HEALTH TECHNOLOGY ASSESSMENT INFORMATION SERVICE™

SPECIAL REPORT

Closing the Loop on Diagnostic Tests: Information Technology Solutions

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Executive Summary

Every year, 5% of Americans experience a diagnostic error in the outpatient setting, half of which have the potential to cause serious harm.[1] Although many factors can contribute to diagnostic errors, failure to communicate test results or medication changes across involved parties is a major contributory factor, often referred to as the problem of "closing the loop." In 2013, ECRI Institute convened the *Partnership for Health IT Patient Safety.* In May 2017, the Partnership's Closing the Loop workgroup began to consider how best to address closing the loop for diagnostic tests and provider-initiated medication changes. To support the workgroup, we performed an evidence report to identify interventions assessed in the literature. Specifically, this literature review addressed the following key questions:

- Key Question 1: What interventions are effective for improving (1) communication of test results to providers and patients and (2) follow-up of actionable results by providers?
- Key Question 2: What interventions are effective for communicating provider changes to patient medication regimens to other providers, pharmacies, and the patient?

We performed a comprehensive literature search to identify all relevant articles from January 2009 to April 2017. Studies performed outside the United States and trials with non-comparative study designs were excluded. Overall, we identified 33 studies addressing follow-up of diagnostic tests: 27 articles (describing 24 interventions) and 6 studies validating potential electronic health record (EHR) tools.

No studies assessed interventions for improving communication of provider initiated medication change. However, a small, but substantive literature base described interventions to close the loop for diagnostic tests across diverse clinical contexts. Specifically, we identified six overarching health information technology (IT) strategies with some evidence of efficacy: alerts (email, pager, EHR), audits, data gathering (i.e. improving discharge summaries), identifying the responsible provider, integrating systems, and automatic consultations/referrals.

A critical remaining challenge for patient safety is ensuring that health systems work towards implementing solutions to close the loop for diagnostic tests and medication changes. Evidence suggests that health IT solutions offer one promising avenue for addressing this critical problem. Future work should include more rigorous study designs in other clinical contexts along with assessment of whether such interventions can improve clinical outcomes.

Content

Tables

Figures

Background

Modern medicine requires physicians to order, interpret, and manage appropriate follow-up of myriad diagnostic evaluations, including laboratory tests, radiologic studies, diagnostic procedures, and consultation reports. One study of primary care physicians (PCPs) in 2008 estimated that each physician interpreted 19.5 laboratory reports, 11.1 imaging reports, and 13.9 consultation reports and refilled 12.1 prescriptions (outside of scheduled office visits) per day.[2] Another study estimated that every day, PCPs process 56 alerts, requiring 49 minutes.[3] Although keeping pace with these notifications poses a challenge, PCPs also face the more daunting problem of recognizing when diagnostic tests are completed, but results are not returned to them for interpretation. Equally complex is the challenge of ensuring that key test results from one clinical context (such as a hospitalization) are always provided to the primary care provider.

Given these challenges, it is not surprising that diagnostic errors remain a significant patient safety issue. In 2014, Singh et al. estimated that annually, 5% of American adults (approximately 12 million people) were subject to an outpatient diagnostic error, half of which had the potential to cause serious harm.[1] Although many factors can contribute to diagnostic errors, failure to communicate test results or clinical changes across involved parties is a major contributory factor, often referred to as the problem of "closing the loop." In 2017, the Joint Commission named this issue the second most important problem for patient safety. The Commission's stated goal is improving staff communication for reporting critical results of tests and diagnostic procedures in a timely manner.[4] A 2013 study of diagnostic errors that led patients to require unplanned urgent medical care within 2 weeks of a primary care visit concluded that a nonexistent or inadequate test-result tracking system contributed to errors in 7.4% of cases.[5]

Increasing adoption of health information technology (IT) platforms offers a potential solution for addressing this critical issue. However, eight years after the Health Information Technology for Economic and Clinical Health (HITECH) Act, considerable variability remains in successful implementation of health IT for closing the loop. A 2015 report from the U.S. Office of the National Coordinator for Health Information Technology (ONC) found the percentage of surveyed hospitals able to receive or use/integrate key clinical information to be 65% and 38% respectively. Only 25% of hospitals were able to send, receive, find, and use/integrate key clinical information.[6] Recognizing the problem, a 2017 U.S. Government Accountability Office (GAO) report indicated a need for more attention to improving information exchange in post-acute care settings.[7]

In 2013, ECRI Institute convened the *Partnership for Health IT Patient Safety,* and its component, single-topic focused workgroups followed. The Closing the Loop workgroup is a multi-stakeholder workgroup of 27 members, including providers, vendors, healthcare leaders, and experts in the field from various healthcare settings. In May 2017, the workgroup began to consider how best to address closing the loop for diagnostic tests and provider-initiated medication changes. The workgroup began by reviewing all events and claims reported to ECRI Institute PSO, an evidence-based literature review, and medical malpractice claims data. After deliberation, the workgroup chose the following definition: " 'Closing the Loop' includes all mechanisms which ensure that all patient data and information that may require an action are delivered and communicated to the right individuals at the right time through the right mode to allow interpretation, critical review, reconciliation, initiation of action, acknowledgement, and appropriate documentation." In conjunction with the workgroup initiative, we performed a literature review, to provide an up-to-date understanding of interventions that have been assessed in the literature. Specifically, this literature review addressed the following key questions:

Key Question 1: What interventions are effective for improving (1) communication of test results to providers and patients and (2) follow-up of actionable results by providers?

Key Question 2: What interventions are effective for communicating provider changes to patient medication regimens to other providers, pharmacies, and the patient?

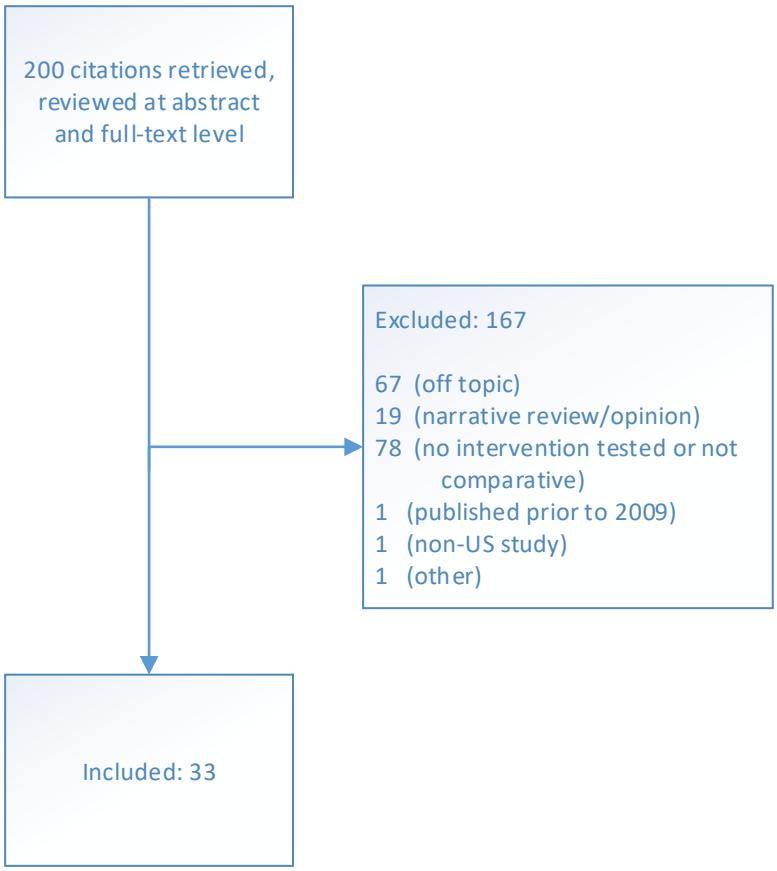
Methods

An ECRI Institute master's level medical librarian conducted searches of PubMed, MEDLINE, EMBASE, CINAHL, and Scopus to identify studies published from January 2009 to April 2017. We used both medical-subject headings and keywords to address four broad concepts: electronic medical records, diagnostic tests, communication, and ambulatory care. The full search strategy is available in Appendix D.

A physician analyst screened all studies for using prespecified inclusion criteria. Figure 1 shows the number of studies screened, included, and excluded. For Key Question 1 (diagnostic tests) studies had to assess an intervention. We excluded studies performed outside of the United States; we also excluded noncomparative studies. Searches identified 200 citations, of which 33 met inclusion criteria. With regard to Key Question 2, searches identified 40 citations; however, no studies met inclusion criteria. In fact, even after dropping the requirement for studies to test an intervention, we identified no studies.

For randomized controlled trials (RCTs), we used the U.S. Preventive Services Task Force (USPSTF) criteria for grading study quality.[8] For pre/post studies, which comprised the majority of studies, we selected six items (pertaining to study design and conduct) to assess study quality. A single physician analyst performed all quality assessments. All assessments are available in Appendix C.

Figure 1. Flow Diagram of Studies for Key Question 1



Results

Overall, we included 33 research articles: 27 articles (describing 24 interventions) and 6 studies validating potential electronic health record (EHR)-based tools. Of intervention studies, 5 were RCTs, and 19 were before/after (pre/post) studies. The six validation studies are not described in the narrative below; however, details regarding these studies are available in Appendix B.

Interventions attempted to improve closing the loop for diagnostic tests in five different clinical contexts: inpatient to outpatient transitions, outpatient to inpatient transitions, communication of actionable radiology findings, follow-up of abnormal outpatient studies, and detection of abnormal inpatient results. An overview of intervention and validations studies is provided in Table 1. Interventions are described in more detail below, with further details available in Appendix A.

Table 1. Overview of Clinical Contexts, Interventions, and Validation Studies

Clinical Context	Number of Studies	Interventions	References
Inpatient to outpatient	7	■ Improved discharge summaries	Cadwallader et al. 2012[9] Gilliam et al. 2017[10] Kantor et al. 2014[11] Watkins et al. 2014[12]
		■ Automated email notification of physicians	Dalal et al. 2014[13]* El-Kareh et al. 2012[14]*
		■ New review protocol for pending urine cultures, followed by nurse phone call	Saha et al. 2017[15]
Outpatient to inpatient	1	■ Electronic medical record (EMR)	Pham-Thomas et al. 2014[16]
Communicating actionable radiology findings	6	■ Secure messaging capability integrated directly into radiology workflow; automated identification of responsible provider contact information; electronic health record (EHR) alerts	Filice 2017[17]* Lacson et al. 2015[18]† Lacson et al. 2014[19]† O'Connor et al. 2012[20]†
		■ Alert to provider, but also surgical oncology clinic for results concerning for malignancy	Browning et al. 2013[21]
		■ Direct messaging plus alerts, with dedicated team to follow up with communication	Dibble et al. 2017[22]
Follow-up of abnormal outpatient studies	12	Fecal occult blood test (FOBT) ■ EHR alert, multifaceted quality improvement initiative including monitoring by preventive medicine coordinator (Singh et al.[23]) ■ Automated referral to gastrointestinal clinic (Humphrey et al.) ■ EHR software reconfigured to ensure results returned to primary care physician (Singh et al.[24]) ■ EHR audit; weekly monitoring for follow-up, with alerts (Larson et al.)	*Humphrey et al. 2011[25] Larson et al. 2009[26] Singh et al. 2009[23] Singh et al. 2009[24]
		Tests raising concern for lung, colorectal, or prostate cancer ■ EHR audit, with manual chart review; secure email alerts for follow-up	Murphy et al. 2015[27]* also described in Meyer et al. 2016[28]
		Pathology tests ■ EHR alerts	Laxmisan et al. 2012[29]

Clinical Context	Number of Studies	Interventions	References
		Abnormal Papanicolaou (Pap) smear ■ EHR-based tracking reports for each provider; with EHR alert and tracking form	Dupuis et al. 2010[30]
		Hyperkalemia (potassium [K] ≥6) ■ EHR alert	Lin et al. 2011[31]
		HIV labs ■ EHR modified to interface between clinic and commercial laboratory (LabCorp)	Bell et al. 2012[32]
		General laboratory/radiology tests ■ EHR	Elder et al. 2010[33]
		Abnormal laboratory tests (creatinine >1.8, K >5.4, thyroid-stimulating hormone [TSH] >10, international normalized ratio [INR] >4, prostate-specific antigen [PSA] >5) ■ PROMISES (Proactive Reduction of Outpatient Malpractice: Improving Safety, Efficiency, and Satisfaction) project; quality-improvement initiative with education and on-site support	Schiff et al. 2017[34]
Detection of abnormal inpatient results	1	■ Decision rule to detect new atrial fibrillation from inpatient electrocardiograms (EKGs) and clinical decision support	Cook et al. 2015[35]
Validation Studies (multiple clinical contexts)**	6	■ Tools to identify potential delays in follow-up for abnormal chest imaging, FOBT, hematuria, iron deficiency anemia, PSA, radiology reports with critical findings, TSH	Lakhani et al. 2012[36] Meyer et al. 2017[37] Murphy et al. 2017[38] Murphy et al. 2016[39] Murphy et al. 2016[40] Murphy et al. 2013[41]

* Denotes randomized controlled trial.

† Three studies describing the same or iterative interventions.

** Not described in narrative text below; however, descriptions of studies can be found in Appendix B, Table 1.

Inpatient to Outpatient Transition

We identified seven studies[9-15] assessing interventions to improve transmission of information about test results from the inpatient to outpatient setting: four interventions[9-12] improved discharge summary information; two studies[13,14] evaluated automated email notification for pending test results, and one study[15] used audits and a new workflow to follow up pediatric urine cultures (pending on discharge.)

Improved Discharge Summaries

All four studies testing improvements to discharge summaries were relatively small, but reported significant improvements. Three of the four studies reported significant improvements in discharge summary documentation of pending tests, and one study found improvement in patients receiving the appropriate follow-up testing. Gilliam et al.[10] described implementation of a electronic discharge summary tool at a Veterans Affairs (VA) Hospital in Ann Arbor, Michigan, which required users to complete medication reconciliation, highlight medication changes, and detail pending tests and follow-up appointments. The proportion of discharge summaries available at the patient's first follow-up appointment increased from 43% (5 months pre-intervention) to 100% at 3 months, a rate sustained at 1.5 years. Kantor et al.[11] allowed physicians to automatically generate a list of pending studies for inclusion in discharge summaries; although use of the tool was voluntary, the proportion of pending studies included in discharge summaries over 1 month increased from 18% to 43% ($p<0.001$). A third study, by Cadwallader et al.,[9] found that creating a dedicated, free-text,

mandatory field for pending tests in the discharge summary significantly improved documentation of pending actionable results (0% to 50%).

Finally, Watkins et al.[12] found an electronic discharge template detailing a discharge plan significantly improved the proportion of patients with low-risk acute chest pain evaluated in the emergency room who subsequently received additional testing (79% vs. 94%, p<0.001) and follow-up with their primary care provider (92.5% vs. 77.3%, p<0.001).

Automated Email Alerts

To improve follow-up of hospital tests pending at discharge, two studies performed cluster RCTs to assess automated email alerts. A good quality 2012 trial by El-Kareh et al.[14] randomly assigned to control or intervention groups 121 inpatient attending physicians at Brigham and Women's hospital over 16 months. Physicians caring for patients discharged with untreated or undertreated microbiology cultures (urine, blood, sputum, or cerebrospinal fluid) received an automated, secure email notification alert after the test result was finalized. In the intervention group, physicians received the alert immediately after finalization of the test result, with a second reminder three days later. In the control group, physicians received only a single alert, on day three. The email alert contained the culture result (including sensitivities), along with demographic information, discharge medication list, medication allergies, and the outpatient physician. Patients cared for by the intervention group had a significantly higher documented response to results within three days (documented conversation with patient or a new prescription), compared with results for patients cared for by the control group (28% vs. 13%, adjusted odds ratio [aOR] 3.2; 95% confidence interval [CI], 1.3 to 8.4).

A subsequent 2014 study by Dalal et al.[13] expanded this intervention to include *all* pending tests for patients discharged from medicine or cardiology services. The study evaluated 500 patients from 117 physicians. At three days after finalization of a pending test result, both inpatient physicians and in-network PCPs in the intervention arm reported a higher awareness of tests pending at discharge. Specifically, inpatient physician awareness was 76% vs. 38%, intervention vs. control; p<0.001; adjusted/clustered odds ratio (OR) 6.30; 95% CI, 3.02 to 13.16; and in-network PCP awareness was 57% vs. 33%; p=0.004; adjusted/clustered OR, 3.08; 95% CI, 1.43 to 6.66. Notably, this RCT had significant methodologic flaws, including a change in method of randomization midway through the trial and failure to randomly assign 23.5% of eligible patients due to unavailability of study personnel.

Audits, With Follow-up Protocol

Finally, one large retrospective pre/post study by Saha et al.[15] assessed whether monitoring results from pediatric urine cultures pending on discharge could reduce inappropriate antibiotic exposure. All pending urine cultures were reviewed by a nurse; if the culture was negative in a patient discharged on antibiotics, the result was forwarded to a clinician who determined whether antibiotic discontinuation was appropriate. The nurse notified the patient/caregiver of the result and discontinuation of the antibiotic was documented in the EHR. The study followed 910 patients over 1.5 years and found a dramatic increase in the rate of documented discontinued antibiotics (from monthly mean of 4% to 84%).

Outpatient to Inpatient

A single study assessed an intervention to improve transitions from outpatient to inpatient care. The study, a retrospective pre/post study by Pham-Thomas et al.[16] evaluated the impact of EHR implementation (Allscripts) and new availability of outpatient prenatal test results (HIV and serum hepatitis) on diagnostic testing and treatment during labor and delivery for 460 uncomplicated singleton pregnancies at Hahnemann University Hospital. Compared with outcomes 3 months before implementation, deliveries in a 3-month period (11 months after implementation) had dramatically improved availability of hepatitis and HIV test results (78.2% to 100%, p<0.001). Furthermore, ordering of repeat hepatitis surface antigen (3.1% to 0%, p=0.07) and HIV testing (3.5% to 0%, p=0.003) significantly decreased.

