medical record: Do any safety concerns remain? *The American Journal of Medicine* 123(3):238–244.	Alerts	To determine whether automated notifications of abnormal laboratory alerts in an EMR received timely follow-up actions	Retrospective cohort study	May to December 2008	– One large Veterans Affairs multispecialty ambulatory clinic – 5 satellite clinics – 78,158 tests – 1,163 transmitted alerts	– Unacknowledged alerts – Lack of timely follow-ups to alerts (not responded to within 30 days)	Safety concerns remain due to unacknowledged alerts and lack of follow-up: – 10.2 percent of all alerts were unacknowledged – 6.8 percent of all alerts lackd timely follow-up
van der Sijs, H., A. Mulder, T. van Gelder, J. Aarts, M. Berg, and A. Vulto. 2009. Drug safety alert generation and overriding in a large Dutch university medical centre. *Pharmacoepidemiology and Drug Safety* 18(10):941–947.	Alerts	To determine rate and types of drug safety alerts generated and overridden	– In wards: Disguised observation study of internal medicine wards – Hospital: Retrospective analysis for entire hospital	– In wards: 25 days – Hospital: 24 months	– Observation study: • 2 internal medicine wards • 6 residents (3 per ward) • 515 prescriptions – Retrospective analysis: 371,261 prescribed orders from one hospital	– Rate of alerts – Alert types – Rate of overrides	– Observation study of internal medicine wards: • Drug safety alerts were generated in 34 percent of all orders, 91 percent of which were overridden • Type of alert (frequency/override rate) – Drug safety alert (56/98 percent) – Overdose (15/89 percent) – Duplicate orders (29/80 percent) – Retrospective analysis of entire hospital: • 20.2 percent of all orders were overridden • 59 percent of all alerts were DDI overrides, of which – 22.4 percent were low-level alerts – 54.5 percent were medium-level alerts – 19.3 percent were high-level alerts – 3.8 percent were unknown
van der Sijs, H., T. van Gelder, A. Vulto, M. Berg, and J. Aarts. 2010. Understanding handling of drug safety alerts: A simulation study. *International Journal of Medical Informatics* 79(5):361–369.	Alerts	To determine frequency and reason why drug safety alerts generated by a CPOE are handled incorrectly	Disguised observation study	Unknown	– 18 physicians – 35 orders of predefined patient cases – 211 generated alerts	– Errors in responding to alerts – Reason why alert was handled incorrectly	– 30 percent of all the generated alerts were handled incorrectly because • An incorrect action was chosen (24 percent of all alerts) and/or • The action was based on incorrect reasoning (16 percent of all alerts) – Types of errors: • Rule-based, 63 percent • Knowledge-based, 24 percent • Skill-based, 13 percent – 25 percent of respondents demonstrated signs of alert fatigue
Ohsaka, A., M. Kobayashi, and K. Abe. 2008. Causes of failure of a barcode-based pretransfusion check at the bedside: Experience in a university hospital. *Transfusion Medicine* 18(4):216–222.	Barcode	To determine the reason for the failures to check bedside barcode identification before blood administration	Retrospective analysis	April 2004 to December 2007	43,068 blood components transfused	– Rate at which transfusions were performed without electronic barcode checking – Reasons for not performing checks, including • Human errors • Handheld device errors • System errors and • Wristband errors	– 2.2 percent of transfusions were performed without electronic checking – Reasons for not performing check: • Human error, 84.7 percent • Handheld device error, 7.7 percent • System error, 5.2 percent • Wristband error, 2.4 percent
Franklin, B. D., K. O'Grady, P. Donyai, A. Jacklin, and N. Barber. 2007. The impact of a closed-loop electronic prescribing and administration system on prescribing errors, administration errors and staff time: A before-and-after study. *Quality & Safety in Health Care* 16(4):279–284.	Barcode	To examine how prescribing and administration errors, confirmation of patient identity, and staff time are affected by a closed-loop electronic prescribing, automated dispensing, barcode patient identification and electronic medication administration record (eMAR) system	Prospective cohort study	– 3 to 6 months pre-intervention – 6 to 12 months postintervention	– 2,319 newly written medications, – 906 opportunities for error – 56 drug rounds	– Percentage of new medication orders with a prescribing error – Percentage of doses with medication administration errors – Percentage of medication administered without checking patient identity – Time spent prescribing and providing a ward pharmacy service – Nursing time spent on medication tasks	– eMAR can reduce errors and increase patient identification rates but is associated with an increase in time spent on medication-related tasks – Prescribing errors were reduced by 1.8 percent (p < 0.001) – Medication administration errors were reduced by 2.7 percent (p = 0.005) – Patient identification not checked before administration of medication was reduced by 63.7 percent (p < 0.001) – Time staff spent prescribing rose 24 seconds (from 15 to 39 seconds) (p = 0.03) – Time per drug administration round was reduced by 10 minutes (from 50 to 40 minutes) (p = 0.006) – Nursing time on medication tasks outside of drug rounds rose 7.6 percent (from 21.1 to 28.7 percent) (p = 0.006)
Koppel R., T. Wetterneck, J. L. Telles, and B. Karsh. 2008. Workarounds to barcode medication administration systems: Their occurrences, causes, and threats to patient safety. *Journal of the American Medical Informatics Association* 15(4):408–423.	Barcode	To identify workarounds used with barcode medication administration systems (BCAS) and the potential MEs those workarounds may cause	– Observing and shadowing staff – Interviews – Participating in staff meetings – Analyzing override logs	2003 to 2006	– A four-hospital, 929-bed east coast health care system – One academic tertiary-care hospital	– Workarounds – Potential MEs associated with workarounds	15 types of workarounds which could lead to patient harm were discovered, including • User administers medication without scanning patient ID • Patient barcode ID placed on another object, not on patient, • User gives partial dose but electronically documents full dose
Poon, E. G., C. A. Keohane, C. S. Yoon, M. Ditmore, A. Bane, O. Levtzion-Korach, T. Moniz, J. M. Rothschild, A. B. Kachalia, J. Hayes, W. W. Churchill, S. Lipsitz, A. D. Whittemore, D. W. Bates, and T. K. Gandhi. 2010. Effect of bar-code technology on the safety of medication administration. *New England Journal of Medicine* 362(18):1698–1707.	Barcode	To assess how the rates of errors in order transcription and medication administration are impacted by the implementation of the barcode eMAR system	Prospective, quasi-experimental	February to October 2005	– 6,723 medication administrations – 3,082 order transcriptions	– Errors in timing of medication administration that were early or late by more than 1 hour – Errors unrelated to timing – Transcription errors	– Use of the barcode eMAR was associated with a substantial reduction in • Rate of errors in order transcription (p < 0.001) • Medication administration (p < 0.001) • Potential adverse drug events (p < 0.001) – Early or late medication administration errors were reduced by 27.3 percent (p = 0.001) – Nontiming errors had a relative reduction rate of 41.4 percent (p < 0.001)

Study	Health IT Component	Study Purpose	Method	Time Frame	Sample Size	Outcome Measures	Relevant Findings
Poon, E. G., J. L. Cina, W. Churchill, N. Patel, E. Featherstone, J. M. Rothschild, C. A. Keohane, A. D. Whittemore, D. W. Bates, and T. K. Gandhi. 2006. Medication dispensing errors and potential adverse drug events before and after implementing bar code technology in the pharmacy. *Annals of Internal Medicine* 145(6):426–434.	Barcode	To determine the effect of barcode technology on dispensing errors and ADEs	Before-and-after study using direct observations	– November and December 2003 – May and September 2004	– 115,164 preimplementation doses – 253,984 postimplementation doses	– Rates of dispensing errors and potential ADEs related to • Carousel fill process (medications are scanned during stocking, retrievals are directed by the carousel machine, and only 1 dose per batch was scanned during filling) • 2-day fill process (medication doses are stocked manually, retrieved by hand, and each dose was scanned during filling) • Alternate zone fill (medication doses are manually stocked, manually retrieved, and only 1 dose per batch was scanned)	– A substantial decrease in dispensing errors and potential ADEs were associated with the implementation of three kinds of barcode systems: – 2-day fill process reduced • Dispensing errors by 96 percent (p < 0.001) • Potential ADEs by 97 percent (p < 0.001) – Carousel fill process reduced • Dispensing errors by 93-96 percent (p < 0.001) • Potential ADEs by 86-97 percent (p < 0.001) – Alternate zone fill reduced • Dispensing errors by 93 percent (p < 0.001) • Potential ADEs by 86 percent (p <0.001)
Graham, T. A., A. W. Kushniruk, M. J. Bullard, B. R. Holroyd, D. P. Meurer, and B. H. Rowe. 2008. How usability of a web-based clinical decision support system has the potential to contribute to adverse medical events. *AMIA Annual Symposium Proceedings* 6:257–261.	CDS	To determine how usability of CDS systems graphic interfaces contribute to ADEs	Observational studies	2006 to 2007	7 attending emergency physicians	Number and type of ADEs	422 events were recorded, including – Events where the system precluded the desired choice – Subjects either ignored or overrode the CDS system purposefully – Subjects not having specific options to select common conditions
Fitzgerald, M., P. Cameron, C. Mackenzie, N. Farrow, P. Scicluna, R. Gocentas, A. Bystrzycki, G. Lee, G. O'Reilly, N. Andrianopoulos, L. Dziukas, D. J. Cooper, A. Silvers, A. Mori, A. Murray, S. Smith, Y. Xiao, D. Stub, F. T. McDermott, and J. V. Rosenfeld. 2011. Trauma resuscitation errors and computer-assisted decision support. *Archives of Surgery* 146(2):218–225.	CDS	To determine whether management errors in the first 30 minutes of trauma resuscitation can be reduced by CDS use	Prospective, open, randomized, controlled interventional study	January 2006 to February 2008	– 1 level I adult trauma center – 1,171 patients	– Error (deviation from trauma care algorithms) rate per patient treated – Morbidity	Management error rates reduced by CDS use: – Control, 0.4 reduction per patient (2.53 to 2.13, p = 0.004) – Intervention, 0.17 reduction per patient (2.30 to 2.13, p = 0.04)
Graumlich, J. F., N. L. Novotny, G. Stephen Nace, H. Kaushal, W. Ibrahim-Ali, S. Theivanayagam, L. William Scheibel, and J. C. Aldag. 2009. Patient readmissions, emergency visits, and adverse events after software-assisted discharge from hospital: Cluster randomized trial. *Journal of Hospital Medicine* 4(7):E11–19.	CDS	To determine the impact of a CPOE discharge software application that prompts physicians to enter pending prescriptions and orders, automatically generating discharge reports, discharge papers, patient instructions, and prescriptions	Cluster randomized controlled trial	– November 2004 to January 2007 – Follow-up occurred for 6 months after discharge	631 inpatients	– Hospital readmission rates within 6 months of discharge – Emergency department visit within 6 months – Postdischarge adverse event within 1 month	Differences between CPOE software and CPOE software tailored to discharge were insignificant: – Hospital readmission, 37.0 percent vs. 37.8 percent (p = 0.894) – Emergency department visit, 35.4 percent vs. 40.6 percent (p = 0.108) – Adverse event within 1 month, 7.3 percent vs. 7.3 percent (p = 0.884)
Wadhwa, R., D. B. Fridsma, M. I. Saul, L. E. Penrod, S. Visweswaran, G. F. Cooper, and W. Chapman. 2008. Analysis of a failed clinical decision support system for management of congestive heart failure. *AMIA Annual Symposium Proceedings* 6:773–777.	CDS	To determine if CDS systems can successfully identify patients with primary congestive heart failure (CHF)	Retrospective analysis	July to September 2006	112 patients	– Sensitivity – PPV – Frequency of alert and false positives – Physician responses to alerts	– CDS systems performed poorly – CDS systems had problems with false negatives: • Sensitivity, 0.79 • Positive predictive value (PPV), .11 – CDS systems had excessive alerts: • CDS system issued multiple alerts (74 percent of patients) • CDS systems issued alerts for patients without primary CHF (63 percent) – Physicians did not respond to alerts the first time
Campbell, E. M., D. F. Sittig, K. P. Guappone, R. H. Dykstra, and J. S. Ash. 2007. Overdependence on technology: An unintended adverse consequence of computerized provider order entry. *AMIA Annual Symposium Proceedings* 5:94–98.	CPOE	To identify adverse consequences caused by overdependence on CPOE systems	Observational analysis	N/A	5 hospitals	Type of ADEs	Overdependence can lead to the following adverse consequences: – Lack of backup systems can lead to chaos when systems are down – Users may trust inaccurate data – Clinicians, who are overdependent on systems, may not be able to adequately efficiently perform without the system
Ramnarayan, P., G. C. Roberts, M. Coren, V. Nanduri, A. Tomlinson, P. M. Taylor, J. C. Wyatt, and J. F. Britto. 2006. Assessment of the potential impact of a reminder system on the reduction of diagnostic errors: A quasi-experimental study. *Medical Informatics & Decision Making* 6:22.	CDS diagnosing	To evaluate the impact of a web-based pediatric diagnostic reminder system that suggests important diagnoses during clinical assessment on the quality of clinical decisions during acute assessment	Quasi-experimental	February to August 2002	• 76 subjects • 18 consultants • 24 registrars, • 19 senior house officers • 15 students • 751 case episodes	– Diagnostic errors of omission (DEO): failing to include all clinically important diagnoses, after consultation with web-based pediatric diagnostic reminder system	– A web-based pediatric diagnostic reminder system can reduce the rate of errors – The mean count of DEOs fell from 5.5 to 5.0 (p < 0.001) after implementation – Reminder system prompted an order of an important test in 10 percent of case episodes
Gurwitz, J. H., T. S. Field, P. Rochon, J. Judge, L. R. Harrold, C. M. Bell, M. Lee, K. White, J. LaPrino, J. Erramuspe-Mainard, M. DeFlorio, L. Gavendo, J. L. Baril, G. Reed, and D. W. Bates. 2008. Effect of computerized provider order entry with clinical decision support on adverse drug events in the long-term care setting. *Journal of the American Geriatrics Society* 56(12):2225–2233.	CDS ePrescribing	To determine if CPOE with CDS are effective at preventing ADEs in long-term care	Cluster, randomized control trial	August 2006 and August 2007	– 1,118 patients; – 29 resident care units	– Number and severity of ADEs – Whether ADEs were preventable	– CDS did not reduce preventable ADEs – No significant differences found between CDS and control groups: • ADEs, 1.06 (95 percent CI 0.92 to 1.23) • Preventable ADEs, 1.02 (95 percent CI 0.81 to 1.30) • Severe ADEs, 1.07 (95 percent CI 0.82 to 1.40)
Bedouch, P., B. Allenet, A. Grass, J. Labarère, E. Brudieu, J.-L. Bosson, and J. Calop. 2009. Drug-related problems in medical wards with a computerized physician order entry system. *Journal of Clinical Pharmacy & Therapeutics* 34(2):187–195.	CDS ePrescribing	To determine the type and frequency of drug-related problems that occur during the use of CPOE system with CDS	Prospective study	November 2001 to April 2003	8,152 patients	Rate and type of drug-related problems	– 33 drug-related problems per 100 admissions – Most common drug-related problems were the following: • Nonconformity to guidelines or contraindication (29.5 percent) • Improper administration (19.6 percent) • Drug interaction (16.7 percent) • Overdose (12.8 percent)
Abarca, J., L. R. Colon, V. S. Wang, D. C. Malone, J. E. Murphy, and E. P. Armstrong. 2006. Evaluation of the performance of drug-drug interaction screening software in community and hospital pharmacies. *Journal of Managed Care Pharmacy* 12(5):383–389.	CDS ePrescribing	To determine the effectiveness of DDI screening software in identifying significant DDIs	Observational study	2004	– 8 community pharmacies, – 5 hospital pharmacies – 6 mock patients – 25 medications – 37 DDIs – 16 clinically meaningful DDIs	DDI alerting system's median: – Sensitivity – Specificity – PPV – Negative predictive value (NPV)	– Significant variation in effectiveness among hospital pharmacy computer systems, even among systems manufactured by the same vendor – Computer systems correctly classified 12 of the 16 DDI pairs – Median sensitivity: 16 DDI pairs was 0.88 (range 0.81-0.94) – Median specificity of the systems was 0.91 (range 0.67-1.00) – Median PPV score was 0.88 (range 0.68-1.00) – Median NPV was 0.91 (range 0.86-0.95)