Communication of Actionable Radiology Findings

We identified six studies describing interventions to improve communication of actionable findings from radiology studies. Four studies tested automated alert systems or secure messaging capability directly integrated into radiology workflow.[17-20] Another study assessed a direct messaging intervention, combined with an automatic alert to a surgical oncology clinic

(for results raising concerns for malignancy).[21] Finally, one study assessed a multicomponent intervention with direct messaging, alerts, and a dedicated team to follow up with communication.[33]

Messaging and Alert Systems

Filice[17] performed an RCT in which traditional communication methods (radiologist paging or calling the operator to identify physician on call) were compared with CORES Smart Handoffs, a plug-in embedded in the picture archiving and communication system (PACS). The plug-in allowed radiologists to identify the covering physician with a single click and message the physician with pre-written text (describing patient and exam information). Three-hundred thirty-eight inpatient studies at Georgetown University Hospital were randomly assigned. Although the study found that time to communication of critical results was shorter for CORES (6.9 vs. 11 minutes), this result was not statistically significant, perhaps in part because the study was stopped after 2 months because of overwhelming, positive feedback from radiologists and a desire to make CORES available to all radiologists.

Lacson et al.[18] describe a retrospective pre/post evaluation of a system for alert notification of critical results (ANCR), which facilitated communication of critical or clinically significant results at Brigham and Women's Hospital, implemented in 2010. Integrated with the provider directory, ANCR allowed synchronous (paging) or asynchronous (secure email alert) notifications accessible to physicians at workstations or by mobile device. From 2009 to 2015, of reports with no communication, the proportion of reports with critical/clinically significant information dropped by 4-fold (from 0.19 to 0.05, $p<0.0001$). To assess whether radiologists were overusing the ANCR alert system, study authors assessed the proportion of alerts issued that contained critical/clinically significant findings. Of reports using ANCR, 91% had critical or clinically significant findings, suggesting the system was not being over-used. A second paper (Lacson et al.[19]) found that, compared to pre-intervention, the ANCR alert system also improved adherence to institutional policy for communication of actionable results (91.3% to 95.0%, $p<0.001$).

A third pre/post study, by O'Connor et al.,[20] assessed whether integrating ANCR alerts into the outpatient EHR (to allow providers to acknowledge alerts from within the EHR) would increase the number of actionable alerts for which PCPs took appropriate action. However, there was no difference in the proportion of actionable alerts followed up by PCPs (94% both before and after the intervention). In fact, physicians appeared to prefer acknowledging alerts through the separate ANCR system instead of within the newly integrated EHR. The majority of alerts continued to be acknowledged through the ANCR system, with only 16% acknowledged via the new integrated system. Furthermore, median time to alert acknowledgement was significantly shorter for ANCR (compared with EHR) responses.

Messaging plus Automatic Consultation

A pre/post study by Browning et al.[21] at the University of Texas Southwestern Medical Center tested the effect of automatic consultations for possible gastrointestinal (GI) malignancies. All radiology results raising concern for previously undocumented GI malignancies resulted in automatic alerts sent not only to the ordering physician, but also to the surgical oncology clinic. A designated physician in the surgical oncology clinic reviewed images and patient records (via the EHR). If deemed appropriate, a follow-up appointment was arranged and the ordering physician notified. The study compared 61 alerts (sent only to the ordering physician) in 10 months pre-intervention, to 49 alerts occurring post-intervention. The study found the intervention was associated with dramatic improvements across all outcomes, including proportion of patients seen by a specialist (increased from 46% to 98%, $p<0.001$), median days to specialist evaluation (decreased from 35 to 7 days, $p<0.001$), completion of diagnostic workup (increased from 77% to 94%, $p<0.001$), median days until diagnosis (decreased from 44 to 18, $p<0.001$), and proportion of patients for whom definitive management was initiated (increased from 72% to 90%, $p<0.05$).

Direct Messaging, Alerts, with Dedicated Team to Follow-up Communication

A retrospective pre/post study by Dibble et al.[22] described implementation of a new system (RADiology CaTegorization 3; RADCAT-3) along with a new workflow for communicating important, but non-urgent radiology findings. The RADCAT software facilitated reports sent via Health Level-7 message to Cloverleaf (the enterprise interface engine), which routed information to both the EHR and the workflow engine. The workflow engine automatically opened a "case" for each report, displaying the provider's contact information. Then a team of 12 quality-assurance staff reviewed the charts, communicated findings to providers (or patients, if providers were unavailable), and documented receipt of information.

The study found no significant difference in proportion of non-urgent findings communicated (100% pre-intervention, 99.7% post-intervention). However, interestingly, the proportion of important non-urgent radiology reports increased from 0.06% pre-intervention to 1.9% of all reports the final year, suggesting increased utilization.

Follow-up of Outpatient Studies

We identified 12 studies describing 11 interventions to improve follow-up of primarily outpatient studies. Four studies[23-26] described interventions to improve follow-up of abnormal fecal occult blood tests (FOBTs). Another study[27] attempted to improve follow-up of tests that raised concern for possible lung, colorectal, or prostate cancer. Studies also described interventions aimed at improving follow-up of pathology tests,[29] abnormal Pap smears,[30] hyperkalemia,[31] HIV labs,[32] and general laboratory/radiology studies.[33,34]

Fecal Occult Blood Tests (FOBT)

Four studies[23-26] tested interventions to improve follow-up of FOBTs at Veteran's Administration (VA) medical centers. Interventions included automated generation of GI consultation referral;[25] altering software to ensure results were always returned to the primary care provider;[24] an EHR alert and multifaceted quality-improvement initiative, including coordinated communication by preventive medicine staff;[23] and weekly audits of positive test results and appropriate follow-up.[26]

Automated Consultation Referrals

Humphrey et al.[25] designed a multicenter cluster randomized trial to assess an automated referral system within VA hospitals. At intervention sites, for every positive FOBT test, an automatic referral to a GI clinic was generated (along with notification of the primary care provider); in contrast, control sites received the standard notification for primary care providers. Consultations were automatically populated with the patient's demographic data and dates of prior imaging studies. Although eight sites were randomly assigned, ultimately, because of logistical problems, data were available from only four sites, and study authors were unable to perform between-group comparisons. Data from 12 months pre-intervention was compared with 6 months post-intervention (n=3,322 positive FOBTs). Compared to pre-intervention, the study found that rates of GI consultation and complete diagnostic workup were significantly higher at intervention sites (at 30, 90, and 180 days), while rates at control sites remained unchanged. Specifically, at 30 days, GI consultation rates increased from 39% to 69% at one intervention site, and from 47% to 80% at a second intervention site ($p<0.001$ for both). Similarly, rates of complete diagnostic workup at 30 days significantly improved for both intervention sites (4% to 30% and 12% to 21%; $p<0.03$ for both).

Software Patch to Return Tests to Primary Care Provider

A mixed methods study by Singh et al.[24] interviewed primary care providers to understand why nearly a third of positive-FOBT alerts were not being received. Based on interviews, study authors identified a workflow problem: because a high number of hemoccult cards were never returned by patients for laboratory processing, laboratory personnel placed an order for the follow-up diagnostic test only upon receipt of a completed card; however, unless the ordering primary care provider's name was on the card itself, test results were returned only to the "ordering provider," in this case, laboratory personnel. To address this problem, the software was reconfigured to link patient results to their primary care provider, even when tests were ordered by others. This intervention reduced lack of timely follow-up (within 30 days) from 29.9% to 5.4% ($p<0.01$) immediately post-intervention, an improvement sustained at 4 months.

Multifaceted Quality Improvement Initiative, Including Manual Chart Audit

Another study by Singh et al.[23] assessed a multifaceted quality-improvement intervention consisting of education (dissemination of updated guidelines), EHR alerts for critical abnormal results, measures to decrease colonoscopy waiting times, and audits of follow-up for positive FOBT tests by a preventive medicine coordinator (with email notifications in cases of incomplete follow-up). A retrospective analysis of randomly selected cases from one year before and one year after the intervention found significant improvements across multiple outcomes. Based on analysis of 533 positive FOBT tests that were indicated, there were significant improvements in colonoscopy referral within 14 days (31.7% to 60.5%, $p<0.001$) and colonoscopy performance within 60 days (3.4% to 11.4%, $p<0.001$). The proportion of patients for whom no colonoscopy was performed decreased (from 35.9% to 24.3%; $p<0.01$).

Manual Chart Audit with Follow-up

Finally, Larson et al.[26] performed a pre/post study to assess whether an electronic note to physicians to remind them of a positive FOBT test in need of follow-up would improve timeliness of referral for colonoscopy. Specifically, a reviewer audited all positive FOBTs weekly to identify cases for which no GI consultation had been ordered. A "lab check note" requiring provider signature was entered in the EHR; these notes reminded providers of the positive result and suggested options for care such as referral for colonoscopy, deferral of colonoscopy because a previous colonoscopy was recently performed, or documentation of other reasons for deferral, such as patient refusal. Compared to referrals for positive FOBT in the year before the intervention, the study found significant improvements. Overall, a lab check note was created for 52% (243 of 468) of patients with positive FOBT during the 1-year intervention period. Rates of GI consultation significantly improved at 14, 30, and 90 days (62% to 82% at 14 days, $p<0.001$). Similarly, timeliness of colonoscopies significantly improved at 60 and 90 days (35% to 48% at 90 days, $p<0.001$) and median time from FOBT to consultation decreased from a median of 6 to 3 days ($p<0.001$).

Tests that Raise Concern for Lung, Colorectal (CRC), or Prostate Cancer

One good quality cluster RCT performed at two VA medical centers (Murphy et al.[27]) assessed whether regular EHR audits using predefined "triggers" to identify at-risk patients, followed by communication to primary care providers, could prevent delays in diagnostic evaluations for lung, CRC, and prostate cancer. Over 15 months, the EHR was queried twice with the following "positive" criteria:

- Lung cancer: chest X-ray or chest CT flagged by radiologist as suspicious for malignancy
- CRC: Positive FOBT, or new hematochezia, abnormal laboratory results (such as hemoglobin ≤11, mean corpuscular volume ≤81, no ferritin ≥100 in prior year)
- Prostate cancer: prostate-specific antigen (PSA) between 4.1 and 15

In addition, the EHR triggers contained many exclusion criteria including age limits, prior history of cancer, presence of terminal illness, and other disease-specific criteria. A clinician manually reviewed each case (using a standardized data collection instrument) to determine whether appropriate diagnostic evaluation had occurred. In cases with delayed evaluation, PCPs were contacted by secure email using a standardized template providing information on the abnormal result and lack of follow-up. If no acknowledgement was received within one week (and chart review did not identify follow-up action), a phone call was made to the PCP or designated nurse. If the PCP or nurse could not be reached over three business days, clinical leadership was contacted.

Seventy-two PCPs caring for 118,400 patients were randomly assigned to intervention or control. The EHR trigger flagged 683 patients in the intervention group, of which 298 (44.7%) were false positives. (The overall positive predictive value [PPV] for delayed diagnostic evaluation was 59.6%, with PPVs of 60.3%, 58.4%, ad 39.6% for CRC, prostate, and lung cancer, respectively). The remaining 385 patients had delayed diagnostic evaluations (CRC, n=284; prostate cancer, n=89; lung cancer, n=12). Sixteen patients were excluded because their PCPs left the facility during the study. Of the remaining 369 patients, 266 (72.1%) received follow-up after the intervention communication. However, the PCP could not be contacted for 11 patients (2.9%) despite multiple attempts, and leadership was contacted. Ultimately, for 98 patients (26.6%), no follow-up action was found at 7 months.

Compared with controls, the study found intervention-group patients had significantly shorter time to diagnostic evaluation for CRC (median 104 vs. 204 days, $p<0.001$) and prostate triggers (40% of patients received diagnostic evaluation at 144 vs. 192 days, $p<0.001$). However, there was no significant difference for lung cancer. At 7 months, patients cared for by PCPs in the intervention were more likely to have received a diagnostic evaluation (relative risk [RR] 1.41; 95% CI, 1.25 to 1.58). Of patients with delayed evaluations, more intervention-group patients had documented follow-up compared with control group patients (73.4% vs. 52.2%). Control group patients also had a longer median time to cancer diagnosis (101 days vs. 69 days; $p=0.04$).

EHR Alerts for Pathology Tests

One retrospective study by Laxmisan et al.[29] assessed the impact of a national policy change within the VA system requiring all anatomic pathology results (normal and abnormal) be transmitted as mandatory EHR alerts. A random monthly sample of all outpatient pathology results (total sampled n=1,637) from 5 months before and 5 months after the intervention was reviewed by a trained physician to assess whether follow-up within 30 days occurred. Although no change in 30-day follow-up was identified, the proportion of abnormal reports lacking follow-up at 6 months decreased from 10.1% to 3.1% ($p<0.05$). Also, multivariate logistic regression controlling for site, provider type, specialty, and test type found that compared with after-implementation of mandatory alerts, pre-intervention results were less likely to receive timely follow-up: AOR, 0.72; 95% CI, 0.54 to 0.96.

Provider-Specific Status Reports for Papanicolaou (Pap) Smear Tests

Dupuis et al.[30] assessed whether an EHR-based intervention to help providers track abnormal Pap smears could improve appropriate follow-up. Data from multiple sources including scheduling, ordering, registration, and pathology was integrated to generate a provider-specific report of all abnormal Pap smears that was disseminated every month. Also, a Pap test tracking table within each patient's chart was populated with results and status of further testing. Multivariate logistic regression adjusting for type of Pap abnormality and practice location found that the intervention was associated with significantly higher odds of achieving diagnostic resolution (OR, 15.4; 95% CI 3.7 to 62) and in a shorter period of time (hazard ratio, 1.4; 95% CI, 1.03 to 1.9) compared with pre-intervention outcomes.

EHR Implementation for Follow-up of Hyperkalemia

We identified one study, by Lin et al.,[31] assessing whether implementation of an EHR at Mount Sinai's adult primary care practice improved the timeliness of follow-up for markedly elevated serum potassium. All nonhemolyzed serum potassium results for three years before the intervention and one year after were analyzed. Overall, 259 hyperkalemic episodes were identified, involving 188 patients (pre-intervention) and 30 patients (post-intervention). Roughly 66% of patients had follow-up within 4 days, and timely follow-up significantly increased after EHR implementation (62.5% to 90.0%, $p=0.003$). A multivariate model also found the EHR group had significantly higher odds of follow-up within 4 days (aOR 4.5; 95% CI, 1.28 to 15.66; $p=0.019$). However, there was no difference in rates of hospitalization or emergency room visits ($p=0.249$).

EHR and Commercial Laboratory Interface for Tracking HIV Labs

One study, by Bell et al.,[32] assessed a direct interface between an ambulatory EHR and a commercial laboratory (LabCorp) to facilitate electronic ordering and return of laboratory results. The study assessed whether the interface could improve timeliness of adjustments to antiretroviral therapy at the comprehensive AIDS resource education clinic at St. Mary's Medical Center. Before the intervention, laboratory orders were entered into the clinic EHR, with paper requisition forms printed for patients to bring to the lab. Test results were received by fax, and reviewed by a physician. Results were then manually entered into the EHR by staff, who also managed the logistics of scheduling follow-up; because of staff availability, laboratory results took one to four weeks to be entered into the record. The intervention interface allowed electronic transmission of orders to the commercial laboratory and laboratory results would automatically appear within the EHR.

The study compared response time to increases in viral load or decreases in CD4 count (from above to below 350 or from above to below 200) from 1 year pre-intervention to 2 years post-intervention. Over 3 years 46% of patients had 1,093 lab results potentially warranting a change in therapy. The intervention was associated with a small, but significant decrease in response time from 48.2 to 37.7 days ($p=0.03$). However, the proportion of patients completing pre-visit laboratory testing did not change, and patient satisfaction remained unchanged. Notably, physicians continued to prefer reviewing faxed results (compared to using the EHR) due to usability issues. First, reviewing laboratory results within the EHR required substantial scrolling and lacked reference values, did not highlight abnormalities, and lacked a mechanism for facilitating follow-up actions (i.e., scheduling follow-up visits). Second, physicians thought the lab interface required about 1 minute per patient to review, compared with less than 10 seconds per patient for faxed results.

Multiple Abnormal Tests

We identified two studies[33,34] describing follow-up of multiple outpatient tests. Schiff et al.[34] reported impact of a multifaceted quality improvement strategy, PROMISES (Practice Reduction of Outpatient Malpractice: Improving Safety, Efficiency, and Satisfaction) on managing laboratory test results in small- to medium-sized adult primary care practices in Massachusetts. Although designed as an RCT, the study only reported findings consistent with a retrospective before and after study. The intervention was supported by a coalition led by the Massachusetts Department of Public Health, and included malpractice insurers and organizations focused on patient safety. The intervention consisted of 15 months of education (including monthly interactive webinars), selection of an on-site champion, and monthly (or twice monthly) site visits from one to two quality-improvement advisors to identify improvement opportunities and plan changes using the Plan, Do, Study, Act model.

A retrospective review was performed of up to 100 charts before and after the intervention at 16 participating primary care practices to assess handling of abnormal laboratory values and potential risks to patients. Specifically, the study focused on abnormal creatinine, international normalized ratio, potassium, prostate-specific antigen, and thyroid-stimulating hormone values, although other abnormalities were included in certain cases. A potential safety risk was defined as lack of evidence the clinician was aware of a result/finding, and a serious potential safety risk was defined as potential or actual harm, meaning, if not treated, harm would either place the patient at risk of death or cause potential persistent deterioration of life function. Overall, 1,577 charts were reviewed, 815 at baseline, and 762 post-intervention. The study found significant reductions in both potential and serious patient safety risks after the intervention. Specifically, serious patient safety risks dropped from 28 to 13 per 1,000 patients (incidence rate ratio, 0.47; 95% CI, 0.22 to 9.98). Significant improvements were also found for documentation of abnormal results in patient charts (absolute improvement 1.4%, p=0.001), patient notification (5.8%, p<0.001), documentation of action/treatment plan (6.1%, p<0.001), and evidence of completed plan (8.6%, p<0.001). Also, after the intervention, follow-up treatment plans were completed 19.4 days earlier on average, compared with pre-intervention plan completion (p<0.001).

A second study, by Elder et al.,[33] evaluated whether eight Ohio primary care offices using EHRs documented test results better than documentation at offices using paper charts. Overall, practices using EHRs had better documentation with regard to tests appearing in the appropriate place within the chart, clinician signatures being present (100% vs. 86%, p<0.001), documentation of clinician interpretation (73% vs. 64%, p=0.039), and patient notification of results (80% vs. 66%, p=0.001).

Inpatient Abnormal Results

We identified a single study testing an intervention to improve follow-up of primarily inpatient test results, performed at the Mayo Clinic. Cook et al.[35] tested a tool detecting atrial fibrillation on electrocardiogram (ECG). A decision rule then determined whether the atrial fibrillation was new-onset and offered evidence-based clinical-decision support for warfarin prescription. The system used MUSE (GE Healthcare) for ECG interpretation, and Blaze Advisor as its integrated expert rule engine. The intervention decision-rule identified 604 possible new cases over the first 3 months after implementation, of which 268 (44%) were confirmed as true positives; similarly, the decision rule was applied retrospectively to identify 226 cases of new-onset atrial fibrillation identified for the same 3 month period during the prior year (pre-intervention). However, the study found no difference in appropriate prescription of warfarin (or aspirin in low-risk patients) within 30 days (45% vs. 43%, for post vs. pre-intervention; OR, 1.05; 95% CI, 0.72 to 1.54). No difference in warfarin prescription for high-risk patients or time to warfarin prescription was found. Study authors speculated that the intervention was ineffective because of a variety of factors, including alert fatigue and the need for providers to click to access the information—or, possibly, disagreement with the guidance offered.

Medication Changes

We identified no studies describing interventions to improve communication of provider-initiated medication changes to other providers, patients, or pharmacies. Overall, studies identified by our search focused on characterizing problems associated with erroneous medication lists or prescriptions. Many articles described case reports of errors associated with ongoing prescriptions of discontinued medications (discontinued by providers within the EHR, but still dispensed by pharmacies) and characterized efforts to determine error rates in patient medication lists or determine the prevalence of

erroneous prescriptions. For instance, one study, by Allen et al., assessed prescriptions for 15 multispecialty ambulatory clinics over one year and determined that 3.7% of patients were prescribed medications that had been discontinued by the physician within the EHR.[42] Study authors estimated that roughly one-third of these prescriptions put patients at "high risk" for experiencing an adverse event.

Although providers can often electronically prescribe medication from within an EHR, outside of health systems with integrated pharmacies (such as the VA medical system), providers can rarely electronically discontinue medications.[43] The combination of providers' inability to easily discontinue prescriptions, along with pharmacy interventions to improve medication adherence (i.e. automated patient phone calls and messages) increases the potential for ongoing use of discontinued medications.

One potential solution highlighted by many articles would be to enable the electronic discontinuation of medications. Although CancelRx, a standard for e-discontinuation has long been available, there is currently no mandate for use, and uptake has been low, perhaps due to lack of significant incentives for adoption.[43] Other strategies to improve medication management include sending electronic provider notifications when patients refill (or fail to refill) prescriptions, which would also allow providers to assess compliance. A mixed methods study by Osborn et al., suggested that many patients use patient portals to request medication refills and would favor broadening the portal's medication management functionality to allow such provider notifications.[44] However, implementing these IT solutions would require bidirectional communication between physician practices and pharmacies, which remains a significant challenge.[42,43]

Health IT Strategies for Closing the Loop

Our review identified a small, but substantive literature base of interventions to help close the loop for diagnostic tests across diverse clinical contexts. Overall, our findings suggest that strategies to harness the power of information systems to improve test tracking are ongoing across different clinical contexts.

A handful of studies assessed the basic impact of simply using an EHR compared to paper charts,[16,31,33] while studies such as Schiff et al.[34] primarily focused on education and engagement of personnel. However, strikingly, most interventions included a key health IT component, although the specific type varied widely. Despite the health IT–focused nature of many interventions, equally striking was the number for which a human component remained critical (e.g., to perform manual chart reviews or communicate with providers).

Our review of the evidence identified six overarching health IT strategies for improving test tracking for diagnostic tests, with some evidence of efficacy, shown in Table 2.

Table 2. Health IT Strategies for Improving Test Tracking

Health IT Strategy	Key Study Examples	Efficacy
Alerts	Automated email alerts, tests pending on discharge (El-Kareh et al.,[14] Dalal et al.[13]) Electronic health record (EHR) alerts, pathology (Laxmisan et al.[29]) Email/page alerts for actionable radiology (Lacson et al.[18]) Email/chart alert, abnormal tests (Singh et al.,[23] Murphy et al.,[27] Larson et al.[26])	Positive
Audits	EHR audits (Murphy et al.,[27] Singh et al.[23]) Integrate EHR, registration, and pathology systems (Dupuis et al.[30])	Positive
Data gathering	Improved discharge summaries (Gilliam et al.,[10] Watkins et al.,[12] Kantor et al.,[11] Cadwallader et al.[9])	Positive
Identifying responsible provider	All fecal occult blood test (FOBT) results reported to primary care physician (Singh et al.[24])	Positive
	Populate contact information for communicating radiology results (Filice,[17] Lacson et al.,[18,19] Dibble et al.[22])	Mixed

Health IT Strategy	Key Study Examples	Efficacy
Integrating systems	Integrate provider directory with radiology alert system (Lacson et al.[18,19]) Integrate EHR, registration, and pathology systems (Dupuis et al.[30]) Radiology alerts integrated to EHR (O'Connor et al.[20]) Integrate EHR and commercial laboratory (Bell et al.[32])	Mixed
Automatic consultations	Radiology results (Browning et al.[21]) Abnormal FOBT (Humphrey et al.[25])	Positive

Alerts

Although the evidence base remains small, studies assessing alerts reported promising results suggesting potential effectiveness in varied clinical contexts, including notifying providers of tests pending on discharge,[14] actionable radiology results,[18] and pathology results.[29] For other interventions, charts were audited to identify tests with delayed follow-up and emails or chart notifications were used to contact providers.[23,26,27]

Several of these interventions probably benefited from designs to maximize usability: for instance, the automated email notification of microbiology test results (pending at discharge) assessed by El-Kareh[14] was sent via secure email, compliant with HIPAA (the Health Information Portability and Accountability Act, governing privacy), and accessible from any workstation or mobile device. Furthermore, in addition to the result itself (including sensitivities), the email contained the patient's admission dates, medication list on discharge, allergies, and outpatient physician—the relevant information a clinician would otherwise need to gather to formulate an appropriate follow-up plan.

Although alerts performed well in these particular settings, potential effectiveness must be balanced against the known challenges of alert fatigue. VA primary care providers may process 56 alerts a day, requiring 49 minutes.[3] In a survey, 87% reported they found the number of alerts excessive, with more than two-thirds stating the volume of alerts was more than they could effectively manage.[45] These problems are also pervasive in non-VA systems.[46] Unfortunately, no studies directly addressed these tradeoffs, which will certainly require careful consideration if new alerts are created, to avoid simply creating additional work for staff already pressed for time.

Audits

In combination with other interventions, audits were effective for improving timeliness of diagnostic evaluations for colorectal and prostate cancer,[23,27] abnormal Pap smears,[30] and discontinuing antibiotics for negative urine cultures.[15] Notably, methods for audits varied in complexity. To identify urine cultures pending at discharge that were negative, a nurse simply monitored the laboratory results. In contrast, an intervention to monitor follow-up of abnormal Pap smears required integration of data from the EHR, pathology test report, and outpatient scheduling systems. Although this system required personnel to run and distribute the audit to providers on a monthly basis, no additional human resources were required. In contrast, the electronic query of EHRs to identify delays in evaluation for lung, colorectal, and prostate cancer tested by Murphy et al. required manual review of each flagged chart to identify "true positives" (criteria or "triggers" used to query the EHR had a positive predictive value of about 60%).[27] Study personnel then contacted providers by email, monitored responses, and escalated communication to leadership if no action was taken.

These studies demonstrate the ability of audits to flag potentially high-risk populations, in turn allowing more efficient targeting of resources. However, audit efficacy is likely to vary with clinical context and "accuracy" of audit criteria. For instance, Murphy et al. found no improvement for lung cancer evaluations, despite positive results for colorectal and prostate cancers. Furthermore, only 11% of emails to physicians led to follow-up, illustrating that even when audits successfully identify at-risk populations, the task of notifying providers faces the same barrier of alert fatigue.[28]

Data Gathering

A third strategy involved gathering data to ensure pertinent diagnostic information was available to responsible providers in a timely fashion. Several studies improved summaries of inpatient or emergency room evaluations available to primary

care providers; approaches included creating electronic templates for discharge summaries,[12] making fields for pending tests mandatory,[9,10] or creating tools capable of importing all pending tests into a discharge summary.[11]

Identifying Responsible Providers

Several interventions leveraged provider directories and coverage information to facilitate identification and contact information of the responsible provider. For instance, Singh et al. dramatically decreased the number of abnormal FOBTs lacking appropriate follow-up by altering the EHR so that primary care providers were always alerted, regardless of who the ordering provider was.[24] Several studies adopted this strategy to facilitate communication of actionable radiology results. For instance, integration of the provider directory with the PACS system allowed radiologists at Brigham and Women's hospital to page or securely email the proper physician with information accessible from mobile devices or workstations.[18,19] Similarly, at Georgetown University Hospital, a plug-in integrated into the PACS and EHR allowed radiologists to easily contact covering physicians.[31] Another approach, by Dibble et al., used special software to route information to the EHR and workflow engine, which automatically opened a "case" for each report, prepopulated with the responsible provider's information.[22] Interestingly, only one[18,19] of these three radiology-based interventions demonstrated significant improvement: in one instance, methodologic flaws may have been responsible;[17] the second negative study[22] did not identify any improvement in its communication outcome because before the intervention, 100% of findings were already being communicated.

Integration of Systems

Several interventions integrated EHRs and various information systems as one component of successful multifaceted interventions such as facilitating chart audits[30] or communicating results to the correct provider.[18,22] However, our report also identified two cases in which interventions primarily focused on integrating distinct systems yielded lackluster results. For instance, a bidirectional interface between an HIV clinic's EHR and the commercial laboratory LabCorp, allowing electronic lab orders and with results returned into the EHR, was unpopular with physicians, who continued to strongly prefer reviewing results by fax.[32] Providers reported frustration with the poor usability of the interface: specifically, laboratory values had no reference ranges, results required significant scrolling to review, and there was no mechanism for communicating next steps for necessary follow-up with office staff.

A second study attempted to replace actionable radiology email/pager notifications with alerts integrated directly into the EHR.[20] However, providers preferred the email/page alerts, which were acknowledged faster and more likely to be acted upon, compared to those acknowledged within the integrated EHR. Study authors speculated that providers preferred "active" notification, versus a "passive" alert, which required them to log into the EHR.

These "negative" studies highlight the importance of usability and convenience; although electronic interfaces between separate systems such as EHRs and laboratories remain a worthy goal, integration without careful attention to the user's experience may lead only to frustration and workarounds.

Automatic Consults

Finally, a sixth strategy involved automatic generation of referrals with abnormal testing. For instance, with reporting of an abnormal FOBT, one VA study tested automatic generation of a GI consultation populated with pertinent demographic and clinical information.[25] Similarly, another health system used this approach to handle radiology results suggestive of previously undocumented GI malignancies; an alert was automatically routed to the surgical oncology clinic, where a physician reviewed the images and patient history via EHR and facilitated appointment scheduling, if appropriate.[21] Both studies found significant improvements in proportion of patients receiving a timely evaluation, as well as time to completion of diagnostic evaluation.

A key benefit of this strategy is the potential to offload additional responsibility from already overburdened primary care providers. Furthermore, in contrast to a "traditional" consultation, this approach offers specialists the opportunity to improve efficiency by using their expertise to determine whether a consultation is appropriate (avoiding unnecessary consults), and also expedite evaluations as needed. However, although bypassing primary care may improve speed of evaluation, if this approach were more broadly applied to other tests, patients might find themselves uncomfortable with being scheduled for tests and evaluations without first discussing issues with a trusted primary care provider.

Strengths and Limitations of the Evidence Base

Although we identified five RCTs, overall, the evidence base primarily consisted of pre/post study designs, reflecting the fact that many interventions were designed as quality-improvement initiatives. Pre/post studies are problematic for inferring efficacy because they lack a parallel control group (with inability to account for secular trends) and are susceptible to the Hawthorne effect (in which behavior changes when people know they are being observed).

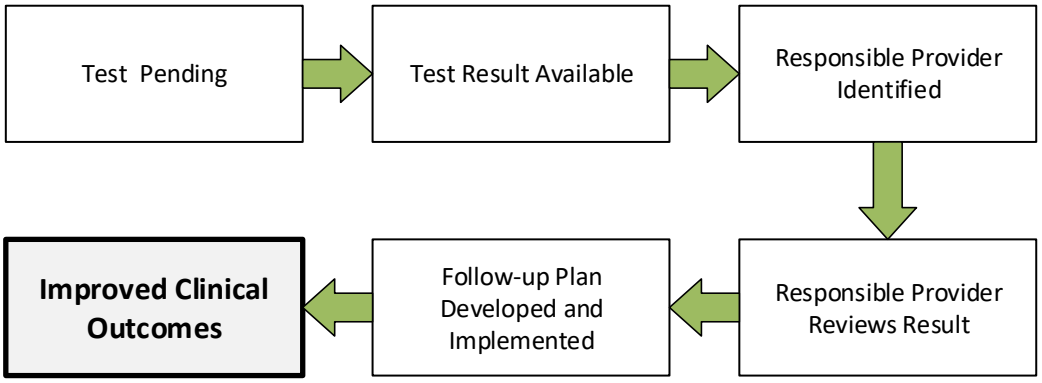
However, despite inherent limitations of study design, we assessed all pre/post studies as good or fair quality. Fair quality pre/post studies (n=14) enrolled consecutive or randomly selected patient populations and used objective outcome measures. Five pre/post studies were rated as good quality because they also used independent or blinded outcome assessors or verified accuracy of a subset of data (see Table 2, Appendix C for more details.) Table 3 summarizes outcome measures, study design, and quality assessment for health IT interventions. Notably, none of the studies addressed clinical outcomes.

Use of Process Measures Alone Limits Assessment of Efficacy

Process measures—such as identifying available results, identifying the responsible provider, documenting acknowledgment of results, and developing and implementing a follow-up plan—are obviously critical to closing the loop for diagnostic tests. Documenting improvement in these various process measures may go a long way towards addressing concerns related to medical liability. However, the ultimate goal of ensuring that diagnostic tests move through this loop is to secure meaningful improvement in clinical outcomes (see Figure 2).

Overall, the studies we identified focused primarily on process measures as study outcomes, with many studies focused on more "proximate" outcomes, such as documentation of a result by the responsible provider (see Table 3). Ten studies assessed whether a follow-up plan was developed and/or implemented, but as mentioned, no studies assessed improvements in clinical outcomes. This absence highlights a critical evidence gap facing IT interventions, as several study authors themselves noted: Do interventions merely promote better documentation, or do they actually improve clinical care?

Figure 2. Closing the Loop



Applicability

In assessing potential applicability of interventions in this report, three main issues deserve consideration. First, of 27 studies (describing 25 interventions), nearly half were performed in either in VA medical systems (n=8) or at a single prominent academic hospital (Brigham and Women's Hospital, [n=5]). VA medical systems are unique in having large unified networks of inpatient and outpatient physicians, which share a common EHR; also, as a well-resourced tertiary care academic medical center, Similarly, Brigham and Women's hospital may have resources that could make developing an automated algorithm for detecting when microbiology results pending on discharge are returned more feasible. Second, some interventions required significant investment of human resources, which may impact feasibility, depending on local resources. For instance, the Dibble et al. study used a team of 12 dedicated personnel to communicate radiology results to providers.[22] Even interventions based on chart audits, such as Murphy et al.[27] used physicians to manually

review every flagged chart. Finally, although we identified six health IT strategies found to be effective (albeit with limited evidence base), the success of these intervention types (e.g., audits, alerts, automatic consults) will likely depend a great deal on the specific clinical context, the test being addressed, and careful intervention design. As previously mentioned, the well-designed RCT by Murphy et al.[27] did not find chart audits and follow-up effective for lung cancer evaluations, although it was effective for prostate and colorectal cancer.

Table 3. Health IT Strategies: Outcome Measures*, Design, and Quality for Key Studies

Interventions (Studies)	Improved Documentation of Pertinent Test Results to Facilitate Communication (n=5)	Responsible Provider Receives Result in Timely Fashion (n=13)	Timely Treatment Plan Generated and/or Communicated to Patient (n=10)	Follow-up Treatment Plan Completed (n=7)	Study Design (Quality)
Alerts, email: Dalal et al.[13]		✓			Cluster randomized controlled trial (RCT) (Fair)
Alerts, email: El-Kareh et al.[14]		✓	✓		Cluster RCT (Good)
Alerts, email: Larson et al.[26]		✓	✓	✓	Pre/post (Fair)
Alerts, electronic health record (EHR): Laxmisan et al.[29]			✓		Pre/post (Fair)
Audits, alerts, follow-up communication: Singh et al.[23]		✓	✓	✓	Pre/post (Good)
Audits, follow-up communication, EHR: Murphy et al.[27,28]		✓	✓	✓	Cluster RCT (Good)
Audits, monthly provider report: Dupuis et al.[30]				✓	Pre/post (Fair)
Data gathering, discharge summary: Cadwallader et al.[9]	✓				Pre/post (Good)
Data gathering, discharge summary: Gilliam et al.[10]	✓				Pre/post (Fair)
Data gathering, discharge summary: Kantor et al.[11]	✓				Pre/post (Fair)
Data gathering, discharge summary: Watkins et al.[12]	✓	✓		✓	Pre/post (Fair)
Identifying provider, primary care physician always alerted: Singh et al.[24]		✓	✓		Pre/post (Fair)
Identifying provider, radiology messaging: Filice[17]		✓			RCT (Poor)
Identifying provider, radiology messaging/alerts: Dibble et al.[22]	✓	✓			Pre/post (Fair)
Identifying provider, radiology messaging/alerts: Lacson et al.[18,19]		✓			Pre/post (Good)

Interventions (Studies)	Improved Documentation of Pertinent Test Results to Facilitate Communication (n=5)	Responsible Provider Receives Result in Timely Fashion (n=13)	Timely Treatment Plan Generated and/or Communicated to Patient (n=10)	Follow-up Treatment Plan Completed (n=7)	Study Design (Quality)
Integrating systems, direct interface between EHR and laboratory: Bell et al.[32]			✓		Pre/post (Fair)
Integrating systems, alert system with EHR: O'Connor et al.[20]		✓	✓		Pre/post (Good)
Automatic clinic referral: Browning et al.[21]		✓	✓	✓	Pre/post (Fair)
Automated consultation referral: Humphrey et al.[25]		✓	✓	✓	Cluster RCT (Fair)

* No studies addressed clinical outcomes.