Study	Health IT Component	Study Purpose	Method	Time Frame	Sample Size	Outcome Measures	Relevant Findings
Eslami, S., A. Abu-Hanna, N. F. de Keizer, and E. de Jonge. 2006. Errors associated with applying decision support by suggesting default doses for aminoglycosides. *Drug Safety* 29(9):803–809.	CDS ePrescribing	To determine the impact of a CPOE system that supplies default doses when ordering on the rate of potential ADEs	Retrospective analysis	May 2002 to December 2004	– 1 Dutch tertiary adult intensive care unit – 392 prescriptions – 253 patients	– Rate of potential ADEs	– Default doses led to a significant increase in potential ADEs – Default dose was wrong in 73 percent of the orders – Rate of potential ADEs: • Patients with renal insufficiencies who were given default dosages, 86 percent • Patients with renal insufficiencies who were not given default doses, 53 percent (p < 0.0001).
Bertsche, T., J. Pfaff, P. Schiller, J. Kaltschmidt, M. G. Pruszydlo, W. Stremmel, I. Walter-Sack, W. E. Haefeli, and J. Encke. 2010. Prevention of adverse drug reactions in intensive care patients by personal intervention based on an electronic clinical decision support system. *Intensive Care Medicine* 36(4):665–672.	CDS ePrescribing	To determine how the rate of DDIs and DDI-related ADEs in intensive care patients were effected when senior clinicians' written prescription orders were typed into a CDS and recommendations are printed for senior clinicians	Prospective controlled intervention cohort study	– 3-month control phase – 3-month intervention phase	265 patients (136 control, 129 intervention)	– Number of DDIs – DDI-related ADEs	– Printed CDS recommendations were associated with a decrease in DDI and DDI-related ADEs – The number of patients with at least one DDI at the end of the study decreased by 18 percent (p = 0.02) – The relative risk of a patient having at least one DDI-related adverse event decreased by 43 percent (p = 0.01)
Colpaert, K., B. Claus, A. Somers, K. Vandewoude, H. Robays, and J. Decruyenaere. 2006. Impact of computerized physician order entry on medication prescription errors in the intensive care unit: A controlled cross-sectional trial. *Critical Care* 10(1).	CDS ePrescribing	To determine if the introduction of a computerized intensive care unit (ICU) system with a moderate level of CDS reduced the incidence and severity of medication prescription errors (MPEs)	Prospective, randomized controlled cross-sectional trial	80 patient days	– 2,510 prescriptions – 2 paper-based units – 1 computerized unit	MPEs (minor and serious)	– The computerized unit had significantly lower occurences and severity of medication errors in the ICU – MPEs: • Computer unit, 3.4 percent • Paper unit, 27 percent (p < 0.001) – Minor MPEs: • Computer, 9 • Paper, 225 (p < 0.001) – Serious MPEs: • Computer, 12 • Paper, 35 (p < 0.001)
Cunningham, T. R., E. S. Geller, and S. W. Clarke. 2008. Impact of electronic prescribing in a hospital setting: A process-focused evaluation. *International Journal of Medical Informatics* 77(8):546–554.	CDS ePrescribing	Examine the effects of natural implementation of a CPOE system with CDS (consisting of a campaign promoting the general awareness and benefits of CPOE, system training, and allowing physicians to continue using paper medication orders)	Multiple-base-line, quasi-experimental study, with a nonequivalent control site	N/A	– Intervention: 194 physicians – Control: 159 physicians	– Compliance with medication-ordering protocols – Mean duration to first dose of antibiotics	– CPOE medication orders were associated with significantly greater compliance – Rate at which orders were 100 percent compliant: • CPOE orders, 59.8 percent • Paper orders at the intervention site, 46.7 percent compliant (p < 0.001) • Paper orders at the control site, 46.6 percent (p < 0.001) – Mean duration to first dose of antibiotics: o CPOE orders, 185 min o Paper orders, 326.2 min (p < 0.001)
Dallenbach, M. F., P. A. Bovier, and J. Desmeules. 2007. Detecting drug interactions using personal digital assistants in an out-patient clinic. *QJM: An International Journal of Medicine* 100(11):691–697.	CDS ePrescribing	To determine if the drug interaction database (ePocrates Rx) can correctly identify clinically significant adverse drug interactions in an outpatient setting	Retrospective chart review	N/A	– 1,801 drug Prescriptions; – 591 consecutive patients	The drug interaction database's – Sensitivity – Specificity – PPV	– The drug interaction database can be an efficient tool to reduce prescription error – Sensitivity: 81 percent (95 percent, CI 77 to 85 percent) – Specificity: 88 percent (95 percent, CI 86 to 89 percent)
Galanter, W. L., D. B. Hier, C. Jao, and D. Sarne. 2010. Computerized physician order entry of medications and clinical decision support can improve problem list documentation compliance. *International Journal of Medical Informatics* 79(5):332–338.	CDS ePrescribing	To test a CDS mechanism that helps maintain an electronic problem list in a real-time clinical environment	Observational study	N/A	1,011 alerts	– Alert validity – Alert yield – Accuracy of problem list additions	CDS was able to improve the problem list with minimal diagnostic inaccuracies – Alert validity: 96±1 percent – Alert yield: 76±2 percent – Accurate problem list additions: 95±1 percent
Gandhi, T. K., S. B. Bartel, L. N. Shulman, D. Verrier, E. Burdick, A. Cleary, J. M. Rothschild, L. L. Leape, and D. W. Bates. 2005. Medication safety in the ambulatory chemotherapy setting. *Cancer* 104(11):2477–2483.	CDS ePrescribing	To determine the effect of a computerized medication ordering (CMO) system on outpatient chemotherapy	Prospective cohort study	March to December 2000	– 1,606 patients • 1,380 adult patients under a CMO system • 226 pediatric patients under a handwritten system orders (HWO) – 10,112 medication orders – 1,602 charts	Medication error rate	– No significant difference between the medication error rates of adult patients with CMO and pediatric patients with handwritten orders – Medication error rate: • Adult patients with CMO, 3 percent (249/8,008) • Pediatric patients with HWO, 3 percent (57/2,104) – The relatively low medication error rate in children may have been due to a high proportion of pediatric patients receiving investigational protocols with very specific dosing and dose modification parameters
Glassman, P. A., P. Belperio, A. Lanto, B. Simon, R. Valuck, J. Sayers, and M. Lee. 2007. The utility of adding retrospective medication profiling to computerized provider order entry in an ambulatory care population. *Journal of the American Medical Informatics Association* 14(4):424–431.	CDS ePrescribing	To determine whether adding a medication profiling program to a CPOE system improves safety	Retrospective review	June 2001 to January 2002	913 patients	– ADE rates – ADE severity, characterized into four categories: 1. Laboratory or test abnormality 2. Symptoms, not serious or serious 3. Disability, cognitive or physical 4. Death – Preventability (determined by the presence of an associated conflict)	– Addition of a medication profiling program did not increase safety – ADE incidence had no significant difference: • Usual care, 37 percent • Provider feedback groups, 45 percent (p = 0.06) – ADE severity was similar: • Usual care group, 51 percent • Provider feedback group, 58 percent (95 percent CI for the difference –15, 2 percent) – ADE preventability did not differ with feedback: • Usual care group, 16 percent • Provider feedback group, 17 (95 percent CI for the difference –7 to 5; p = 0.79)
Han, Y. Y., J. A. Carcillo, S. T. Venkataraman, R. S. B. Clark, S. Watson, T. C. Nguyen, H. L. Bayir, and R. A. Orr. 2005. Unexpected increased mortality after implementation of a commercially sold computerized physician order entry system. *American Academy of Pediatrics* 116.6:1506–1513.	CDS ePrescribing	To determine whether the mortality rate among children transported for specialized care is reduced by the implementation of CPOE with CDS	Retrospective analysis	– 13 months before implementation of CPOE – 5 months after implementation	1,942 children	Mortality rate	An increased odds of mortality was associated with the implementation of CPOE (OR 3.28; 95 percent CI 1.94-5.55) – Pre-CPOE mortality rate: 3.86 percent – Postimplementation: 6.57 percent (p < 0.001)
Holdsworth, M. T., R. E. Fichtl, D. W. Raisch, A. Hewryk, M. Behta, E. Mendez-Rico, C. L. Wong, J. Cohen, S. Bostwick, and B. M. Greenwald. 2007. Impact of computerized prescriber order entry on the incidence of adverse drug events in pediatric inpatients. *Pediatrics* 120(5):1058–1066.	CDS ePrescribing	To evaluate how the incidents and types of ADEs in hospitalized children are impacted by the use of a CPOE system with substantial decision support	Prospective cohort study	– Pre-CPOE period: September 2000 to May 2001 – Post-CPOE period: April to October 2004	– Pre-CPOE: 1,197 admissions – Post-CPOE: 1,210 admissions	Number of ADEs	– ADEs were substantially reduced by CPOE with CDS – Total ADEs • Pre-CPOE: 76 • Post-CPOE: 37 (RR of total ADEs in post-CPOE compared to pre-CPOE 95 percent CI 0.43 to 0.95). – Preventable ADEs • Pre-CPOE: 46 • Post CPOE: 26 • RR: 0.56 (95 percent CI 0.34 to 0.91) – Potential ADEs • Pre-CPOE: 94 • Post CPOE: 35 • RR: 0.37 (95 percent CI 0.25 to 0.55)