Conclusion

A critical remaining challenge for patient safety is ensuring that health systems work towards implementing solutions to close the loop for diagnostic tests and medication changes. Although the prescription of discontinued medications continues to pose significant potential harms, we identified no studies assessing interventions. Potential health HIT solutions include integrating EHR and pharmacy systems to allow providers to electronically discontinue medications (similar to the ability to electronically prescribe which is already widely available). Creation of bidirectional interfaces between physician practices and pharmacies could allow provider notifications with refills (facilitating knowledge of medication compliance) and facilitate communication with patients through patient portals.

In this report, we identified evidence of ongoing innovative efforts to leverage the potential of health IT to improve tracking and follow-up of diagnostic tests. In particular, we found six health IT strategies with moderate to significant success in pre/post studies or RCTs. Specifically, we found some evidence to suggest that alerts, audits, data gathering, processes to facilitate identification of the responsible provider, integration of systems, and automatic consultations can be effective for closing the loop on diagnostic tests. However, with the exception of a few RCTs, the evidence base remains relatively weak, consisting of pre/post studies, and studies used process measures without assessing clinical impact. Future work should include more rigorous study designs in other clinical contexts; furthermore, in addition to assessing whether test results are acknowledged and responded to, studies should also assess whether or not interventions are ultimately capable of improving clinical outcomes.

References

1. Singh H, Meyer AN, Thomas EJ. The frequency of diagnostic errors in outpatient care: estimations from three large observational studies involving US adult populations. BMJ Qual Saf. 2014 Sep;23(9):727-31. Also available: http://dx.doi.org/10.1136/bmjqs-2013-002627. PMID: 24742777.
2. Baron RJ. What's keeping us so busy in primary care? A snapshot from one practice. N Engl J Med. 2010 Apr 29;362(17):1632-6. Also available: http://dx.doi.org/10.1056/NEJMon0910793. PMID: 20427812.
3. Murphy DR, Reis B, Sittig DF, Singh H. Notifications received by primary care practitioners in electronic health records: a taxonomy and time analysis. Am J Med. 2012 Feb;125(2):209.e1-7. Also available: https://dx.doi.org/10.1016/j.amjmed.2011.07.029.
4. The Joint Commission (TJC). Hospital: 2017 National Patient Safety Goals. Oakbrook Terrace (IL): The Joint Commission (TJC); 2016 Dec 2. 17 p. Also available: https://www.jointcommission.org/assets/1/6/NPSG_Chapter_HAP_Jan2017.pdf.
5. Singh H, Giardina TD, Meyer AN, Forjuoh SN, Reis MD, Thomas EJ. Types and origins of diagnostic errors in primary care settings. JAMA Intern Med. 2013 Mar 25;173(6):418-25. Also available: doi: 10.1001/jamainternmed.2013.2777. PMID: 23440149.
6. Patel V, Henry J, Pylypchuk Y, Searcy T. Interoperability among U.S. non-federal acute care hospitals in 2015. Washington (DC): Office of the National Coordinator for Health Information Technology; 2016 May. 11 p. (ONC Data Brief; no.36). Also available: https://www.healthit.gov/sites/default/files/briefs/onc_data_brief_36_interoperability.pdf.
7. United States Government Accountability Office (GAO). Electronic health records: HHS needs to improve planning and evaluation of its efforts to increase information exchange in post-acute care settings. Report to Congressional Requesters GAO-17-184. Washington (DC): United States Government Accountability Office (GAO); 2017 Jan. 39 p. Also available: http://www.gao.gov/assets/690/682337.pdf.
8. U.S Preventive Services Task Force (USPSTF) procedure manual. Rockville (MD): U.S. Preventive Services Task Force (USPSTF); 2015 Dec. 80 p. Also available: https://www.uspreventiveservicestaskforce.org/Page/Name/methods-and-processes.
9. Cadwallader J, Asirwa C, Li X, Kesterson J, Tierney WM, Were MC. Using computerized provider order entry to enforce documentation of tests with pending results at hospital discharge. Appl Clin Inform. 2012;3(2):154-63. Also available: https://dx.doi.org/10.4338/ACI-2012-01-RA-0001.
10. Gilliam M, Krein SL, Belanger K, Fowler KE, Dimcheff DE, Solomon G. Novel combined patient instruction and discharge summary tool improves timeliness of documentation and outpatient provider satisfaction. SAGE Open Med. 2017;5:1-6. Also available: http://dx.doi.org/10.1177/2050312117701053. PMID: 28491308.
11. Kantor MA, Evans KH, Shieh L. Pending studies at hospital discharge: a pre-post analysis of an electronic medical record tool to improve communication at hospital discharge. J Gen Intern Med. 2015 Mar;30(3):312-8. Epub 2014 Nov 22. Also available: https://dx.doi.org/10.1007/s11606-014-3064-x.
12. Watkins LM, Patrician PA. Handoff communication from the emergency department to primary care. Adv Emerg Nurs J. 2014 Jan;36(1):44-52. Also available: http://dx.doi.org/10.1097/TME.0000000000000003.
13. Dalal AK, Roy CL, Poon EG, Williams DH, Nolido N, Yoon C, Budris J, Gandhi T, Bates DW, Schnipper JL. Impact of an automated email notification system for results of tests pending at discharge: a cluster-randomized controlled trial. J Am Med Inform Assoc. 2014 May-Jun;21(3):473-80. Also available: https://dx.doi.org/10.1136/amiajnl-2013-002030.
14. El-Kareh R, Roy C, Williams DH, Poon EG. Impact of automated alerts on follow-up of post-discharge microbiology results: a cluster randomized controlled trial. J Gen Intern Med. 2012 Oct;27(10):1243-50. Also available: https://dx.doi.org/10.1007/s11606-012-1986-8.
15. Saha D, Patel J, Buckingham D, Thornton D, Barber T, Watson JR. Urine culture follow-up and antimicrobial stewardship in a pediatric urgent care network. Pediatrics. 2017 Apr;139(4):e1. Also available: http://dx.doi.org/10.1542/peds.2016-2103.
16. Pham-Thomas N, Pereira N, Powell AM, Croft DJ, Guilfoil DS, Montgomery OC. Outcomes of effective transmission of electronic prenatal records from the office to the hospital. Obstet Gynecol. 2014 Aug;124(2 Pt 1):317-22. Also available: https://dx.doi.org/10.1097/AOG.0000000000000349.
17. Filice R. Who you gonna call? Automatically connecting radiologists to the right clinician. J Digit Imaging. 2017 Feb 21;Epub ahead of print. Also available: http://dx.doi.org/10.1007/s10278-017-9962-9. PMID: 28224380.
18. Lacson R, O'Connor SD, Sahni VA, Roy C, Dalal A, Desai S, Khorasani R. Impact of an electronic alert notification system embedded in radiologists' workflow on closed-loop communication of critical results: a time series analysis. BMJ Qual Saf. 2016 Jul;25(7):518-24. Epub 2015 Sep 15. Also available: https://dx.doi.org/10.1136/bmjqs-2015-004276.

19. Lacson R, Prevedello LM, Andriole KP, O'Connor SD, Roy C, Gandhi T, Dalal AK, Sato L, Khorasani R. Four-year impact of an alert notification system on closed-loop communication of critical test results. AJR Am J Roentgenol. 2014 Nov;203(5):933-8. Also available: https://dx.doi.org/10.2214/AJR.14.13064.
20. O'Connor SD, Dalal AK, Sahni VA, Lacson R, Khorasani R. Does integrating nonurgent, clinically significant radiology alerts within the electronic health record impact closed-loop communication and follow-up? J Am Med Inform Assoc. 2012;23(2):333-8. Also available: https://dx.doi.org/10.1093/jamia/ocv105.
21. Browning T, Kasper J, Rofsky NM, Camp G, Mang J, Yopp A, Peshock R. Quality improvement initiative: enhanced communication of newly identified, suspected GI malignancies with direct critical results messaging to surgical specialist. BMJ Qual Saf. 2013 Feb;22(2):168-75. Also available: https://dx.doi.org/10.1136/bmjqs-2012-001069. PMID: 23038409.
22. Dibble EH, Swenson DW, Cobb C, Paul TJ, Karn AE, Portelli DC, Movson JS. The RADCAT-3 system for closing the loop on important non-urgent radiology findings: a multidisciplinary system-wide approach. Emerg Radiol. 2017 Apr;24(2):119-25. Also available: https://dx.doi.org/10.1007/s10140-016-1452-8.
23. Singh H, Kadiyala H, Bhagwath G, Shethia A, El-Serag H, Walder A, Velez ME, Petersen LA. Using a multifaceted approach to improve the follow-up of positive fecal occult blood test results. Am J Gastroenterol. 2009 Apr;104(4):942-52. Also available: https://dx.doi.org/10.1038/ajg.2009.55.
24. Singh H, Wilson L, Petersen LA, Sawhney MK, Reis B, Espadas D, Sittig DF. Improving follow-up of abnormal cancer screens using electronic health records: trust but verify test result communication. BMC Med Inform Decis Mak. 2009 Dec 09;49. Also available: https://dx.doi.org/10.1186/1472-6947-9-49.
25. Humphrey LL, Shannon J, Partin MR, O'Malley J, Chen Z, Helfand M. Improving the follow-up of positive hemoccult screening tests: an electronic intervention. J Gen Intern Med. 2011 Jul 22;26(7):691-7. Also available: https://dx.doi.org/10.1007/s11606-011-1639-3.
26. Larson MF, Ko CW, Dominitz JA. Effectiveness of a provider reminder on fecal occult blood test follow-up. Digestive Diseases and Sciences. 2012 Oct;54(9):1991-6. Also available: https://dx.doi.org/10.1007/s10620-009-0751-2.
27. Murphy DR, Wu L, Thomas EJ, Forjuoh SN, Meyer AN, Singh H. Electronic trigger-based intervention to reduce delays in diagnostic evaluation for cancer: a cluster randomized controlled trial. J Clin Oncol. 2015 Nov 1;33(31):3560-7. Also available: http://dx.doi.org/10.1200/JCO.2015.61.1301. PMID: 26304875.
28. Meyer AN, Murphy DR, Singh H. Communicating findings of delayed diagnostic evaluation to primary care providers. J Am Board Fam Med. 2016 Aug;29(4):469-73. Also available: https://dx.doi.org/10.3122/jabfm.2016.04.150363.
29. Laxmisan A, Sittig DF, Pietz K, Espadas D, Krishnan B, Singh H. Effectiveness of an electronic health record-based intervention to improve follow-up of abnormal pathology results: a retrospective record analysis. Med Care. 2012 Oct;50(10):898-904. PMID: 22929995.
30. Dupuis EA, White HF, Newman D, Sobieraj JE, Gokhale M, Freund KM. Tracking abnormal cervical cancer screening: evaluation of an EMR-based intervention. J Gen Intern Med. 2010 Jun;25(6):575-80. Also available: https://dx.doi.org/10.1007/s11606-010-1287-z.
31. Lin JJ, Moore C. Impact of an electronic health record on follow-up time for markedly elevated serum potassium results. Am J Med Qual. 2011 Jan;26(4):308-14. Also available: https://dx.doi.org/10.1177/1062860610385333.
32. Bell DS, Cima L, Seiden DS, Nakazono TT, Alcouloumre MS, Cunningham WE. Effects of laboratory data exchange in the care of patients with HIV. Int J Med Inform. 2012 Oct;81(10):e74-e82. Also available: https://dx.doi.org/10.1016/j.ijmedinf.2012.07.012.
33. Elder NC, McEwen TR, Flach J, Gallimore J, Pallerla H. The management of test results in primary care: does an electronic medical record make a difference? Fam Med. 2010 May;42(5):327-33. PMID: 20455108.
34. Schiff GD, Reyes Nieva H, Griswold P, Leydon N, Ling J, Federico F, Keohane C, Ellis BR, Foskett C, Orav EJ, Yoon C, Goldmann D, Weissman JS, Bates DW, Biondolillo M, Singer SJ. Randomized trial of reducing ambulatory malpractice and safety risk: results of the Massachusetts PROMISES Project. Med Care. 2017 Aug;55(8):797-805. Also available: http://dx.doi.org/10.1097/MLR.0000000000000759. PMID: 28650922.
35. Cook DA, Enders F, Caraballo PJ, Nishimura RA, Lloyd FJ. An automated clinical alert system for newly-diagnosed atrial fibrillation. PLoS ONE. 2015;10(4):e0122153. Also available: https://dx.doi.org/10.1371/journal.pone.0122153.
36. Lakhani P, Kim W, Langlotz CP. Automated detection of critical results in radiology reports. J Digit Imaging. 2012 Feb;25(1):30-6. Also available: https://dx.doi.org/10.1007/s10278-011-9426-6.

37. Meyer AN, Murphy DR, Al-Mutairi A, Sittig DF, Wei L, Russo E, Singh H. Electronic detection of delayed test result follow-up in patients with hypothyroidism. J Gen Intern Med. 2017;32(7):753-9. Also available: https://dx.doi.org/10.1007/s11606-017-3988-z.

38. Murphy DR, Meyer AN, Vaghani V, Russo E, Sittig DF, Richards KA, Wei L, Wu L, Singh H. Application of electronic algorithms to improve diagnostic evaluation for bladder cancer. Appl Clin Inform. 2017 Mar 22;8(1):279-90. Also available: http://dx.doi.org/10.4338/ACI-2016-10-RA-0176. PMID: 28326433.

39. Murphy DR, Thomas EJ, Meyer AN, Singh H. Development and validation of electronic health record-based triggers to detect delays in follow-up of abnormal lung imaging findings. Radiology. 2016 Mar;277(1):81-7. Also available: https://dx.doi.org/10.1148/radiol.2015142530.

40. Murphy DR, Meyer AN, Bhise V, Russo E, Sittig DF, Wei L, Wu L, Singh H. Computerized triggers of big data to detect delays in follow-up of chest imaging results. Chest. 2016 Sep;150(3):613-20. Also available: https://dx.doi.org/10.1016/j.chest.2016.05.001.

41. Murphy DR, Laxmisan A, Reis BA, Thomas EJ, Esquivel A, Forjuoh SN, Parikh R, Khan MM, Singh H. Electronic health record-based triggers to detect potential delays in cancer diagnosis. BMJ Qual Saf. 2014;23(1):8-16. Epub 2013 Jul 19. Also available: https://dx.doi.org/10.1136/bmjqs-2013-001874.

42. Allen AS, Sequist TD. Pharmacy dispensing of electronically discontinued medications. Ann Intern Med. 2012 Nov 20;157(10):700-5. Also available: https://dx.doi.org/10.7326/0003-4819-157-10-201211200-00006.

43. Fischer S, Rose A. Responsible e-prescribing needs e-discontinuation. JAMA. 2017 Feb 7;317(5):469-70. Also available: https://dx.doi.org/10.1001/jama.2016.19908. PMID: 28170486.

44. Osborn CY, Mayberry LS, Wallston KA, Johnson KB, Elasy TA. Understanding patient portal use: implications for medication management. J Med Internet Res. 2013 Jul 3;15(7):e133. Also available: http://dx.doi.org/10.2196/jmir.2589. PMID: 23823974.

45. Singh H, Spitzmueller C, Petersen NJ, Sawhney MK, Sittig DF. Information overload and missed test results in electronic health record-based settings. JAMA Intern Med. 2013;173(8):702-4. Also available: https://dx.doi.org/10.1001/2013.jamainternmed.61.

46. Cutrona SL, Fouayzi H, Burns L, Sadasivam RS, Mazor KM, Gurwitz JH, Garber L, Sundaresan D, Houston TK, Field TS. Primary care providers' opening of time-sensitive alerts sent to commercial electronic health record InBaskets. J Gen Intern Med. 2017 Aug 14;Epub ahead of print. Also available: http://dx.doi.org/10.1007/s11606-017-4146-3. PMID: 28808942.

Policy Statement

This Special Report presents a literature review and is designed to provide a snapshot of the status of this issue at the time literature searches and literature review were conducted. The information contained herein is derived primarily from the available, published, peer-reviewed scientific literature and searches of the World Wide Web. Publications referenced are limited to the English language. The conclusions and recommendations must be interpreted cautiously and judiciously. ECRI Institute implies no warranty and assumes no liability for the information, conclusions, and recommendations contained in this Special Report.

The conclusions and recommendations and the studies on which they are based are highly perishable and reflect the state of the issue at the time at which the report was compiled. The report was produced and updated by a multidisciplinary staff of scientists, clinicians, information specialists, medical writers, and other health professionals. For quality assurance, all reports are subject to review by experts within ECRI Institute and one or more selected external experts. Neither ECRI Institute nor its employees accept gifts, grants, or contributions from, or consult for medical device or pharmaceutical manufacturers.