Study	Health IT Component	Study Purpose	Method	Time Frame	Sample Size	Outcome Measures	Relevant Findings
Jani, Y. H., M. A. Ghaleb, S. D. Marks, J. Cope, N. Barber, and I. C. K. Wong. 2008. Electronic prescribing reduced prescribing errors in a pediatric renal outpatient clinic. *Journal of Pediatrics* 152(2):214–218.	CDS ePrescribing	To evaluate how the rate of incidents, type of prescribing errors, and the number of error-free visits are affected by an electronic prescribing (EP) system with CDS	Before-and-after study	July 1, 2005 to July 31, 2006	– 520 patients – 2,242 items prescribed – 1,141 prescriptions	Prescribing error rates: – Items missing essential information – Items judged illegible – Number of patient visits that were error-free	– Overall prescribing error rate was significantly reduced: • 77.4 percent for handwritten items (95 percent CI 75.3 to 79.4 percent) • 4.8 percent for EP (95 percent CI 3.4 to 6.7 percent) – Items missing essential information: • 73.3 percent pre-EP (95 percent CI 71.1 to 75.4 percent) • 1.4 percent post-EP (95 percent CI 0.7 to 2.6 percent) – Items judged illegible: • 12.3 percent pre-EP (95 percent CI 10.8 to 14 percent) • Zero percent post-EP – Percentage of patient visits that were error-free increased by 69 percent (95 percent CI 64 to 73.4 percent)
Kadmon, G., E. Bron-Harlev, E. Nahum, O. Schiller, G. Haski, and T. Shonfeld. 2009. Computerized order entry with limited decision support to prevent prescription errors in a PICU. *Pediatrics* 124(3):935–940.	CDS ePrescribing	To compare the impact of prescription error rates of weight-based dosing in a pediatric ICU (PICU) with the introduction of a CPOE without a CDS system and a subsequent introduction of a CPOE with a CDS	Retrospective cohort study	September 2005 to September 2007	5,000 orders	Rates of ADEs and medication prescription errors (MPEs) per period – Period 1: 1 month pre-CPOE – Period 2: 1 year post-CPOE – Period 3: post-CDS system – Period 4: post-change in prescription authorization	– Introduction of CPOE alone had no significant impact on potential errors: • Period 1 ADE, 2.5 percent • Period 2 ADE, 2.4 percent • Period 1 MPE, 5.5 percent • Period 2 MPE, 5.3 percent – Introduction of CDS system significantly lowered the rate of potential errors: • Period 3 ADE, 0.8 percent ($p < .05$). • Period 4 ADE, 0.7 percent ($p < 0.005$) • Period 3 MPE, 3.8 percent ($p < 0.05$) • Period 4 MPE, 0.7 percent ($p < 0.0005$)
Metzger, J., E. Welebob, D. W. Bates, S. Lipsitz, and D. C. Classen. 2010. Mixed results in the safety performance of computerized physician order entry. *Health Affairs* 29(4):655–663.	CDS ePrescribing	To determine the abilities of different CPOE systems with CDS in different hospitals	Quasi-experimental	April to August 2008	62 hospitals	Percentage of simulated orders detected that would have led to serious ADEs	– Wide variation in the ability of CDS systems to detect serious ADEs – Range for the percentage of test orders detected that would have caused fatalities: 10 to 82 percent – Mean percent of test orders detected: • Overall score, 44.3 (SE: 2.3) • CPOE systems that are easy to implement, 61.4 (SE: 2.4) • CPOE systems that require configuration and customization, 24.8 (SE: 2.6)
Poller, L., M. Keown, S. Ibrahim, G. Lowe, M. Moia, A. G. Turpie, C. Roberts, A. Van den Besselaar, F. J. M. Van der Meer, A. Tripodi, G. Palareti, C. Shiach, S. Bryan, M. Samama, M. Burgess-Wilson, A. Heagerty, P. Maccallum, D. Wright, and J. Jespersen. 2008. An international multicenter randomized study of computer-assisted oral anticoagulant dosage vs. medical staff dosage. *Journal of Thrombosis and Haemostasis* 6(6):935–943.	CDS ePrescribing	To compare the safety and effectiveness of two computer-assisted anticoagulant dosage programs (PARMA 5 or DAWN AC) with dosage by experienced medical staff delivered	Multicenter, randomized trial	June 2002 to December 2006	– 32 centers – 13,219 patients – 6,503 patients randomized to medical staff – 6,716 randomized to computer-assisted dosage	Comparison of dosing by – Safety – Effectiveness – Clinical events by group	– The computer-assisted dosage programs were found to be similar or more effective than the manual delivery group – Clinical events by computer-assisted dosage was not significantly different (incidence rate ratio = 0.90; 95 percent CI 0.80–1.02; p = 0.10) – Clinical events for patients with deep vein thrombosis or pulmonary embolism were reduced by 24 percent (p = 0.001)
Saverno, K.R., L. E. Hines, T. L. Warholak, A. J. Grizzle, L. Babits, C. Clark, A. M. Taylor, D. C. Malone. 2011. Ability of pharmacy clinical decision-support software to alert users about clinically important drug-drug interactions. *Journal of the American Medical Informatics Association* 18: 32–37.	CDS ePrescribing	To determine the effectiveness of a pharmacy CDS software in detecting DDIs	Quasi-experimental	December 2008 to November 2009	– 64 pharmacies – 24 software vendors	Sensitivity, specificity, positive predictive value, negative predictive value, and percentage of correctly detected DDIs present in a simulated patient's medical orders	– Many pharmacy CDS systems inadequately identified DDIs – 28 percent of pharmacies correctly identified eligible DDIs and non-DDIs – Median percentage of correct DDI responses: 89 percent – Median sensitivity to detect well-established interactions: 0.85 (range 0.23-1.0) – Median specificity: 1.0 (range 0.83-1.0)
Smith, D. H., N. Perrin, A. Feldstein, X. Yang, D. Kuang, S. R. Simon, D. F Sittig, R. Platt, and S. B. Soumerai. 2006. The impact of prescribing safety alerts for elderly persons in an electronic medical record: An interrupted time series evaluation. *Archives of Internal Medicine* 166(10):1098–1104.	CDS ePrescribing	To determine if the use of potentially contraindicated agents in elderly persons is reduced by implementing a CPOE system with CDS	Interrupted time series analysis	October 1999 to December 2002	209 family practitioners and internal medicine clinicians	Number of dispensings of nonpreferred and preferred drugs per 10,000 population	– Implementation of CPOE system with CDS is significantly correlated with a sudden reduction in the rate of initial dispensing of nonpreferred agents among elderly persons – Rate of dispensing nonpreferred agents (per 10,000): • Preimplementation, 21.9 • Postimplementation, 16.8 (p < 0.01)
Niès, J., I. Colombet, E. Zapletal, F. Gillaizeau, P. Chevalier, and P. Durieux. 2010. Effects of automated alerts on unnecessarily repeated serology tests in a cardiovascular surgery department: A time series analysis. *Health Services Research* 10:70.	CDS laboratory	To determine whether CDS reminders of previous existing serology results would result in less unnecessarily repeated HBs antigen tests	Time series analysis	January 2004 to December 2007	– Pre-CDS: 3,480 viral serology tests – Post-CDS: 2,095 HBs antigen tests performed	Proportion of unnecessarily repeated HBs antigen tests	– Implementation of CDS system stopped the rising rate of unnecessarily repeated HBs antigen tests – Mean proportion of unnecessarily repeated HBs antigen tests: • Pre-CDS, increase of 0.4 percent per month (95 percent CI 0.2 to 0.6, p < 0.001) • Post-CDS, decrease of 0.4 percent per month (95 percent CI –0.7 to –0.1 percent, p = 0.02)
Koppel, R., J. P. Metlay, A. Cohen, B. Abaluck, A. R. Localio, S. E. Kimmel, and B. L. Strom. 2005. Role of computerized physician order entry systems in facilitating medication errors. *Journal of the American Medical Association* 293(10):1197–1203.	CPOE	To identify and quantify the role of CPOE in facilitating prescription error risks	Quantitative and qualitative study	2002 to 2004	– 261 hospital house staff – 5 focus groups – 32 one-on-one interviews and observations	Examples of medication errors caused or worsened by the CPOE system	CPOE system caused or exacerbated 22 types of medication error risks, including – Fragmented CPOE displays that prevent a coherent view of patients' medications – Pharmacy inventory displays mistaken for dosage guidelines – Ignored antibiotic renewal notices placed on paper charts rather than in the CPOE system – Separation of functions that facilitate double dosing and incompatible orders – Inflexible ordering formats generating wrong orders
DesRoches C. M., E. G. Campbell, C. Vogeli, J. Zheng, S. R. Rao, A. E. Shields, K. Donelan, S. Rosenbaum, S. J. Bristol, and A. K. Jha. 2010. Electronic health records' limited successes suggest more targeted uses. *Health Affairs* 29(4):639–646.	EHR	To determine the impact of EHRs on quality of medical care	Observational analysis (survey)	March to September 2008	2,952 institutions	Hospital Quality Alliance summary scores	– No relationship between the adoption of EHRs and quality of care was found – Hospital Quality Alliance summary scores (percent): • Acute myocardial infarction: – Comprehensive EHR adoption, 97.5 – Basic EHR adoption, 96.4 – No EHR adoption, 96.3 (p = 0.24) • Congestive heart failure: – Comprehensive EHR adoption, 91.2 – Basic EHR adoption, 90.5 – No EHR adoption, 89.1 (p = 0.08) • Pneumonia: – Comprehensive EHR adoption, 93.2 – Basic EHR adoption, 92.9 – No EHR adoption, 92.4 (p = 0.33) • Surgical Care Improvement Project measures: – Comprehensive EHR adoption, 93.7 – Basic EHR adoption, 93.3 – No EHR adoption, 92.0 (p = 0.01)

Study	Health IT Component	Study Purpose	Method	Time Frame	Sample Size	Outcome Measures	Relevant Findings
Ferris, T. G., S. A. Johnson, J. P. T. Co, M. Backus, J. Perrin, D. W. Bates, and E. G. Poon. 2009. Electronic results management in pediatric ambulatory care: Qualitative assessment. *Pediatrics* 123(Suppl 2):S85–S91.	EHR	To determine the impact of electronic results management (ERM) systems on pediatric care	Observational Analysis (semi-instructed, key informant interviews and surveys)	N/A	– 86 respondents – 18 surveyed practices – 8 of the surveyed practices were interviewed	Physicians responses to questions regarding – Patient safety – Effectiveness of care – Availability of results – Confidence that results would not be lost	– Fully adopted ERMs reported an increase in efficiency, safety, and physicians satisfaction • 72 percent of practitioners reported an increase in patient safety • 63 percent reported an increase in more effective care – Partially adopted ERMs resulted in a perceived decrease in safety and efficiency
Gearing, P., C. M. Olney, K. Davis, D. Lozano, L. B. Smith, and B. Friedman. 2006. Enhancing patient safety through electronic medical record documentation of vital signs. *Journal of Health care Information Management* 20(4):40–45.	EHR	To compare the error rate of electronic vital signs (EVS) documentation to paper documentation	Prospective cohort study	2006	1,236 vital sign sets	Error rate	– Medical error rates can be reduced almost by half through the use of EVS documentation – Medical error rate: • EVS documentation: 4.4 percent • Paper chart: 10 percent
Gordon, J.R.S., T. Wahls, R.C. Carlos, I.I. Pipinos, G.E. Rosenthal, and P. Cram. 2009. Failure to recognize newly identified aortic dilations in a health care system with an advanced electronic medical record. *Annals of Internal Medicine* 151(1):21–27.	EHR	To determine the frequency which clinicians enter CT-documented dilations of the abdominal aorta into the EMR	Retrospective cohort study	2003	– 2 hospitals – 440 patients with abdominal aortic abnormalities	Percentage which – Dilations were not recorded in EMR – Abnormalities were documented in EMR	– A substantial proportion of new aortic dilations were not recorded in the EMR – 58 percent of dilations were not recorded in the EMR by clinical teams within 3 months of the CT – No EMR documentation of abnormalities existed for 29 percent of surviving patients during a mean follow-up of 3.2 years
Lo, H. G., L. P. Newmark, C. Yoon, L. A. Volk, V. L. Carlson, A. F. Kittler, M. Lippincott, T. Wang, and D. W. Bates. 2007. Electronic health records in specialty care: A time-motion study. *Journal of the American Medical Informatics Association* 14(5):609–615.	EHR	To determine if EHRs decrease the amount of time spent per patient by specialized clinicians in cardiology, dermatology, endocrine, and pain clinics	Prospective study	– Pre-EHR: May 2002 to August 2003 – Post-EHR: December 2002 to May 2004	– 5 outpatient, urban specialty care clinics – Pre-EHR: 15 physicians treating 157 patients – Post-EHR: 15 physicians treating 146 patients	Average adjusted total time spent per patient on – Direct patient care – Indirect patient care (writing, reading, and involved actions such as writing emails, reading patient charts, or finding digitized radiographs) – Administration – Miscellaneous	– EHR use slightly, but not significantly, increased average adjusted total time spent per patient across all specialties: • Pre-EHR, 28.8 min • Post-EHR, 29.8 min (p = 0.83) – Change in time for • Direct patient care, 0.26 min (p = 0.85) • Indirect patient care (write), 2.1 min (p = 0.21) • Indirect patient care (read), 1.8 min (p = 0.07) • Indirect patient care (other), –0.53 min (p = 0.49) • Administration, –0.40 min (p = 0.55) • Miscellaneous, –3.1 min (p = 0.03)
O'Donnell, H. C., R. Kaushal, Y. Barrón, M. A. Callahan, R. D. Adelman, and E. L. Siegler. 2008. Physicians' attitudes towards copy and pasting in electronic note writing. *Journal of General Internal Medicine* 24(1):63–68.	EHR	To determine physician use and attitudes towards copy and paste functions (CPFs) in computerized note writing	Cross-sectional survey	June to August 2007	– 2 medical facilities – 253 physicians	– Reported use of CPF – Reported opinions toward CPF	– 90 percent of respondents used CPF – 70 percent used CPF almost always or most of the time – 71 percent believed electronic records developed with CPF are more likely to contain mistakes and outdated information
Parente, S.T., and J.S. McCollough. 2009. Health information technology and patient safety evidence from panel data. *Health Affairs* 28(2):357–360.	EHR	To determine the impact of PACS, EMRs, and nurse charts on patient safety	Retrospective analysis	1999 to 2002	N/A	PSIs: – Infection due to medical care – Postoperative hemorrhage or hematoma – Postoperative pulmonary embolism or deep vein thrombosis (DVT)	– PACS and nurse charts showed no statistical significance on patient safety – EMR use was the only health IT application that showed a significant effect on patient safety • EMRs were significantly correlated with the reduction of infection rates • Two infections are avoided per year at an average hospital • EMR use became more effective over time
Smith, L.B., L. Banner, D. Lozano, C. Olney, and B. Friedman. 2009. Connected care: Reducing errors through automated vital signs data upload. *Computers Informatics Nursing* 27(5):318–323.	EHR	To evaluate the accuracy of vital sign data when collected from an automated vital sign monitor, transmitted through an infrared port to a personal digital assistant (PDA), and then automatically uploaded into an EMR	Prospective observational study	October to November 2006	9,084 vital sign data elements	– Vital sign documentation errors – Omission errors – Transcription errors – Transmission errors	– A significant reduction in documentation errors was associated with the use of direct electronic upload into EMR (p < 0.001) – Vital signs captured on paper and then typed into the EMR were incorrect 4.4 percent of the time – Vital signs electronically uploaded directly into EMR were incorrect: • Total errors, 0.66 percent • Omission errors, 0.58 percent • Transcription errors, 0.08 percent • Transmission errors, 0 percent
Zhou, L., C. S. Soran, C. A. Jenter, L. A. Volk, E. J. Orav, D. W. Bates, and S. R. Simon. 2009. The relationship between electronic health record use and quality of care over time. *Journal of the American Medical Informatics Association* 16(4):457–464.	EHR	To examine the extent of EHR usage and how that use over time affects the quality of different ambulatory care practices	Cross-sectional study	2000 to 2005	1,181 physicians	– Length of EHR use – Change in 6 HEDIS quality measures after EHR implementation: • Cancer screening • Diabetes care • Asthma care • Well child and adolescent visit • Behavioral and mental health • Women's health	– No association between length of time using EHR and quality of care was found for any of the six quality measures – By 2005: • Adoption of EHRs doubled since 2000 • Average length of EHR use was 4.8 years
Hanuscak, T. L., S.L. Szeinbach, E. Seoane-Vazquez, B. J. Reichert, and C. F. McCluskey. 2009. Evaluation of causes and frequency of medication errors during information technology downtime. *American Journal of Health-System Pharmacy* 66(12):1119–1124.	ePrescribing	To determine the rate of MEs when health IT systems are down	Survey	February and May 2007	32 respondents	MEs occurring while health IT systems were down	– Standard protocols and backup systems did not prevent MEs during a downtime of a health IT system – 16 percent of errors occurring during downtime had the potential to cause patient harm
Santell, J. P., J. G. Kowiatek, R. J. Weber, R. W. Hicks, and C. A. Sirio. 2009. Medication errors resulting from computer entry by nonprescribers. *American Journal of Health-System Pharmacy* 66(9):843–853.	ePrescribing	The characteristics of medication errors associated with the use of computer order-entry systems by nonprescribers	Retrospective analysis of records submitted to MEDMARX	July 2001 to December 2005	– 693 unique facilities – 90,001 medication error records that were the result of computer entry by nonprescribers	Rates and causes of MEs	– Computer systems can create new opportunities for error – Percentage of harm associated with computer-entry errors: 0.99 percent (only national level data reported) – Causes for error included • Inaccurate or omitted transcription, 30 percent • Documentation, 19.5 percent • Procedure or protocol not followed, 21.7 percent – Most computer-entry errors occurred in the inpatient pharmacy department: 49.3 percent