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Appendix A. Evidence Tables

Table A-1. Transition from Inpatient to Outpatient

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
Improved discharge summary			
Reference: Gilliam et al. 2017[10] **Study Design:** Pre/post study (retrospective evaluation) **Purpose:** To assess effect of a new electronic discharge summary tool on timeliness of documentation and communication with outpatient providers. **Quality Rating: Fair** Retrospective; random selection of all patients before and 2 points after implementation. Objective outcomes measures; no information about outcome assessors reported.	**Diagnostic Test:** All tests performed during inpatient stay **Setting:** Academic Veterans Affairs hospital (Ann Arbor, Michigan, USA) **Number of Patients:** 90 randomly selected patients admitted to academic medical service **Inclusion Criteria:** Patients admitted to academic medicine service during select study months **Exclusion Criteria**: NR **Study Methods:** Chart reviews of patients admitted 5 months before implementation (June 2012) to 3 months after implementation and 1.5 years after implementation. Random selection of 30 patients from each period.	**Intervention:** Electronic discharge summary tool; prompts user to complete medication reconciliation and highlights medication changes ■ Combines final day progress note ■ Discharge instructions and summary for patient at time of discharge ■ Forces completion of every item ■ Includes pending tests, medication changes, current medication list, and follow-up appointments (Previously, discharge summary dictated or typed by senior resident) **Outcome**: (measured at 5 months prior, 3 months post and 1.5 years after implementation) ■ Discharge summary available at first follow-up with outpatient provider (including nurse phone call within 48 hours of discharge) ■ Provider satisfaction	Implemented June 2012 Completion rate of required content was 100% after implementation. Proportion of discharge summaries available at time of first follow-up significantly increased : ■ 5 months prior: 43% ■ 3 months after: 100% ■ 1.5 years after: 100% Provider satisfaction: (surveyed 3 months after full implementation [Oct 2012]): 22 of 50 providers responded (44% response rate): ■ 86% Always/Most of the time review discharge summary before primary care appointment ■ 90% Most/Completely Satisfied with new discharge note ■ 86% preferred to old note ■ Comments suggested highlighting medication changes during hospitalization Efficiency: In 2010, time from decision to discharge to posting of discharge instructions: 5.6 hours (average) In 2012, this significantly decreased to 4.1 hours (reduction of 27%, p=0.04) In 2015, decreased further: 2.8 hours (p<0.001)

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
Reference: Watkins et al. 2014[12] **Study Design:** Retrospective before and after study **Purpose:** To assess whether new electronic discharge format improves communication between emergency department (ED) and primary care physicians. **Quality Rating: Fair** All eligible patients enrolled during time period; retrospective study Investigator reviewed charts to determine outcome; outcomes were objective; assessor not blinded	**Diagnostic Test:** Stress test **Setting:** Jackson Veterans Affairs Medical Center (JVAMC), Mississippi, USA **Number of Patients:** 358 patients with low-risk acute chest pain **Inclusion Criteria:** Veterans enrolled at JVAMC (1) receiving care from primary care clinics, community based outreach clinics, or mental health clinics; (2) presenting to ED with onset of chest pain ≤12 hours; (3) pain free at presentation with normal electrocardiogram (EKG) or no change to prior EKG. **Exclusion Criteria:** Arrival by ambulance; chest pain >12 hours; abnormal EKG (ST elevations >1 mm, ST depression >0.5 mm, new left bundle branch block, bradycardia <55 beats/min; tachycardia >110 beats/minute, prolonged QY internal >550 mm, abnormal vital signs (pulse oximeter <90%, systolic blood pressure >210 or <90, pulse <55 or >110, and troponin level >0.03. Positive test for cocaine or cannabis. **Study Methods:** All ED visits between April 1, 2008, and April 15, 2012, for chest pain extracted from electronic health record (EHR). Records reviewed for (1) scheduled diagnostic test (stress test) and (2) follow-up appointments with primary care physician (PCP) after ED visit.	**Intervention:** New electronic template—the electronic emergency provider written plan of discharge (eEPWPD) (Previously, patients given verbal instructions and letter mailed with appointment dates.)	358 patients total Historical control group: 132 patients Intervention group: 226 Compared to pre-intervention group, more patients in the intervention group underwent additional testing (93.8% vs. 78.8%) and had PCP follow-up (92.5% vs. 77.3%); p<0.001. After the intervention, patients had shorter duration of time to additional testing (15.5 ± 21.7 days vs. 21.6 ± 26.9 days; p=0.03). Time to PCP follow-up was shorter, but this difference was not statistically significant (24.4 ± 24.4 days vs. 31.8 ± 35.5 days). The intervention group had significantly more patients receiving diagnostic testing in ≤5 working days (41.6% vs. 22.7%) and PCP follow-up within 30 days (72.6% vs. 56.8%), p<0.001 and <0.01, pre- and post-intervention, respectively.
Reference: Kantor et al. 2014[11] **Study Design:** Prospective pre/post analysis **Purpose:** To determine prevalence, characteristics, and communication of studies pending at hospital discharge after implementation of electronic medical record (EMR) tool that generates list of pending studies	**Diagnostic Test:** Inpatient tests pending on discharge **Setting:** Inpatient general medicine services (Stanford Health Care, Palo Alto, California, USA) **Number of Patients:** 260 patients discharged from general medicine service **Inclusion Criteria:** Consecutive patients discharged from general medicine wards during 1 month (July to August 2013) **Exclusion Criteria:** Death during hospitalization, discharge to hospice, transferred to another service,	**Intervention:** EMR tool that automatically generates a list of pending studies for discharge summaries All charts reviewed for pending studies within 24 hours (via automatic data gathering from EMR, verified by manual review) **Outcomes:** ■ Prevalence, characteristics, communication of studies pending at hospital discharge	Overall, 70% of patients discharged with at least 1 pending study EMR tool used for 30% of discharge summaries for patients with pending studies **Inclusion of pending studies in discharge summary**: EMR tool increased inclusion of pending studies from **18% to 43%;** p<0.001 (proportion of studies included) After the intervention, discharge summaries including *all* pending studies for an individual

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
Quality Rating: Fair Prospectively planned; consecutive patients enrolled; charts reviewed for outcome by nonblinded physician reviewer; primary outcome was objective Voluntary basis for tool use; may have biased use from those more motivated to be inclusive (tool used for only 30% of discharge summaries)	transferred to another hospital, or left against medical advice **Study Methods:** EMR tool made available to all physicians to be used on voluntary basis; intervention was introduced mid-month	▪ Attitudes about communication of pending studies	patient increased from 7.6% to 26% (p=0.002). Only 6% of summaries created *without* the EMR tool included all pending studies compared with 74% of summaries created using the tool (p<0.001). **Attitudes towards tool**: 79 of 111 house staff and sub-interns (71% response rate) ▪ 81% considered outpatient primary care physician responsible for following up on pending studies at discharge Discussion: Fewer than half of pending studies communicated even with tool: authors hypothesize a main barrier to be "lack of standardized practices of work in the discharge process"
Reference: Cadwallader et al. 2012[9] **Study Design:** Pre/post comparative (retrospective) **Purpose:** To evaluate effectiveness of using a computerized provider order entry (CPOE) system to enforce documentation of tests with pending results into hospital discharge summaries. **Quality Rating: Good** Appears to be prospectively planned, but data collection retrospective All eligible patients enrolled over a timeframe; 2 physicians performed manual chart review; discussion to resolve disagreements. High agreement between reviewers (kappa=0.8).	**Diagnostic Test:** Pending tests at discharge **Setting:** Midwest urban public teaching hospital on the campus of an academic medical center, Indiana University School of Medicine, Indianapolis, USA **Number of Patients:** 182 patients being discharged before implementation and 203 patients being discharged after implementation **Age (Years):** mean age 56.7 in the pre-implementation period and 54.0 years in the post-implementation period **Gender:** 48% female in pre-and post-implementation periods **Inclusion Criteria**: Implementation of new tool began February 2009, so discharge summaries in the months before and after implementation were compared. Of 2,715 patients discharged during the study months, 742 patients in this period had 1 or more pending tests. 419 randomly selected summaries (378 unique patients) were enrolled and 34 summaries were excluded because the patients died during hospitalization, were transferred to another hospital,	**Intervention:** Creation of dedicated free-text mandatory field in discharge summary for pending tests. If no test results were pending at the time of patient discharge, the doctor had to choose the "no pending test results" option. In the pre-implementation period, physicians could enter any pending tests as a narrative entry **Outcomes:** ▪ Documentation in the discharge summary rates ▪ Proportion of actionable tests that were documented ▪ Satisfaction with the tool	**Documentation rates** were 87/701 (12%) and 178/812 (22%) for the pre- and post-implementation periods, respectively; p=0.02. **Actionable results documented as pending:** 0/24 vs. 14/28 (50%) in the pre- and post-implementation periods, respectively; p statistically significant. **Satisfaction with the tool:** Survey response rate was 50%. Providers reported the tool was useful (3.7 on a 5-point scale), improved quality of the discharge summary (3.8), improved communication with follow-up providers (3.6), and improved the documentation of tests that had pending results at discharge (3.7). Providers disagreed that the tool added time to complete the discharge summary (2.7) or that enforcement made documentation more difficult (2.2). 19/26 wanted to continue using the tool, 6 were neutral, and 1 wanted the tool removed.

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
Primary outcome (documentation of pending tests) was objective. For secondary outcomes, survey response rate was low (50%), study was performed at a single hospital using a specific tool, so generalizability may be an issue.	left against medical advice, or were discharged to hospice and 1 because the new tool malfunctioned. **Exclusion Criteria**: Patients who died during the hospitalization, left against medical advice, were discharged to hospice, or were transferred to another hospital. **Study Methods:** Pre-post comparison of discharge summaries. In the pre-implementation period, physicians could enter any pending tests at the time of discharge as a narrative entry. In the post-implementation period, they were required to add any pending test results. Discharge summaries for study patients were manually reviewed by 2 physicians. All test results returned within 2 months after discharge were reviewed, even if abnormal, and physicians determined whether they were actionable or not.		
Multi-faceted intervention, with review and communication by nurse and clinician			
Reference: Saha et al. 2017[15] **Study Design:** Retrospective pre/post study **Purpose:** To develop a protocol for follow-up management of negative urine culture results to reduce inappropriate antibiotic exposure. **Quality Rating: Fair** Retrospective data collection; all eligible patients within timeframe enrolled Objective outcome measure; outcome assessor not reported (NR); measures to verify accuracy of data NR	**Diagnostic Test:** Urine culture **Setting:** National Children's Hospital (NCH), Columbus, Ohio, USA: academic tertiary care hospital with network of off-campus urgent care centers **Number of Patients:** 910 patients **Inclusion Criteria:** Patient evaluated at any of 6 urgent care centers; received empiric antibiotic therapy for urinary tract infection (UTI), with subsequent negative result **Exclusion Criteria:** Antibiotic prescribed for reason other than UTI; antibiotic prescribed for ≤3 days **Study Methods:** New protocol implemented in September 2014; eligible encounters from July 2013 to December 2015 were identified by searching EMR for negative urine culture results	**Intervention:** Multidisciplinary task force; clinicians educated on documenting antibiotic discontinuation New protocol created: (1) nurse reviewed urine culture result; (2) negative result in patient with antibiotics forwarded to clinician; (3) clinician determines whether antibiotic discontinuation is appropriate; (4) nurse notifies patient/caregiver of result (2 phone calls, followed by letter if unable to reach), and (5) clinician documents discontinuation of medication in EMR **Negative urine culture defined as:** No organisms, <10,000 colony forming units (CFU) or only mixed urethral/perineal flora **Primary Outcome:** Documented antibiotic discontinuation within 48 hours of finalized urine culture result	910 patients with negative urine culture results during this time frame. Rate of documented antibiotic discontinuation: increased monthly mean from 4% to 84%. Statistical significance NR. A total of 8,684 days of antibiotic prescribed: urine culture follow-up and antibiotic discontinuation resulted in 3,429 (40%). Reasons for continued antibiotic use despite negative urine culture results: (chart provided, but percentages not reported) ■ Culture result not reviewed by either nurse or clinician ■ Result reviewed, but no documentation of action taken ■ Result reviewed, but clinician determined clinical scenario warranted continuation of antibiotic

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
			Clinician discontinued antibiotic and patient/caregiver notified, but medication list in EMR not updated
Automated electronic notification of pending tests or new test result			
Reference: Dalal et al. 2014[13] **Study Design:** Cluster randomized control trial (RCT) **Purpose:** To evaluate the impact of the automated email notification system on physician awareness of results of tests pending at discharge (TPAD) and assess overall satisfaction with this strategy. **Quality Rating: Fair** Method for randomization NR; however, method was changed from "manual" midway through the study Participation was voluntary, but recruitment rate NR 23.5% (n=398) of potential patients excluded because either technical difficulties in random assignment or staff was unavailable to randomize Further partial sampling of patients with microbiology results performed to decrease risk of alert fatigue NR whether outcome assessors were blinded. Outcome of self-reported physician awareness, indirect and subjective Therefore, as per U.S. Preventive Services Task Force	**Diagnostic Test:** Tests pending at discharge (TPADs) **Setting:** Academic tertiary care hospital (Brigham and Women's hospital, Boston, Massachusetts, USA) **Number of Study Participants:** 500 patients (267 intervention, 233 usual care); 59 attending physicians (intervention), 58 attending physicians (usual care) **Inclusion Criteria:** Adult patients with TPADs, discharged from inpatient general medicine and cardiology services if their inpatient attending physician and primary care physician (PCP) were both randomly assigned to the same study arm **Exclusion Criteria:** Patients with discordant physicians pairs, concordant physician pairs but partial sampling of microbiology TPADs, attending and PCP was the same physician **Study Method:** Patients assigned to the intervention or usual care if both the attending physician and PCP were in the same study arm. After pending tests finalized, system automatically emailed the inpatient attending physician and network PCP. If the patient had a non-network PCP or no PCP was listed in the database, only the attending physician received the email. Physicians surveyed 72 hours after all TPAD results were finalized. Because microbiology results were most common, to minimize possibility of alert fatigue from receiving multiple notifications, these patients were partially sampled.	**Intervention:** Automated system notifying responsible inpatient physician with carbon copy sent to primary care provider of TPAD results via secure, network email (accessible from all in-network computers and mobile devices). The system assigns responsibility for TPAD results to the inpatient attending physician, is configured to minimize alert fatigue, and facilitates timely communication with the PCP. "The system coordinates a series of electronic events triggered by the patient's discharge time stamp, suppresses certain TPADs based on configurable rules, updates the status of the TPADs on a daily basis, and automatically sends an email notifying the patient's attending physician and PCP of TPAD results on the day these results are finalized." **Outcomes:** (at 3 days after notification) Self reported awareness of TPAD Self reported awareness of actionable TPAD results Provider satisfaction	**Outcomes:** Automated email notification represents a promising strategy for managing TPAD results, potentially mitigating an unresolved patient safety concern. Compared to usual care, awareness of TPADs pending at discharge significantly increased for attending physicians and PCPs receiving automated email notifications. **Primary Outcome:** Self-reported awareness of TPAD results: Attending physicians in the intervention arm reported higher awareness of TPAD: 76% vs 38%; adjusted/clustered odd ratio (OR), 6.30; (95% confidence interval [CI], 3.02 to 13.16); p<0.001 Effect was similar for both hospitals and nonhospitals. In-network PCPs in the intervention arm reported significantly higher awareness. Statistically significant increase exclusively for network PCPs: 57% vs. 33%, Adjusted/clustered OR, 3.08 (95% CI, 1.43 to 6.66); p=0.004 **Secondary Outcome:** Self-reported awareness of TPAD results by PCP (network and non-network), self-reported awareness of actionable TPAD results by attending physician and PCP, and provider satisfaction. Attending physician: ■ 59% vs 29%

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
(USPSTF) criteria, this study was rated Fair quality.			■ Adjusted/clustered OR, 4.25; (95% CI, 0.65 to 27.85) ■ p=0.13 PCP awareness: ■ 65% vs 48% ■ Adjusted/clustered OR, 2.15 (95% CI, 0.54 to 8.60) ■ p=0.28 Survey result—managing TPAD results Attending physicians, 441/275; PCPs, 353/152 ■ 15 (11%) attending physicians and 14 (17%) PCPs were satisfied with current method ■ 95 (70%) attending physicians and 54 (65%) PCPs reported dissatisfaction with current method 118 (85%) attending physicians and 43 (63%) PCP reported satisfaction with the intervention
Reference: El-Kareh et al. 2012[14] **Study Design:** Prospective, cluster RCT **Purpose:** To design, implement, and evaluate an automated system to improve follow-up of microbiology results that return after hospitalized patients are discharged. **Quality Rating: Good** Randomization method described. No significant differences in physician characteristics between groups. Diverse specialties represented (medicine, oncology, surgery).	**Diagnostic Test:** Blood, urine, sputum, or cerebral spinal fluid (CSF) cultures **Setting:** Brigham and Women's Hospital (Boston, Massachusetts, USA) **Number of Study Participants:** 157 results from 121 physicians (73 intervention, 48 control) **Age (Years):** >18 **Gender:** All **Inclusion Criteria:** Inpatient physicians were included if they were listed as the responsible attending providers at the time of discharge for patients of age 18 years or older with clinically important post-discharge blood, urine, sputum, or CSF culture results that were not adequately treated with an antibiotic at the time of discharge **Exclusion Criteria:** Patients with a code status of comfort measures only	**Intervention:** An automated email-based system alerting inpatient and outpatient physicians to positive post-discharge culture results not adequately treated with an antibiotic at the time of discharge. The email-based alert included patient demographic information, inpatient and outpatient physicians responsible for the patient, hospital admission and discharge dates, culture result, discharge medication list, and patient allergy information. **Primary Outcome:** Documentation of response within 3 days of test finalization, where a response was defined as at least 1 of the following in the patient's outpatient	Overall, charts from 73 intervention physicians and 48 control physicians were reviewed. **Outcome:** The alerting system improved the proportion of important post-discharge microbiology results with documented follow-up, although the proportion remained low. The alerts were well received and may be expanded in the future to include broader scenarios. **Intervention vs. Control** **Primary Outcome:** Documented follow-up of results within 3 days was significantly higher for the intervention group. 27/97 vs 8/60 28% vs. 13%; adjusted OR, 3.2 (95% CI, 1.3 to 8.4); p=0.01 **Secondary Outcome:**

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
Outcome assessors blinded as to group assignment. Low response rate to survey (secondary outcome); apparently no attrition for primary outcome.	**Study Method:** Inpatient physicians were pseudorandomized to intervention or control based on the odd or even status of their physician identification numbers. The intervention group received electronic alerts for potentially untreated infections identified though blood, urine, sputum, and CSF cultures results that returned after their patients were discharged from the hospital. The intervention group received this email alert the day the result was finalized. 3 days after test finalization, both intervention and control group received an alert, along with a link to an online survey. Alerts were also sent to the outpatient physician if they were part of the hospital system. The study followed hospitalized patients February 2009 to June 2010 (16-month period). 2 reviewers assessed charts and were blinded as to whether charts were from intervention or control groups.	chart: a note describing follow-up with the patient and a note with acknowledgement of the result or a new antibiotic prescription.	Physician awareness and assessment of result urgency, impact on clinical assessments and plans, and preferred alerting scenarios 32/82 (39%) were previously aware of the results 45/77 (58%) believe the results changed their assessments and plans 43/77 (56%) believe the results required urgent action 67/70 (96%) preferred alerts for current or broader scenarios.

Table A-2. Transition Outpatient to Inpatient

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
Reference: Pham-Thomas et al. 2014[16] **Study Design:** Retrospective before and after study **Purpose:** To investigate the outcomes associated with improved transmission of prenatal test results between the outpatient and inpatient obstetric setting after implementing an electronic prenatal record system **Quality Rating: Fair** Retrospective study; all eligible patients in time period enrolled; objective outcome measure, but obtained by manual chart review; information regarding outcome assessors NR	**Diagnostic Test:** Prenatal test results (maternal hepatitis B and HIV) **Setting:** Hahnemann University Hospital, Philadelphia, Pennsylvania, USA. Outpatient clinics to labor and delivery unit **Number of Study Participants:** 460 charts **Inclusion Criteria:** All uncomplicated singleton pregnancies delivered at the facility between November 2007 and January 2008 and November 2008 and January 2009 **Exclusion Criteria:** Patients who initiated care at the health centers **Study Method:** A retrospective chart review of 460 admission charts were reviewed, 229 pre-implementation and 231 post-implementation of an electronic prenatal record. Paper admissions charts reviewed for evidence of test availability.	**Intervention:** Electronic prenatal record system (Allscripts) **Outcomes:** ■ Availability of serum hepatitis and HIV serology on admission to labor and delivery unit ■ Ordering of repeat hepatitis B surface antigen and rapid HIV blood testing ■ Administration of hepatitis B immunoglobulin to newborns without available maternal hepatitis B	**Intervention vs. control:** The electronic prenatal record facilitated the effective transmission and communication of prenatal test results between the outpatient and inpatient obstetric setting. Transmission of prenatal test results after implementation ■ Increased from 78.2% to 100% of charts contained maternal hepatitis B and HIV serology results, ($p<0.001$) ■ Repeat hepatitis B surface antigen testing decreased from 3.1% to 0%, ($p=0.007$) ■ Repeat rapid HIV blood testing decreased from 3.5% to 0%, ($p=0.003$); 100% availability of testing results prevented unnecessary administration of hepatitis B immunoglobulin post implementation

Table A-3. Communication of Radiology Results Requiring Action

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
Automated alert system or secure messaging capability integrated into radiology workflow			
Reference: Filice 2017[17] **Study Design:** Randomized controlled trial (RCT) **Purpose:** To determine whether using the CORES Smart Handoffs, (TransformativeMed Inc., Seattle, Washington, USA) with picture archiving and communication system (PACS) plugin embedded in the electronic health record (EHR) decreased the amount of time it took radiologists to communicate critical results compared with the traditional methods of clinician contact. **Quality Rating:** Poor Method of randomization not reported (NR); primary outcome (critical turnaround time) was not objective, but relied on subjective radiologist recall; no clear definition was provided to study participants. Authors note time recalled often in 5-minute increments (i.e., 5, 10, or 15 minutes). Outcome assessor blinding NR, but not a factor given nature of this outcome. This study was rated Poor quality as per USPSTF criteria due to flawed outcome measurement.	**Diagnostic Test:** Inpatient test results conveyed through EHR **Setting:** Inpatient (Georgetown University Hospital, Washington, DC, USA) **Number of Patients:** 36 radiologists reporting on 338 exam results **Inclusion Criteria:** Radiologists working at Georgetown University Hospital. Random assignment occurred between September 2014 and October 2014. The trial was stopped early because the system received such positive feedback that the investigator decided to make it available to all radiologists. **Study Methods:** RCT: 160 exams were randomized to CORES system and 178 were randomized to the traditional communication method. **Survey:** 37 radiologists completed the survey including 21 attending physicians, 15 residents, and 1 fellow	**Intervention:** CORES Smart Handoffs, (TransformativeMed) with plugin embedded in the PACS as well as EHR. With a single click, the radiologist could identify covering physicians and message them using pre-written text that specified the patient and exam information. System is intended to decrease the critical-result turnaround time. One feature of the system is that pre-written messages to clinicians are provided. Traditional communication methods: Traditionally radiologists would call the floor trying to reach the physician responsible for the patient (83%), called the hospital operator (40%), paged physician on the order sheet (66%), paged service/405-BLUE (66%), asked a resident/fellow (14%), looked up covering physician on the CORES page in Cerner/MedConnect (31%), or used another method (6%). **Outcomes:** ■ Critical result turnaround time (time between recognition and communication of the critical result) ■ Attitudes towards tool	Critical result turnaround time CORES: a total of 12/160 exams had a critical result and the average critical turnaround time was 6.9 minutes. Traditional communication method: 16/178 had critical results with a critical turnaround time of 11 minutes. The difference between CORES and traditional communication did not reach statistical significance. Of note, before implementation of the system critical turnaround time was 11.2 minutes. Attitudes towards tool: 83% of radiologists rated the CORES system and easy and intuitive, 5 on a 1 (terrible/confusing) to 5 (easy and intuitive) scale; 17% rated it as a 4/5. 29% of radiologists rated the CORES system a 5 on a 1 (completely unreliable) to 5 (works like a charm every time) scale; 71% rated it a 4/5 on reliability. 97% of users of the CORES system users rated the prepopulated page text as correct. For reliability the traditional communication method received a 5/5 rating only 3% of the time, 4/5 (9% of the time), 3/5 (54%), 2/5 (34%), and 1/5 (0%). Generalizability limited by availability of information system with provider coverage; also, direct integration into EHR and systems used to transfer information and to-do lists. Authors report attempts to implement this system at sister hospital failed because of "poor usage and inaccuracies in their CORES database."

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
Reference: Lacson et al. 2015[18] **Study Design:** Retrospective before and after study **Purpose:** To evaluate the impact of a patient safety initiative with an alert notification system on reducing critical results lacking documented communication, and to assess potential overuse of the alerting system for communicating results. **Quality Rating:** Good ■ Randomization of physicians was difficult ■ Unable to measure the other means of communication that were used before implementation of alert notification of critical results (ANCR) ■ Outcome assessor blinding NR	**Diagnostic Test:** Imaging **Setting:** Inpatient (Brigham and Women's Hospital, Boston, Massachusetts, USA) **Number of Study Participants:** 840 radiology reports (420 without communication, 420 using ANCR) **Inclusion Criteria:** Second half of 2009 to the first half of 2014 **Exclusion Criteria:** N/A **Study Method:** Authors implemented an alert notification system—Alert Notification of Critical Results (ANCR)—in January 2010. A random sample of radiology reports finalized in the 2009 to 2014 period that lacked documented communication between the radiologist and another care provider (n=420) were reviewed by 2 raters (a radiologist and internist—blinding NR) To assess for potential over-utilization, a random sample of reports with documented communication (n=420) was also assessed. The impact of ANCR on the proportion of such reports with critical findings, using trend analysis over 10 semiannual time periods. Cochrane-Armitage trend test).	**Intervention:** Implementation of an automated system, ANCR, in January 2010 in conjunction with the Communication of Critical imaging Test Results (CCTR) policy in 2006. "The policy defined types of radiological findings (critical or discrepant), urgency level (red, orange or yellow) and timelines for notification, acceptable communication and documentation method based on recommendations from the Joint Commission, American College of Radiology and Massachusetts Coalition for the Prevention of Medical Errors." ANCR facilitates provider identification (integrated with the institution's physician directory service) Alerts vary in urgency and may be communicated synchronously (i.e., via the paging system) or asynchronously (i.e., via secure and Health Insurance Portability and Accountability Act [HIPAA]-compliant email). Alerts could be acknowledged securely from workstations or mobile devices, providing added convenience for ordering providers. More importantly, every alert is monitored and generates subsequent pages and/or emails until the communication loop is closed.	**Outcomes:** The implementation of an electronic alert notification system as a part of patient safety initiative to facilitate closed-loop communication contributed to enhanced patient safety. The system did not promote over reporting of noncritical results. **Intervention vs. control** **Non-transmitted test results** Significant nearly 4-fold decrease (from 2009 to 2014) in proportion of reports with critical or clinically significant findings that were not communicated: ■ 0.19 to 0.05, p<0.0001 Potential ANCR overutilization The proportion of reports without critical and clinically significant findings was lower in reports not using ANCR (compared to reports that did): ■ 0.09 vs. 0.20, p<0.002 Of reports using ANCR: ■ 91 % were critical and/or clinically significant The proportion of provider-communicated reports with noncritical results remained unchanged over time before and after ANCR implementation ■ 0.20 to 0.15, p=0.4
Reference: Lacson et al. 2014[19] (Analysis of same data described in Lacson et al. 2015[18] but with different outcomes.) **Study Design:** Prospective pre/post study **Purpose:** To assess the impact of automated alert notification system for critical results	**Diagnostic Test:** All radiologic imaging studies **Setting:** Academic tertiary referral medical center (Brigham and Women's Hospital, Boston, Massachusetts, USA) **Number of Studies:** 47,034 radiology reports **Inclusion Criteria:** Radiology reports from emergency department, inpatient hospital, outpatient clinics from January 2009 to December 2013.	**Intervention:** Automated alert system: ANCR. Embedded in radiology and referring provider workflow; integrated with PACS, paging and email systems and EMR. Allows provider notification through paging, or secure/HIPAA-compliant email. **Critical imaging result**: defined as new or unexpected radiologic findings that could result in mortality or significant morbidity	Random sampling of reports before and after implementation for review: ■ 9,430 (of 375,985 reports) pre-implementation ■ 37,604 (of 1,538,059 report) post-implementation **Adherence to communication policy:** Compared to 2009 (pre-implementation), analysis of results from 2010 to 2013 showed a

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
Quality Rating: Good Prospective study (both planning and data collection); random sample of all studies from 1 day of the month reviewed; 2 physician reviewers independently reviewed; 10% of charts were reviewed by both for agreement; reviewers instructed in how to extract data and rate data with objective outcome measure.	**Study Methods:** Intervention implemented in January 2010. Manual review of random sample of all radiology reports from 1 year before intervention vs. 4 years after. All radiology reports from randomly selected day every other month were assessed for presence of critical results.	without appropriate follow-up or interpretations differing from a previously communicated preliminary interpretation Multiple imaging tests resulting in a single report were treated as 1 report. **Primary Outcome:** Proportion of radiology reports with critical results adherent to policy provisions. Documentation considered complete if it included name of ordering provider contacted and date and time critical results were communicated. **Secondary outcome**: System adoption (proportion of all finalized radiology reports using ANCR). Number of distinct ANCR alerts / unique reports containing findings communicated by radiologists with another clinician.	significant improvement in adherence to policy for communicating results of critical imaging (95% vs. 91.3%, p<0.0001). Pre-implementation 10.5% (987 of 9,430) of reports with critical results, and 91.3% adherent to policy. Post-implementation: 13.1% (4,935 of 37,604) of reports with critical results, and 95% adherent to policy. Significant improvement in policy adherence over 4-year period: 90.7%, 97.9%, 98.1%, 97.9% from 2010 to 2013 respectively, p<0.0001. **Adoption of ANCR**: Compared to first 6 months of ANCR implementation, the last 6 months of study showed a 9-fold increase in use of ANCR as a proportion of all unique radiology reports (p<0.0001).
Reference: O'Connor et al. 2015[20] **Study Design:** Pre/post design (retrospective) **Purpose:** To assess whether integrating critical result management software—ANCR—with an EHR-based results management application impacts closed-loop communication and follow-up of nonurgent, clinically significant radiology results by primary care physicians (PCPs). **Quality Rating:** Good Retrospective; random sample of alerts taken; 3 blinded outcome assessors; objective outcome measure	**Diagnostic Test:** Radiology results **Setting:** Tertiary academic medical center, Brigham and Women's Hospital (Boston, Massachusetts, USA) for outpatient care **Number of Patients:** 171 PCPs working at 13 affiliated outpatient practices. 1,503 alerts were included from the pre-intervention period and 4,428 were included from the post-intervention period. **Age (Years):** 57 years for included alerts **Gender:** 74% female for included alerts **Inclusion Criteria:** Non-urgent, clinically significant alerts received by 171 PCPs working at 13 affiliated outpatient practices during a 12-month pre-intervention and 24-month post-intervention period. Pre-intervention period was May 2011 through April 2012 and post-intervention period was June 2012 through May 2014. Only outpatient radiology examinations order by PCPs were included.	**Intervention:** Integration of critical result management software (ANCR) plus EHR-based results management application (Previously, ANCR results could not be acknowledged in EHR, although laboratory results could.) ANCR generates emails or pages with radiology results. Acknowledging this information within the EHR required providers to log into the patient's record. **Outcomes:** ■ System adoption (proportion of nonurgent, clinically significant ANCR-generated alerts acknowledged in the EHR) ■ Rate of alert follow-up (proportion of actionable ANCR-generated alerts that	Overall, integration of these systems did not increase the proportion of actionable alerts that PCPs acted upon. Also, only 16% of alerts were acknowledged within the EHR (using the integrated system); PCPs continued to acknowledge most alerts within the ANCR system. System adoption: EHR was used to acknowledge 16% of alerts (688 of 4,428) generated in ANCR in the post intervention period Alert follow-up before and after the intervention: Compared to pre-intervention, there was no significant difference in proportion of actionable alerts (90% and 84%, respectively, p not significant.) There was no difference in proportion of actionable alerts PCPs acted on: Pre-intervention 94% (85 of 90; 95% CI, 88% to 98%); post-

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
	Exclusion Criteria: Alerts not in the EHR and those generated on inpatients or emergency department patients were excluded. **Study Methods:** Pre/post comparative trial testing the level of adoption of a newly integrated system for communicating, tracking, and acknowledging abnormal radiology results. A random sample of alerts was reviewed by 3 raters, who assessed whether the alert was actionable and whether the PCP had taken action. Assessors were blinded to method of alert.	were acted upon appropriately or "actioned") ■ Time to acknowledgement (interval between alert generation by the radiologist and acknowledgement by the PCP)	intervention: 94% (79 of 84; 95% CI, 87% to 97%), p>0.99. In the post-intervention period, PCPs acted on 79% of actionable alerts acknowledged in the EHR and 97% of actionable alerts acknowledged in ANCR, p=0.03 Time to alert acknowledgement: Post-intervention, the median time to acknowledgement was significantly shorter 0.6 hours (IQR [interquartile range] 0.03 to 6.9 hours) vs. 0.6 hours (IQR 0.03 to 20.5 hours) pre-intervention, p=0.003. Median time to alerts acknowledgment was significantly shorter for alerts acknowledged within the EHR vs. ANCR: 7 hours and 0.3 hours for EHR and ANCR systems, respectively; p<0.001.
Direct messaging to provider and also surgical oncology clinic with results raising concerns			
Reference: Browning et al. 2013[21] **Study Design:** Pre/post study (retrospective) **Purpose:** To improve timely evaluation and management of incidental findings of newly identified, suspected, gastrointestinal (GI) malignancies discovered on radiologic imaging at a safety-net hospital through direct critical results messaging to surgical specialists. **Quality Rating:** Fair Retrospective chart review; outcome objective, but differed from pre-intervention (follow-up at GI clinic accepted as being seen by a specialist; post-intervention, only	**Diagnostic Test:** Radiology results concerning for previously undocumented GI malignancy **Setting:** UT Southwestern Medical Center at Dallas (Texas, USA), an urban, safety-net level 1 trauma hospital, with patients moving to outpatient care **Number of Patients:** 61 critical alerts pre-intervention; 49 post-intervention From February 2009 through December 2009, there were 355,116 diagnostic exams performed in the radiology department, generating 1,438 yellow critical results in the Veriphy system. From February 2010 through December 2010, there were 354,765 diagnostic exams performed in the radiology department generating 3,037 yellow critical results. **Age (Years):** Median age 54 and 57 in the pre- and post-intervention periods, respectively **Gender:** Male 28/110, or 25% **Inclusion Criteria:** Imaging for symptoms suspicious for an otherwise undocumented GI malignancy	**Intervention:** Existing electronic radiology critical results system notified ordering physician of imaging findings, but also surgical oncology clinic for critical results being sent on patients seen in emergency or ambulatory settings in whom the radiologist identified findings suspicious for a previously undocumented GI malignancy. All notifications were reviewed by a physician in the surgical oncology clinic, along with EHR, and appointment scheduled for patient if deemed appropriate, with notification of ordering provider. In the quality improvement period before the ordering physicians' contact information was autopopulated but the radiologist had to manually mark the record as a yellow alert and manually add additional contacts, then a text message was automatically sent to all listed contacts.	■ Pre-intervention: 61 critical alerts sent to ordering physician ■ Post-intervention: 49 yellow critical results were sent to the oncology clinic ■ There was significant improvement post-intervention: ■ **Seen by a specialist (in person or by phone) in the pre- and post-intervention period: Increased from** 45.9% to 98%, p<0.001 ■ **Median days until seen by a specialist (in person or by phone: Decreased from** 35 to 7 days, p<0.001 ■ **Mean days until seen by a specialist (in person or by phone): Decreased from** 69 to 9 days, p<0.05 ■ **Completing a diagnostic workup (diagnosis established): Increased from** 77% to 94%, p<0.001

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
follow-up in oncology clinic counted) Single outcome assessor, blinding NR	(such as melena), or for patients arriving newly to the institution with undocumented but verbal history of a "mass" **Exclusion Criteria:** Messages sent for reasons other than suspected GI malignancies incidentally identified or previously unknown to the institution were excluded. Messages on patients admitted on the day of imaging for workup and treatment of the finding **Study Methods:** This study evaluated the impact of notifying the oncology clinic of suspected incidental malignancy findings on imaging. The process change started in February 2010 through December 2010. This period was compared to the same 10-month period in the preceding year (pre-process change). Charts were reviewed by a single attending radiologist; blinding was NR	Outcomes: ■ Seen by a specialist ■ Time to be seen by a specialist ■ Completing a diagnostic workup ■ Time to diagnosis ■ Initiating definitive management ■ Time to initiating definitive management	■ **Median number of days until diagnosis: Decreased from** 44 to 18 days, p<0.001 ■ **Mean number of days until diagnosis: Decreased from** 84 to 25 days, p<0.001 ■ **Proportion of patients for whom definitive management was initiated: Increased from** 72% to 90%, p<0.05 ■ **Mean days to initiate management in the pre- and post-intervention period: Decreased from** 98 to 43, p<0.05
Direct messaging plus alerts, with dedicated team to follow up communication			
Reference: Dibble et al. 2016[22] **Study Design:** Pre/post study (retrospective) **Purpose:** To assess new system /workflow for communication of important but nonurgent findings with providers and/or patients and to document that communication in the electronic medical record **Quality Rating: Fair** Retrospective study; all possible studies in time period enrolled; objective outcome measure; outcome assessors NR	**Diagnostic Test:** Radiology studies **Setting:** Multi-hospital center, radiologists reading inpatient, outpatient, and emergency department studies **Number of Study Participants:** 13,408 studies (250 pre-implementation; 13,1585 post-implementation) **Inclusion Criteria:** Reports with important findings 1 year pre-intervention (June 2011 to June 2012) and 2 years post-implementation (June 2012 to June 2014) **Study Methods:** EMR queried to identify number and handling of reports with "important" results, and their follow-up before and after RADiology CATegorization 3 (RADCAT-3) intervention	**Intervention:** New system and workflow to communicate nonurgent findings to providers or patients (RADCAT-3): ■ Radiologists trained in appropriate use of the new macro (RADCAT-3): "Results with recommendation for non-urgent imaging follow-up"). ■ Reports sent via Health Level-7 (HL7) message to Cloverleaf, the enterprise interface engine; routed to both the EMR (Siemens Invision) and the Siemens workflow engine (WFE) ■ WFE identified all reports with this MACRO, opened a "case," automatically displayed provider's contact information ■ Team of 12 quality assurance staff reviewed charts and communicated findings to providers (or patients, when providers unavailable) and documented receipt of information	**Intervention vs.control** The RADCAT-3 system has the potential to improve patient care by increasing the identification of nonurgent findings and the likelihood of communication and appropriate follow-up care of those findings with providers and/or patients and to document that communication in the EMR. 12 months before implementation ■ 12 months before implementation, 250 radiology reports (0.06 % of all reports) important nonurgent findings entered the workflow. ■ 100% were successfully communicated **24 months after implementation** ■ 13,158 important nonurgent findings radiology reports (1.4 % of all reports) entered the workflow

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
		Outcomes: Proportion of nonurgent imaging requiring follow-up successfully communicated	■ 3,995 (0.8%) of all important non-urgent findings reports during year 1 entered the workflow ■ 9,163 (1.9 %) of all important nonurgent findings reports during year 2 entered the workflow ■ 99.7% of reports were successfully communicated "Communicating the RADCAT-3 findings took approximately 0.55 full time equivalents (FTE) of nursing staff time and 0.25 FTE of non-nursing staff time."