Study	Health IT Component	Study Purpose	Method	Time Frame	Sample Size	Outcome Measures	Relevant Findings
Singh, H., S. Mani, D. Espadas, N. Petersen, V. Franklin, and L. A. Petersen. 2009. Prescription errors and outcomes related to inconsistent information transmitted through computerized order entry: A prospective study. *Archives of Internal Medicine* 169(10):982–989.	ePrescribing	To identify the nature and frequency of errors related to inconsistent information entered into a CPOE system	Prospective study	4-month period	– One tertiary care facility – 55,992 new prescriptions	– Percentage of orders containing inconsistent communication – Percentage of orders with inconsistent information that could cause moderate to severe harm	– Inconsistent communication in CPOE systems creates significant risks to safety – 0.95 percent of orders contained inconsistent information – Approximately 20 percent of errors could have resulted in moderate to severe harm
Walsh, K. E., W. G. Adams, H. Bauchner, R. J. Vinci, J. B. Chessare, M. R. Cooper, P. M. Hebert, E. G. Schainker, and C. P. Landrigan. 2006. Medication errors related to computerized order entry for children. *Pediatrics* 118(5):1872–1879.	ePrescribing	To determine the frequency of MEs associated with a CPOE system	Retrospective analysis	– April to June 2002 – 3 to 12 months after implementation of computerized order entry	– One urban teaching hospital – 6,916 medication orders – 1930 patient-days	Severity and rate of MEs per 1,000 patient days	– Although CPOE systems can introduce new pediatric MEs, serious computer-related pediatric computer errors are uncommon – Study yielded 37 serious MEs per 1,000 patient-days; rate of serious computer-related pediatric errors was 3.6 errors per 1,000 patient-days

Zhan, C., R. W. Hicks, C. M. Blanchette, M. A. Keyes, and D. D. Cousins. 2006. Potential benefits and problems with computerized prescriber order entry: Analysis of a voluntary medication error-reporting database. *American Journal of Health-System Pharmacy* 63(4):353–358.	ePrescribing	To compare the rate of prescribing errors in facilities with and without CPOE systems	Retrospective analysis from MEDMARX reports	2003	– 570 facilities
					– 235,164 medication error reports
						Rate and type of errors	– Due to underreporting, MEDMARX data cannot be used to determine if CPOE prevents errors
							– However, types of errors related to CPOE systems can be determined:
							  • Dosing errors, 51.4
							  • Unauthorized drug, 3.6
							  • Wrong patient, 3.5
							  • Wrong time, 2.7

Ali, N. A., H. S. Mekhjian, P. L. Kuehn, T. D. Bentley, R. Kumar, A. K. Ferketich, and S. P. Hoffmann. 2005. Specificity of computerized physician order entry has a significant effect on the efficiency of workflow for critically ill patients. *Critical Care Medicine* 33(1):110–114.	ePrescribing	To compare the effects patient care of a standard CPOE on ICU to that of a modified CPOE designed for ICU patient care	Retrospective before and after cohort study	May 2000 to May 2002	91 Patients	– Orders for complex ICU care
						– Use of higher-efficiency CPOE order paths
							– CPOE specifically designed for ICU care significantly increased efficiency
							– Under the modified CPOE system, significant reductions in orders per patient were found for
							  • Vasoactive infusions from 4.8 to 2.2 (p < 0.01),
							  • Sedative infusions, and from 6.4 to 2.9 (p < 0.01),
							  • Ventilator management from 13.1 to 6.9 orders/patient (p < 01).
							– Significant increase in orders executed through ICU-specific order sets occurred after system modifications

Callen, J., R. Paoloni, A. Georgiou, M. Prgomet, and J. Westbrook. 2010. The rate of missed test results in an emergency department: An evaluation using an electronic test order and results viewing system. *Methods of Information in Medicine* 49(1):37–43.	ePrescribing	Determine the impact of long term use of a CPOE system	Cross-sectional qualitative study	January 2002 to November 2004	– 4 clinical units in 2 large Australian teaching hospitals – Hospital A: Used CPOE for 10-plus years – Hospital B: Orders ordered manually	– Comments regarding use of health IT made by clinicians during interviews – Observations regarding use of health IT made by study staff on site	– Different clinical environments and diversity among clinicians affect the way clinicians ordered lab tests and therefore the safety of the CPOE system – Diversity of physicians' test management practices need to be understood, analyzed, and accommodated before and during the CPOE implementation

Condren, M., I. J. Studebaker, and B. M. John. 2010. Prescribing errors in a pediatric clinic. *Clinical Pediatrics* 49(1):49–53.	ePrescribing	To identify the rate and type of prescribing errors occurring in a pediatric clinic with an EMR system	Prospective cohort study	February to April 2007	– 3,523 records
					– 1,802 new prescriptions
						Rates of
						– Errors entered into the EMR
						– Incomplete prescription
						– Dosing outside recommended range
						– Drug selection error
						– Documentation error
						– Administration error
							– 9.7 percent of all prescriptions were found to contain prescribing errors
							– Types and rates of error:
							  • Incomplete prescription, 42 percent
							  • Dosing outside recommended range, 34 percent
							  • Drug selection error, 14.5 percent
							  • Documentation error, 6.5 percent
							  • Administration error, 1.25 percent

Devine, E. B., R. N. Hansen, J. L. Wilson-Norton, N. M. Lawless, A. W. Fisk, D. K. Blough, D. P. Martin, and S. D. Sullivan. 2010. The impact of computerized provider order entry on medication errors in a multispecialty group practice. *Journal of the American Medical Informatics Association* 17(1):78–84.	ePrescribing	To determine an ambulatory CPOE system's effect on medication errors and ADEs	Quasi-experimental study	July 2004 to November 2007	10,169 prescriptions
					– 5,016 handwritten
					– 5,153 electronic
						Percent change in ME rate and ADE rate	– A significant reduction in medication errors is associated with the use of a CPOE system
							– Adjusted odds of an error occurring postimplementation of CPOE: 70 percent lower than preimplementation (OR: 0.30; 95 percent CI 0.23 to 0.40; p < 0.001)
							– Frequency of errors declined from 18.2 percent to 8.2 percent
							– Largest reduction of errors as a result of CPOE implementation for the following:
							  • Illegibility (97 percent)
							  • Inappropriate abbreviations (94 percent)
							  • Missing information (85 percent)

Magrabi, F., S. Y. W. Li, R. O. Day, and E. Coiera. 2010. Errors and electronic prescribing: A controlled laboratory study to examine task complexity and interruption effects. *Journal of the American Medical Informatics Association* 17(5):575–583.	ePrescribing	To determine the impact of interruptions and task complexity caused by CPOE systems on the types and rates of prescribing errors	Observational analysis	N/A	32 doctors	– Types of prescribing errors
						– Error rate
							– Most errors were "slips" in updating and creating EHRs, such as selecting incorrect:
							  • Medications
							  • Doses
							  • Routes
							  • Formulations
							  • Frequencies of administration
							– Among the several types of prescribing errors that were observed, the rates for each type of error ranged from
							  • 0.5 percent (incorrect medication selected) to
							  • 16 percent (failure to enter patent allergy information).

Nam, H. S., S. W. Han, S. H. Ahn, J. Y. Lee, H. Y. Choi, I. C. Park, and J. H. Heo. 2007. Improved time intervals by implementation of computerized physician order entry-based stroke team approach. *Cerebrovascular Diseases* 23(4):289–293.	ePrescribing	To determine if the implementation of CPOE reduces the time interval from a patient's arrival at the emergency department to thrombolysis	Quasi-experimental study	– Pre-CPOE: June 2003 to May 2004
				– Post-CPOE: June 2004 to May 2005
					– Pre-CPOE: 14 patients
					– Post-CPOE: 25 patients
						Time intervals from patient arrival to:
						– Registration
						– CT scan
						– Thrombolysis
							– Implementation of the CPOE significantly shortens the median time interval from arrival to evaluation and treatment
							– Median time intervals (minutes) from arrival to
							  • Registration:
							    – Pre-CPOE, 5
							    – Post-CPOE, 5
							    (p = 0.52)
							  • CT scan
							    – Pre-CPOE, 34
							    – Post-CPOE, 19
							    (p = 0.01)
							  • Thrombolysis:
							    – Pre-CPOE, 79
							    – Post-CPOE, 56
							    (p < 0.01)

Oyen, L. J., R. A. Nishimura, N. N. Ou, J. J. Armon, and M. Zhou. 2005. Effectiveness of a computerized system for intravenous heparin administration: Using information technology to improve patient care and patient safety. *The American Heart Hospital Journal* 3(2):75–81.	ePrescribing	To evaluate the impact of HepCare (a computerized heparin nomogram system) on heparin safety	Cohort study	2001 to April 2003	– 419 patients using HepCare
					– 98 using standard care
						– Percentage of patients achieving goal activated partial thromboplastin time values (aPTT)
						– Time to achieve the goal aPTT
							– Significant improvements in safety, quality assurance, and targeted aPTT values were associated with HepCare use
							– Mean percentage of aPTT values at goal:
							  • HepCare, 44 percent
							  • Standard care, 27 percent (p < 0.01)
							– Percent of patients reaching at least one goal aPTT within 24 hours:
							  • HepCare, 54 percent
							  • Standard care, 13 (p < 0.01)

Study	Health IT Component	Study Purpose	Method	Time Frame	Sample Size	Outcome Measures	Relevant Findings
Pirnejad, H., Z. Niazkhani, H. van der Sijs, M. Berg, and R. Bal. 2008. Impact of a computerized physician order entry system on nurse-physician collaboration in the medication process. *International Journal of Medical Informatics* 77(11):735–744.	ePrescribing	To determine if CPOE impedes nurse-physician collaboration and thereby undermines the efficiency and safety of the medication process	Prospective cohort study (survey)	Nov 2003 to Apr 2004	– Six internal medicine wards – Pre-CPOE: 76 nurses – Post-CPOE: 73 nurses	Concerns respondents expressed with the medication ordering system	– Although the CPOE system addressed concerns of paper-based systems, new concerns were associated with the CPOE system – Concerns with paper-based system: • Illegibility of handwritten medication data, 64.3 percent • Poor overview of current medication, 46.4 percent • Slowness of system, 46.4 percent – Concerns with CPOE system: • No possibility to check what medication had already been administered to a patient, 52.2 percent • Less possibility for nurses to correct physicians' prescription errors, 43.5 percent
Shulman, R., M. Singer, J. Goldstone, and G. Bellingan. 2005. Medication errors: A prospective cohort study of hand-written and computerised physician order entry in the intensive care unit. *Critical Care* 9(5):R516–R521.	ePrescribing	To compare the rate of MEs with hand-written prescribing (HWP) system to a CPOE system without CDS in an intensive care unit	Prospective cohort study	65 weeks	– 2,429 CPOE prescriptions – 1,036 HWP prescriptions	Rate of MEs	– Rate of MEs is significantly lowered by introduction of CPOE: • HWP, 6.7 percent • CPOE, 4.8 percent (p < 0.04) – Strong linear trend of a declining proportion of MEs over time (p < 0.001) – Moderate and major errors (such as harms without any associated causes or can lead to death) are still of significant concern after implementation of CPOE (nonintercepted and intercepted harm: 0.9 percent)
Sinopoli, D. J., D. M. Needham, D. A. Thompson, C. G. Holzmueller, T. Dorman, L. H. Lubomski, A.W. Wu, L. L. Morlock, M. A. Makary, and P. J. Pronovost. 2007. Intensive care unit safety incidents for medical versus surgical patients: A prospective multicenter study. *Journal of Critical Care* 22(3):177–183.	ePrescribing	To determine the differences in harm related to CPOE in medical and surgical patients	Multicenter prospective study	July 2002 to June 2004	– 646 incidents involving adult medical patients – 707 incidents involving adult surgical patients	Reported safety incidents	Incidents related to CPOE occurred more often in medical patients than surgical patients: – Surgical, 6 percent – Medical patients, 13 percent (p ≤ 0.001) – Increased frequency of incidents may be due to more medication orders being made in medical patients group
Thompson, D.A., L. Duling, C.G. Holzmueller, T. Dorman, L.H. Lubomski, F. Dickman, M. Fahey, L.L. Morlock, A.W. Wu, and P.J. Pronovost. 2005. Computerized physician order entry, a factor in medication errors: Descriptive analysis of events in the Intensive Care Unit Safety Reporting System. *Journal of Clinical Outcomes Management* 12(8):407–412.	ePrescribing	To determine how the rate of medication errors are affected by the implementation of a CPOE system	Observational analysis	Unknown	18 intensive care units	Rate of incidence reported to an anonymous web-based incident reporting system	– 55 incidents were related to CPOE – CPOE incidents that resulted in a medication error: 85 percent – Types of errors: • User errors, 67 percent of the error and near misses • Software errors, 20 percent • Computer malfunction, 13 percent
Weant, K. A., A. M. Cook, and J. A. Armitstead. 2007. Medication-error reporting and pharmacy resident experience during implementation of computerized prescriber order entry. *American Journal of Health System Pharmacy* 64(5):526–530.	ePrescribing	To compare the number and type of medication errors reported before and after the implementation of CPOE	Prospective cohort study	– Pre-CPOE: Sept to Oct 2003 – Post CPOE: Sept to Oct 2004	1 neurosurgical ICU	Number of ordering errors	– Number of ordering errors increased fivefold after CPOE implementation (0.938 vs. 1.839 per 1,000 doses) – Number of errors resulting in patient harm decreased following CPOE implementation (0.137 vs. 0.0152 per 1,000 doses)
Agrawal, A., and W. Y. Wu. 2009. Reducing medication errors and improving systems reliability using an electronic medication reconciliation system. *Joint Commission Journal on Quality & Patient Safety* 35(2):106–114.	Other health IT-assisted care	To evaluate the effectiveness of an electronic Medication Reconciliation System (MedRecon) system with computerized alerts	Observational study	August 2006 to December 2007	– 120 unique MedRecon events over initial 2-week pilot study – 19,356 unique MedRecon events during 17-month study period	– Unintended discrepancy rate between a patient's home medications and admission medication orders – Compliance with the MedRecon process	– Medication errors on admission were substantially reduced by an electronic MedRecon System – Unintended discrepancy rate was reduced from 20 to 1.4 percent – Physician adherence with the MedRecon process: • Preimplementation, 34 percent • Postimplementation, 98-100 percent
Agrawal, A., W. Wu, and I. Khachewatsky. 2007. Evaluation of an electronic medication reconciliation system in inpatient setting in an acute care hospital. In *Building Sustainable Health Systems*, edited by K. A. Kuhn, J. R. Warren, and T.-Y. Leong. Conference Proceedings: 12th World Congress on Health (Medical) Informatics. Amsterdam: IOS Press. Pp. 1027–1031.	Other health IT-assisted care	To evaluate the performance of an electronic MedRecon system	Observational analysis	Unknown	3,426 consecutive inpatient admission MedRecon events	Type and rate of discrepancies between medications taken at home and what is recorded in the admission orders	– Compared to the literature, discrepancy rate between patient's home medication history and admission orders was low (3.12 percent) – Most common type of discrepancy was omission of a home medication (56.52 percent)
Schnipper, J. L., C. Hamann, C. D. Ndumele, C. L. Liang, M. G. Carty, A. S. Karson, I. Bhan, C. M. Coley, E. Poon, A. Turchin, S. A. Labonville, E. K. Diedrichsen, S. Lipsitz, C. A. Broverman, P. McCarthy, and T. K. Gandhi. 2009. Effect of an electronic medication reconciliation application and process redesign on potential adverse drug events: a cluster-randomized trial. *Archives of Internal Medicine* 169(8):771–780.	Other health IT-assisted care	To determine the effect of a web-based medication reconciliation intervention on medication discrepancies with potential for adverse drug events	Cluster, randomized trial	May to June 2006	– 2 hospitals – 322 patients – 160 control patients • Residents documented medication histories in admission notes • Pharmacists reviewed medication orders • Physicians wrote discharge orders without access to preadmission medication histories – 162 interventions: electronic medication reconciliation program integrated into the CPOE	– Preadmission medication list compared to medical histories taken from medical team – Number of unintentional medication discrepancies with potential for causing harm per patient: potential adverse drug event (PADE)	– Computerized medication reconciliation tool decreased unintentional medication discrepancies with potential for patient harm. – Control Group: 230 unintentional medications discrepancies with potential for patient harm (1.44 PADEs per patient) – Intervention group: 170 unintentional medication discrepancies with potential for patient harm (1.05 PADEs per patient) – Adjusted relative risk (ARR): 0.72 (95 percent CI 0.52 to 0.99) – Because the effect differed among the hospitals, integration issues are likely important for successful implementation • Hospital 1 (ARR, 0.60; 95 percent CI, 0.38 to 0.97) • Hospital 2 (ARR, 0.87; 95 percent CI 0.57 to 1.32) (p = 0.32 for test of effect modification)