Table A-4. Follow-up of Abnormal Outpatient Results

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
Fecal occult blood test (FOBT)			
Reference: Humphrey et al. 2011[25] **Study Design:** Designed as cluster randomized trial, but results reported as prospective cohort study **Purpose:** To evaluate whether an automated electronic consult intervention improved the follow-up of patients with a positive fecal occult blood test (FOBT) result. **Quality Rating: Fair** Method of randomization described; high attrition: half of initially randomized sites dropped out for various reasons; however, patient characteristics across the included sites did not differ (intervention vs. control).	**Diagnostic Test:** FOBT **Setting:** Outpatient Veterans Affairs (VA) Medical Centers (locations NR) **Number of Study Participants:** 3,322 positive FOBTs **Inclusion Criteria:** Beginning May 2005, all patients with positive FOBT results 12 months pre-intervention and 6 months post-intervention **Study Method:** A multisite cluster randomized trial involving eight VA medical centers. Sites were paired according to colonoscopy volume, and then randomized within the pair to usual care vs. intervention. The primary investigator at each site facilitated the institutional review board (IRB) approval, implementation of the interventions, and data collection. Primary care providers at the control site continued to be notified of positive FOBT results in the usual manner.	Intervention: Automated, electronic consultation directly sent to GI providers with every positive FOBT result. ■ Once a positive FOBT is recorded in the laboratory, the automatic notification is sent to the PCP and to the GI clinic The consult also contained the following information: Age, gender, relevant laboratory data, procedures from the past 5 years (including prior endoscopic procedures), and all imaging procedures and dates of hospital admission over the past year. The control group continued to notify PCPs in the usual manner. Any patient follow-up was initiated by the PCP **Primary outcome:**	**Outcomes:** An automated electronic notification system that includes redundancy can significantly improve the follow-up of positive FOBT results. Interventions such as this could improve patient care and may be applicable to other practice settings, as well as other types of tests. Time to GI consult and CDE decreased significantly over time in the interventions sites ($p<0.001$), but remained unchanged in the usual care sites. **Intervention vs. control** **Primary outcome:** 30-, 90-, and 180-day GI consultation rates: ■ At 30 days, GI consultation rates increased from 39% to 69% at one intervention site, and 47% to 80% at the second intervention site ($p<0.001$ for both). ■ No change in the usual care sites **Secondary outcome:** 30-, 90-, and 180-day CDE rates:

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
Methods for outcome assessment NR, but not that relevant. As per USPSTF criteria, this study was rated Fair quality due to high attrition.	1 intervention site withdrew participation after random assignment; technical changes in software made data unextractable from 1 intervention and 2 control sites.	Proportion of patients with positive FOBT results undergoing further workup Proportion of patients receiving complete diagnostic evaluation (CDE)	■ At 30 days, rates of CDE at 30 days significantly improved for both intervention sites (4% to 30% and 12% to 21%, p<0.03 for both). ■ No significant change in the usual care sites
Reference: Singh et al, 2009[24] **Study Design:** Before and after study (pre-intervention data retrospective) **Purpose:** We determined whether technical and/or workflow-related aspects of automated communication in the EHR could lead to the lack of response. **Quality Rating:** Fair Retrospective study; all studies within time period enrolled; objective outcome measure; outcome assessor/blinding NR	**Diagnostic Test:** Positive FOBT Setting: Inpatient and outpatient, Houston VA Medical Center (Texas, USA) **Number of Study Participants:** 490 FOBT alerts (360 pre-intervention, 130 post-intervention) **Inclusion Criteria:** Positive FOBT **Study Method:** Qualitative methods to identify problems with follow-up of positive FOBTs, followed by before and after study of intervention. FOBT communication in the EHR of a large, urban facility between May 2008 and March 2009 was evaluated (Intervention introduced 11/2098). The authors identified the source of test result communication breakdown and developed an intervention to fix the problem. Explicit medical record reviews measured timely follow-up (defined as response within 30 days of positive FOBT) pre- and post-intervention.	**Intervention:** Corrected software configuration of the technical problem by adding code to link patients to their PCP for tests ordered by others.	**Outcomes:** Qualitative interviews revealed the following: The ordering provider was often not accessible to laboratory personnel processing FOBT; laboratory personnel entered test requisition when card was delivered to lab; unless ordering provider's name was written on card, this information as inaccessible and results were not returned to PCP. To achieve the most benefits of cancer screening programs, robust monitoring systems are necessary in EHR systems to ensure that abnormal cancer screening results are being delivered to the correct providers in a timely manner. Problem identified ■ Software improperly configured and more than a third of positive FOBTs were not transmitted to PCPs. Post Intervention ■ Lack of timely follow-up decreased immediately from 29.9% to 5.4% (p<0.01) ■ Improvement was sustained at month 4 after the intervention.
Reference: Singh et al. 2009[23] **Study Design:** Before and after study (retrospective) **Purpose:** To evaluate the effect on timeliness and appropriateness of multifaceted quality-improvement (QI) activities implemented to	**Diagnostic Test:** FOBT **Setting:** Specialty Ambulatory Care clinic of Michael DeBakey Veterans Affairs Medical center, Houston, Texas, USA **Number of Study Participants:** 800 positive FOBT cases (randomly selected 401 pre-intervention cases, and 399 post-intervention) identified for analysis; 533 included **Inclusion Criteria:**	**Intervention:** Multifaceted (QI) initiative: ■ Updated guidelines disseminated to primary care providers through electronic email and memorandum ■ GI service took measures to reduce their colonoscopy backlog and waiting times using dedicated staff and FOBT algorithm to reduce the number of unnecessary consults	Of 800 positive FOBT tests analyzed, 267 excluded, leaving 533 cases for analysis. **Outcome:** Multifaceted QI intervention improved rates of timely colonoscopy referral and performance in an electronic medical record system. **Intervention vs. control** Overall, the QI intervention significantly improved all reported measures.

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
improve the follow-up of abnormal FOBT. **Quality Rating: Good** Retrospective study; random sample taken of patients before and after; objective, standardized data collection form used; 10% of cases reviewed to ensure accuracy of data; blinding of outcome assessors NR	Pre-implementation FOBT-positive cases January 1, 2003, to December 31,2003 Post-implementation FOBT-positive cases March 1, 2006, to February 28, 2007 **Exclusion Criteria:** Patient referred for colonoscopy or colonoscopy performed before positive FOBT; colorectal cancer screening inappropriate or not warranted **Study Methods:** Two reviewers reviewed EHR using a pretested standardized data collection form to determine (1) whether colonoscopy was appropriate based on predetermined criteria and (2) timeliness of colonoscopy referral. From 1,869 FOBT-positive cases, 800 were randomly selected from 1 year before and after QI intervention. Each case was assigned to a single chart reviewer (2 reviewers worked on the study). Study personnel checked 10% of cases to validate data entry; however, NR if reviewers were blinded as to pre- or post-intervention.	■ EHR notification system, the View Alert, immediately notified clinicians of a critically abnormal test result ■ All positive tests were categorized as critical ■ Providers received alerts on positive FOBT and were expected to read and initiate follow-up ■ An additional notification strategy was put in place. A preventive medicine coordinator used a laboratory software to identify all FOBT-positive results and sent an email notification to the PCP. ■ Preventive medicine coordinator tracked the FOBT positive cases for follow-up action (i.e., PCP response and colonoscopy performance)	For patients in whom colonoscopy was indicated: Timely colonoscopy referral (within 14 days): ■ Increased from 31.7% to 60.5% p<0.001 Performance of colonoscopy within 60 days: ■ Increased from 3.4% to 11.4%, P=0.0005 Median time from positive FOBT result to referral ■ Decreased from 19 days to 6 days, P<0.0001 Median time to performance of colonoscopy ■ Decreased from 190 days to 96.5 days, P<0.0001 No colonoscopy performed ■ Decreased from 35.9 to 24.3%, P<0.0045 Predictors of indicated colonoscopy not performed: ■ Procedure other than colonoscopy performed, such as barium enema or flexible sigmoidoscopy (odds ratio [OR],16.9; 95% CI, 1.9 to 145.1) ■ Patient nonadherence (OR=33.9; 95% CI, 17.3 to 66.6) ■ Not providing an appropriate provisional diagnosis on the consultation (OR, 17.9; 95% CI, 11.3 to 28.1) ■ GI service did not reschedule colonoscopy after an initial cancellation (OR, 11.0; 95% CI, 5.1 to 23.7)

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
Reference: Larson et al. 2009[26] **Study Design:** Pre/post design (retrospective) **Purpose:** To determine the impact of an electronic reminder upon the timeliness and proportion of patients referred for evaluation of a positive FOBT and receipt of colonoscopy. **Quality Rating: Fair** Retrospective study; all eligible patients within time frame enrolled; objective outcome; outcome assessor NR	**Diagnostic Test:** FOBT Setting: VA Puget Sound Health Care System, which provides primary care to more than 65,000 veterans in western Washington state, with more than 41,000 patients enrolled in primary care clinics. **Number of Patients:** 1,102 total, 634 control patients and 468 intervention patients **Age (Years):** 65 years controls; 64 years intervention group **Gender:** 95% male in both study arms **Inclusion Criteria:** All outpatients who had a positive FOBT from July 2004 through July 2006 **Exclusion Criteria:** FOBT performed as part of a clinic-based digital rectal examination **Study Methods:** Comparative pre/post design conducted between July 2004 and July 2005 (pre-intervention period) and July 2005 through July 2006 (post-intervention period). In the intervention period, for all patients with a positive FOBT, a reviewer checked the record weekly to see whether a GI consultation was requested. If one had not been requested, a "Lab Check Note" was entered into the patient's electronic chart. The medical record then automatically alerted the provider that he or she had a note to sign. The note alerted the provider of the positive result and offered choices for care options including referral for colonoscopy, defer colonoscopy as one recently done, defer colonoscopy due to severe comorbidity, document patient refusal or other. Each patient chart was monitored for a full year after the positive test result for compliance with referral follow-up.	**Intervention:** Weekly audit of chart for abnormal results that had not been followed up. Electronic reminder note to physicians indicating that the patient had a positive test result, as a stimulus to prompt follow-up planning. **Outcomes:** ■ Timeliness of referral to a GI doctor for evaluation of a positive FOBT ■ Proportion of patients referred to a GI doctor for evaluation of a positive FOBT ■ The proportion of patients who receive a colonoscopy	Lab Check Note was generated for (243/468) 52% of patients with a positive FOBT in the intervention period. **Timeliness of GI consultation improved at all measured time points (p<0.001 for all):** ■ Within 14 days: 62% to 82% ■ Within 30 days: 70% to 86% ■ Within 90 days: 77% to 88% **Timeliness of colonoscopy significantly improved at 60 and 90 days:** ■ Within 60 days: 15% to 25%, p<0.001 ■ Within 90 days: 35% to 46%, p<0.001 ■ Within 1 year: 60% to 64%, p=0.28 FOBT to consultation time significantly decreased from a median of 6 (IQR 2 to 69) to 3 (IQR 1 to 10), p<0.001. Of those without a GI consultation in the intervention period 45/51 (88%) had a documented reason, including prior colonoscopy (18), defer evaluation to another provider (9), significant comorbidity (5), and other (13) 75% of patients had a consultation within 10 days of the positive FOBT in the intervention group versus 69 days for the control group. Median time to colonoscopy decreased significantly in the intervention period from 143 days to 105 days, p<0.001

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
Tests raising concern for lung, colorectal, or prostate cancer			
Reference: Murphy et al. (2015),[27] secondary analysis of communication methods described in Meyer et al. 2016[28] **Study Design:** Cluster randomized control trial **Purpose:** To evaluate whether EHR-based trigger algorithms to identify patients at risk of diagnostic delays could prevent delays in diagnostic evaluation for lung, colorectal, and prostate cancer. **Quality Rating: Good** Randomization method described (block randomization with Excel); 72 of 109 PCPs recruited participated; no differences in PCP demographics between groups; outcome assessors performing 7-month review of outcomes were blinded to group assignment. Low study attrition.	**Diagnostic Test:** Laboratory and radiology results for lung, colorectal, and prostate cancer **Setting: 2** (VA facility and a private health system) **Number of Study Participants:** 72 PCPs from 2 sites **Inclusion Criteria:** April 20, 2011, through July 19, 2012 **Study Methods:** Trigger applied to records of all patients cared by enrolled PCPs; trigger applied twice over 15-month period	**Intervention:** EHR-based trigger, followed by manual chart review; PCPs contacted; if no response, leadership contacted **EHR Trigger:** **Lung Cancer:** Chest x-ray or chest computed tomography (CT) flagged by radiologist as suspicious for malignancy **Colon cancer:** Positive FOBT, new hematochezia, abnormal laboratory results (hemoglobin ≤11, mean corpuscular volume ≤81, no ferritin ≥100 in prior year) **Prostate:** Prostate-specific antigen results; PSA between 4.1 and 15 (Various exclusion criteria applied for all categories, such as presence of terminal illness) Delayed diagnostic evaluation: Absence of documented follow-up action within 30, 60, and 90 days for lung, colorectal, and prostate workup from the date of red flag's first presentation. **Primary Outcome: (assessed at 7 months)** ■ Time to diagnostic evaluation (# of days between red flag date and documented follow-up action or deliberate decision not to take follow-up action (e.g., patient refusal or decision to engage in watchful waiting) **Secondary outcome:** ■ Between-group differences in proportion of patients with follow up evaluation by 7 months ■ Reasons for delayed diagnostic evaluation ■ Date of subsequent nonmalignant or cancer diagnosis	72 PCPs randomly assigned: 36 to intervention, 36 to control group. Trigger applied to all patients cared for study PCPs from April 20, 2011, to July 19, 2012: 118,400 patients. Red flag criteria identified in 10,673 records, and 1,256 were trigger positive. 683 intervention patients identified; 298 of these (44.7%) identified as false positives after manual review. 385 patients with delayed diagnostic evaluation: Colon (n= 284) Prostate (n=89) Lung cancer: (n=12) 4 providers left facility between red flag and final review dates and 16 patients under their care were excluded. Of remaining 369 patients: 266 (72.1%) received follow up after intervention. 11 (2.9%) PCP unable to be contacted despite multiple attempts; leadership contacted 98 (26.6%) no follow-up action documented by 7 month review Intervention vs. Control: Time to diagnostic evaluation: Lung cancer: No difference (median 65 vs. 93 days; p=0.56; n=19) Colorectal and prostate: Intervention group had significantly shorter time to evaluation. Colorectal (median 104 vs. 200 days; p<0.001; n=557) Prostate: 40% with evaluation at 144 vs. 192 days; p<0.001; n=157 No association between time to diagnosis and patient or provider characteristics or site. Of the 23 cancers eventually identified:

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
		■ Positive predictive value (PPV) for each trigger	No significant difference between incidence of cancer or time to diagnostic evaluation for intervention vs. control groups (p=0.66, p=0.04, respectively). However, the median time to cancer diagnosis was shorter for the intervention compared to control group (69 days [IQR 62 to 88] vs. 101 days [IQR 67 to 149], p=0.04. At 7 months, patients followed by intervention group were more likely to receive a diagnostic evaluation (relative risk [RR] 1.41; 95% CI 1.25 to 1.58). Furthermore, of patients with delayed diagnostic evaluation, those followed by intervention group were more likely to have documented follow-up action (73.4% vs. 52.2%). **Trigger PPVs:** Overall **59.6% PPV** for delayed diagnostic evaluation (794 true positives from all 1,256 trigger positive records) PPVs for respective cancers: 60.3% (colorectal), 58.4% (prostate), 39.6% (lung) cancer **Secondary analysis of communication methods (email vs. phone vs. clinic director)** Emails led to follow-up in 11% of cases (41 of 369). Telephone calls led to follow-up in 69% of cases where this escalation occurred (225 of 328) or in 71.0% of cases in which a provider could be reached (225 of 317). Lastly, contacting clinic directors led to follow-up in 5 of the 11 cases where communication escalated to the highest level. Cumulatively, this led to 11%, 72%, and 73% response rates for the various communication attempts. There were between-site differences in follow-up rates after phone calls to physicians but similar follow-up rates across sites in response to emails. **Secondary analysis of communication methods (phone call to physician vs. nurse:** 68% (133 of 223) and 70% of cases (92 of 146), respectively, p not significant.