Study	Health IT Component	Study Purpose	Method	Time Frame	Sample Size	Outcome Measures	Relevant Findings

Porter, S. C., R. Kaushal, P. W. Forbes, D. Goldmann, and L. A. Kalish. 2008. Impact of a patient-centered technology on medication errors during pediatric emergency care. *Ambulatory Pediatrics* 8(5):329–335.	Patient engagement	To identify the effect of ParentLink (application that obtains child's medication/allergy history and provides tailored advice to both parents and clinicians) on the rate of medication errors	Quasi-experimental intervention study	June 2005 to June 2006	– 1,410 parent–child pairs
					– 835 pairs under usual care
					– 575 pairs used ParentLink
						Number of medication errors	– Use of ParentLink had no significant impact on medication errors
							– Number of errors per 100 patients:
							  • Control, 173
							  • Intervention, 134 (p = 0.35)

McAlearney, A. S., J. Vrontos, Jr, P. J. Schneider, C. R. Curran, B. S. Czerwinski, and C. A. Pedersen. 2007. Strategic work-arounds to accommodate new technology: The case of smart pumps in hospital care. *Journal of Patient Safety* 3(2):75–81.	Smart-pumps	To assess nurses' attitudes towards computerized intravenous infusion pumps with decision support (smartpumps)	Focus groups	March to April 2005	– 24 nurses
					– 4 focus groups
						– Nurses' perceptions of smartpumps
						– Examples of how nurses work around smartpump problems
							– Nurses largely perceive smartpumps to be beneficial to patient safety
							– Nurses use a number of workarounds to overcome issues with smartpumps, which may lead to new sources of error
							– Examples of workarounds:
							  • Bypassing both the decision support and dose mode safety features to give doses that are not contained in the smartpump's dosage library
							  • Placing pillows over the pump to quiet alerts that could not be turned off

Claridge, J. A., J. F. Golob, Jr., A. M. A. Fadlalla, B. M. D'Amico, J. R. Peerless, C. J. Yowler, and M. A. Malangoni. 2009. Who is monitoring your infections: Shouldn't you be be? *Surgical Infections* 10(1):59–64.	Surveillance	To compare the Surgical Intensive Care-Infection Registry (SIC-IR) (a health IT system integrated into the hospital's laboratory information system and medication administration record for automatic data loading) with traditionally trained infection control teams' (IC) ability to identify ventilator-associated pneumonia (VAP) in critically ill patients	Prospective analysis	12 months	769 patients	Number, sensitivity, and specificity of patients diagnosed with VAP by a panel of doctors compared to number of patients diagnosed by SIC-IR and IC	– SIC-IR was more accurate in diagnosed VAPS than the IC team
							– Number of patients diagnosed VAPs by
							  • Physician panel: 40
							  • SIC-IR, 39
							  • IC, 22
							– Sensitivity for identifying VAP:
							  • SIC-IR, 97 percent
							  • IC, 56 percent
							– Specificity for identifying VAP:
							  • SIC-IR, 100 percent
							  • IC, 99 percent

Jha, A. K., J. Laguette, A. Seger, and D. W. Bates. 2008. Can surveillance system identify and avert adverse drug events? A prospective evaluation of a commercial application. *Journal of the American Medical Informatics Association* 15(5):647–653.	Surveillance	To determine whether Dynamic Pharmacovigilance (a health IT system that monitors laboratory and pharmacy data and uses preset rules to determine whether an ADE may occur) can successfully identify and prevent ADEs in a community hospital	Prospective study	N/A	– 2,407 patients screened – 266 alerts	– Frequency and types of alerts produced – Frequency which alerts were associated with ADEs and potential ADEs – Potential financial impact of monitoring for ADEs	– Dynamic Pharmacovigilance can be an effective tool for identifying and preventing ADEs – 11.3 percent of the studied alerts were considered substantially important to warrant contacting the physician – 23 percent of high priority alerts were associated with an ADE (95 percent CI 12 to 34 percent) – 15 percent were associated with a potential ADE (95 percent CI 6 to 24 percent)
van der Sijs, H., R. Bouamar, T. van Gelder, J. Aarts, M. Berg, and A. Vulto. 2010. Functionality test for drug safety alerting in computerized physician order entry systems. *International Journal of Medical Informatics* 79(4):243–251.	ePrescribing	To determine the effectiveness of CPOE systems' alert functions	Comparative evaluations	2006 to 2007	6 different CPOE systems	The sensitivity and specificity to detect drug safety problems	– There is a large variations in different CPOE's ability to detect and alert clinicians to drug safety problems – Sensitivity: 0.38 to 0.79 – Specificity: 0.11 to 0.84