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
Pathology tests			
Reference: Laxmisan et al. 2012[29] **Study Design:** Retrospective pre/post chart review **Purpose:** To assess the impact of mandatory automated notification system for all outpatient pathology results **Quality Rating:** Fair Retrospective review; random sample taken on monthly basis of pathology reports; low "attrition" rate (23 charts with missing data; excluded); single physician reviewer performed chart review at each site using standardized data collection instrument (objective measure); blinding of assessors NR	**Diagnostic Test:** Pathology tests **Setting:** Two VA hospitals for which local default settings did not require mandatory alert for pathology setting **Number of Patients:** 34,043 reports; 1,637 sampled for review **Inclusion Criteria:** All outpatient pathology results **Study Methods:** EHR data reviewed for normal and abnormal outpatient pathology results reported between September 1, 2008, and February 27, 2009 (pre-intervention) compared with April 1, 2009, and September 1, 2009 (post-intervention)—5 months before and after intervention; follow-up outcomes collected through manual review. Reviewed a sample (about 5%) of randomly selected records on a monthly basis. At each of 2 sites, a trained physician reviewer collected data from EHR using standardized data collection instrument.	**Intervention:** National intervention policy implemented throughout the VA on March 11, 2009: all pathology results (normal or abnormal) transmitted as mandatory alerts **Lack of follow-up** defined as absence of direct response to the test and indirect follow-up actions in situations where follow-up was required. Direct response was defined as: ■ Documentation of ordering subsequent follow-up/test referral ■ Prescribing or changing treatment, or contacting the patient about results ■ Subsequent hospitalization where the report was addressed ■ Appropriate recognition of the report, such as noting patient preferences to follow-up at outside institution ■ Documentation of patient refusal for additional workup **Outcomes:** ■ Proportion of timely follow-up responses (within 30 days) ■ Median time to direct response for abnormal reports ■ Proportion of abnormal reports with lack of follow-up at 6 months ■ Proportion of abnormal reports with documentation of patient notification of test result	Pre-intervention: 16,738 reports Post-intervention: 17,305 reports Randomly sampled reports: 830 (pre-intervention); 807 (post-intervention); 23 with missing data and excluded from analysis Proportion of abnormal reports: 81.6% (666 of 816) pre-intervention 86.2% (688 of 798) post-intervention **Overall, no change in timely follow-up:** 67.1% (447 of 666) vs. 69.3% (477 of 688) post intervention; p=0.4. **Median time to direct response was unchanged:** 8 days (IQR 5 to 18) vs. 8 days (IQR 5 to 15), p=0.65. **Direct responses to abnormal reports were unchanged post-intervention**: p=0.3. However, lack of follow-up for abnormal reports at 6 months decreased post-intervention (10.1% vs. 3.1%; p<0.05). One site accounted for nearly all reports without follow-up (11.8% vs. 4.2%), p<0.05 for nearly all results without follow-up. **Multivariate logistic regression found an effect on timely follow-up:** Compared to post-intervention, pre-intervention tests were less likely to receive timely follow-up: adjusted odds ratio (AOR): 0.72; 95% CI, 0.54 to 0.96. After intervention, site A providers less likely to provide timely-follow-up: AOR 0.36; 95% CI, 0.20 to 0.66 General medicine providers less likely to provider timely follow-up compared to specialty providers (such as hematology, oncology, ophthalmology, urology, pulmonary). Adjusted for location, ordering provider, ordering provider type, and procedure type

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
			Local and contextual factors play an important role in determining whether an intervention such as this can be successful.
Abnormal Pap smears			
Reference: Dupuis et al 2010[30] **Study Design:** Pre/post study (retrospective) **Purpose:** To develop and evaluate an electronic tracking system to improve follow-up of abnormal Papanicolaou (Pap) tests. **Quality Rating:** Fair Retrospective chart review; all Pap smears during time frame were included: objective outcome measure; outcome assessment, data accuracy check NR	**Diagnostic Test:** Abnormal Pap smear **Setting:** 2 clinical practices at an inner-city academic health center, Boston University School of Medicine, Boston, Massachusetts, USA **Number of Patients:** 137 pre-implementation and 69 post-implementation **Age (Years):** for pre- and post-implementation 18 to 21 years (8% and 9%), 22 to 26 years (24% and 32%), 27 to 35 years (32% and 25%), ≥36 years (36% and 35%) **Gender:** NR **Inclusion Criteria**: Adults (≥18 years of age) with abnormal Pap test. Abnormal tests included in this study were atypical squamous cells of undetermined significance with positive high-risk human papillomavirus (HPV) serotype, low-grade squamous intraepithelial lesion; atypical glandular cells of undetermined significance, atypical squamous cells cannot exclude high-grade squamous intraepithelial lesion, high-grade squamous intraepithelial lesion, and carcinoma in situ or invasive cancer. **Study Methods:** Follow-up of abnormal tests from 2 years pre-intervention was compared to 12 months post-intervention (with post-intervention period starting 3 months after implementation). All tests followed for 12 months to determine whether diagnostic evaluation performed. EMR-based pap test tracking system that includes a tracking report of abnormal Pap tests generated for the provider each month and a Pap test	**Intervention:** EMR-based Pap test tracking system consisting of: ■ Tracking report of abnormal Pap tests generated for the provider each month ■ Pap test tracking table (including resolution) embedded in the EMR for each patient ■ Required an interface between pathology reports and EMR and outpatient scheduling system (in part to track missed appointments) An abnormal Pap test was considered adequately followed up after colposcopy and the case ceased to appear on the tracking log. No specific protocol on how they should manage the information was provided. Delayed follow-up was 1 to 2 months after an abnormal Pap smear test result **Outcomes:** ■ Timeliness of diagnostic resolution (biopsy with pathology or clinical evaluation determining that no further evaluation was needed) of an abnormal test ■ Reduction of number of subjects with inadequate follow-up ■ Colposcopy result	206 abnormal Pap tests were identified. Pre- and post-implementation, respectively **Achieved resolution:** 93% and 97%, p=0.20 **Median days to resolution:** 72 and 58, p=0.04 **Mean days (adjusted for baseline data) to resolution:** 108 and 86, p =0.0002 **Adjusted odds ratio (AOR) of ever achieving resolution:** 15.4 (95% CI, 3.7 to 62), p=0.0002, favors post-implementation **AOR of resolving in a shorter period of time:** 1.40 (95% CI, 1.03 to 1.9), p=0.03, favors post-implementation **Colposcopy result** Non-neoplastic 48% and 57%, p not significant Cervical intraepithelial neoplasia (CIN) 1: 38% and 28% CIN 2: 9% and 9% CIN 3: 5% and 5% Invasive cervical cancer: 0 and 1% Other: <1% and 0

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
	tracking table embedded in the EMR for each patient.		
Hyperkalemia (potassium ≥6)			
Reference: Lin et al. 2011[31] **Study Design:** Before and after study (retrospective) **Purpose:** To investigate the impact of an ambulatory EHR on follow-up of markedly elevated serum potassium K(+) **Quality Rating: Fair** Retrospective study; all patients with elevated K(+) during study period included; "standardized review" undertaken of chart; no details regarding outcome assessor provided	**Diagnostic Test:** Serum potassium **Setting:** Outpatient (Mount Sinai Medical Center adult primary care practice, New York, NY, USA) **Number of Study Participants:** 188 pre-EHR/30 post EHR **Inclusion Criteria:** All patients seen at the primary care practice who had at least one non-hemolyzed serum potassium result ≥6.0 mEq/L. ■ Between January 2002 and December 2005 (before the implementation) ■ Between July 2007 and June 2008 (1 year after implementation) **Exclusion Criteria:** For recurrent episodes of hyperkalemia, only the initial episodes were considered for inclusion in the study. **Study Method:** The laboratory system was queried for patients meeting the criteria.3 years before and 1 year after EHR implementation	**Intervention:** An electronic EHR with test results functionality ■ All abnormal lab results for all patients are viewable on a single screen ■ All new abnormal lab results are flagged with a "◊" symbol followed by "New" ■ Final results not yet in the system flagged as "Pend" ■ Results viewed by physician are flagged as "Read" **Primary Outcome:** Follow-up within 4 days; if no documentation in chart that the patient was contacted for follow-up, time to follow-up was defined as when any of the following occurred: ■ Documentation that hyperkalemia followed up at outside institution ■ Subsequent patient visit addressed this result ■ Repeat serum potassium ordered	The ambulatory EHR with a results management system improved documentation and time to follow-up for patients with markedly abnormal K(+) results. **Intervention vs. control:** Follow-up in 4 days of serum potassium ≥6 mEq/L ■ Initial episode 90% vs 62.25% p=0.003 ■ Repeat test 63.3% vs 43.6%, p=0.044 The EHR group had 4.5 times the odds (95% CI, 1.3 to 15.8) of having their episodes of hyperkalemia followed up within 4 days.
HIV laboratory results			
Reference: Bell et al. 2012[32] **Study Design:** Pre/post study (retrospective) **Purpose:** To assess whether bidirectional laboratory interface within existing ambulatory EHR would improve timeliness of antiretroviral therapy changes **Quality Rating:** Fair	**Diagnostic Test:** HIV labs (viral load, CD4 count) **Setting:** Comprehensive AIDS resource education clinic at St. Mary's Medical Center (Long Beach, California, USA), serving entirely HIV-positive patients **Number of Patients:** 1,181 patients **Inclusion Criteria:** Patients with any encounter in year before intervention (December 1, 2007, to November 30, 2008); encounters included face-to-face visits with physician, nurse practitioners,	**Intervention:** Bidirectional lab interface integrated into clinic's data management system: ■ Orders directly transmitted to LabCorp ■ Patients still asked to obtain tests 2-3 weeks before future visits ■ Results automatically returned to EHR Indications for change in regimen:	Physicians continued to use faxed results to screen for abnormalities (no change from intervention) because onerous to view results in EHR. Over 3 years, 46% (547/1191 cohort) had 1,093 sets of lab results potentially warranting change in therapy. 171 of these lab changes (for 144 patients) were followed by change in antiretroviral therapy (ART) regimen within 80 days. **Mean response time 35.9 days** (Adjusted for clustering by individual patient)

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
Retrospective study; all patients meeting eligibility criteria within time period were included; objective outcome measure; unclear if outcome assessors were blinded, but independent information systems personnel de-identified all data for analysis	registered nurse, social worker, dietician or adherence counselor; injection; tuberculosis checks, lab draw, telephone calls resulting in EHR note; medication refills; chart updates; subspecialty referrals. **Exclusion Criteria:** NA **Study Methods:** Patient data was extracted from EHR from 1 year before to 2 years after intervention.	■ Increase in viral load (VL) by half-log (relative) or from below to above 100,000 copies/ml ■ Decreases in CD4 count from above to below 350; or from above to below 200 Patient considered to have regimen response if new ART medication prescribed in 1 to 80 days after lab result	Overall, the intervention modestly reduced response time: 37.7 days pre-intervention to 48.2 days in the quarter after intervention, and decreased to 31.4 days over remaining post-intervention period: **Decrease of 6.3 days, p=0.03**). Proportion of patients completing pre-visit laboratory testing did not significantly increase. No change in patient satisfaction with communication about lab results. Need for better usability.
Laboratory results (Cr, K, INR, PSA, TSH)			
Reference: Schiff et al. 2017[34] **Study Design**: Pre/post (retrospective) Although primary care practices were randomly assigned, only pre/post results reported for outcomes of interest **Purpose**: To improve management of laboratory test results, referrals, and medications **Quality Rating**: Fair Planned prospectively; retrospective chart reviews; a sampling of charts from each site—initially for abnormal laboratory results with goal of reaching 20 charts per abnormal test type (per site); if less than 20 identified, oversampling of "other critical lab results" to reach 100 was performed; outcome assessors supervised; high interrater reliability (K=0.82); objective outcome measure; blinding NR	**Diagnostic Test:** Creatinine (Cr) >1.8, Potassium (K) >5.4; thyroid stimulating hormone (TSH) >10; international normalized ratio >4, and PSA >5; "Additional abnormal laboratory values uncovered during the chart review and meeting specific threshold criteria were also included in data collection." **Setting**: Small to medium adult primary care practices in Massachusetts, USA **Number of Practices**: 16 intervention, 9 control sites **Inclusion Criteria**: Primary care practices with 1 to 10 physicians and included affiliates of larger health care networks and independent providers **Study Methods**: Practices identified through collaborating malpractice insurers; of 176 practices invited to participate, 25 agreed to participate; randomized to 16 intervention and 9 control sites stratified to balance practice size and health systems. Sites received $1,000 reimbursement; interventions sites received additional $3,000. Retrospective review of up to 100 charts at each intervention site pre- and post-intervention.	**Intervention:** Practice Reduction of Outpatient Malpractice: Improving Safety, Efficiency, and Satisfaction (PROMISES) Coalition led by Massachusetts Department of Public Health, Brigham and Women's Center for Patient Safety Research, the state's 2 leading malpractice insurers, the Massachusetts Coalition for the Prevention of Medical Errors, and the Institute of healthcare improvement (IHI). 15 months of QI support including: ■ Exposure to learning network ■ Monthly interactive didactic webinars ■ Quarterly face-to-face learning sessions ■ 1 to 2 onsite quality improvement advisors, visiting site 1 to 2 times monthly to identify improvement opportunities and plan small scale change using the Plan, Do, Study, Act model for improvement ■ Selection of on-site champion **Outcomes**: (1) Abnormality noted by responsible provider; (2) documentation of action or referral plan; (3) documentation	815 charts reviewed at baseline; 762 post-intervention (range 17 to 100 charts per office) Pre-intervention: 1,629 abnormal laboratory tests Post-intervention: 1,530 abnormal tests After the intervention: Reduction in rates of potential patient safety risks from 155 (per 1,000 patients) with abnormal lab value to 54 (per 1,000) (incidence rate ratio 0.35; 95% CI, 0.24 to 0.50). Reduction in rates of serious patient safety risks: from 28 per 1,000 patients with abnormal lab value to 13 per 1,000 (incidence rate ratio, 0.47; 95% CI, 0.22 to 0.98). Potential vs. serious harm determined by general internist: ■ Potential safety risk: No documented evidence clinician aware of result or finding ■ Serious potential safety risk: Potential or actual harm (if not treated, harm would place the patient at risk of death or potential to cause persistent deterioration of life function) Significant improvements in each stage of abnormal test follow-up: ■ Documentation of abnormal results in chart: absolute improvement: 1.4%, p=0.001

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
		of patient notification of abnormality, and (4) evidence of completion of treatment plan for these abnormal results as well as predefined high-risk results or findings (e.g., suspicious skin lesion, abnormal colonoscopy imaging mass, suspicious breast mass, abnormal Pap smear)	■ Patient notification: 5.8%, p<0.001 ■ Documentation of action/treatment plan: 6.1% (p<0.001) ■ Evidence of completed plan: 8.6%. p<0.001 Evidence that action / treatment plan was completed, mean reduction of 19.4 days, p< 0.001.
General laboratory and radiology tests			
Reference: Elder et al. 2010[33] **Study Design:** Mixed methods, observational cohort study **Purpose:** To assess whether management with an EMR or in systems with standardized results/ management processes improved result documentation **Quality Rating:** Fair Sampling method for charts NR; objective outcome measures; outcome assessors NR	**Diagnostic Test:** Laboratory and imaging results **Setting:** 8 primary care offices in southwest Ohio, USA **Number of Participants:** 200 (461 test results from 200 charts) **Inclusion Criteria:** For EMRs, patient seen 2 months before the site visit. For paper charts, the first chart on each medical record shelf was chosen from 2007 through 2009 **Study Method:** 25 charts with recent office visits from each of the 8 office sites were reviewed. Noted were the type of records used (EMR or paper) and how many management steps had standardized results-management processes in place.	**Intervention:** EMR and results-management process Commonly grouped tests (complete blood counts, etc.) were considered a single test. **Outcomes:** ■ Results in appropriate chart location ■ Clinician signature on result ■ Clinician interpretation of results anywhere in chart ■ Presence/method of patient notification ■ For clinically significant abnormal test results, assessment of documented follow-up	461 test results from 200 charts (from 8 offices) were analyzed. 4 offices: written protocols and adhered to office practices for patient notification, clinician signature, and test tracking 274 results were managed by EMR (at 4 offices) **EMR vs. paper charts** Overall, EMR systems performed significantly better for all documentation metrics: ■ Results in appropriate place (100% vs. 98%, p=0.027) ■ Clinician signature present (100 vs. 86%, p<0.001) ■ Clinician interpretation documented (73% vs. 64%, p=0.039) ■ Patient notification documented (80% vs. 66%, p=0.001) 170 abnormal results identified: (82 paper based vs. 88 EMR): For these results, a significantly higher proportion of follow-up steps were documented in EMR compared with paper systems (64% vs. 40%, p=0.001) **Results managed with more vs. fewer standardized processes** ■ Having 2 or more standardized results-management steps did not significantly improve documentation of any step ■ No offices had standardized processes for documenting interpretation of test results or follow-up for abnormal results.

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
			■ Offices with fewer standardized processes more likely to document follow-up (67 of 112 results [60%] results from offices with 0/1 versus 24 [40%] of the 58 results for offices with 3/2, p=.01) ■ There was inter-office variability in the successful documentation of results management steps, but 75% of the top performing offices had EMRs. "An important unresolved issue is whether an EMR…increases test result management quality or just documentation."

Table A-5. Detection of abnormal inpatient results

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
Reference: Cook et al. 2015[35] **Study Design:** Pre/post study (retrospective) **Purpose:** To develop, implement, and evaluate the impact of a computer-based clinical alert system intended to improve atrial fibrillation (AF) stroke prophylaxis and identify reasons providers do not implement a guideline-concordant response. **Quality Rating: Good** Retrospective chart review; all patients meeting eligibility criteria enrolled; however, patient groups differed with respect to comorbidities (congestive heart failure, diabetes), although these co-morbidities are not directly relevant to warfarin prescription; objective outcome measures; 2 trained outcome assessors reviewed data; assessors were not blinded as to study period, but were blinded as to each other's assessments	**Diagnostic Test:** Electrocardiogram (EKG) **Setting:** Tertiary care hospital (Mayo Clinic, Rochester, Minnesota, USA); inpatient EKGs, performed on services other than cardiology **Number of Patients:** 604 patients identified as having potentially newly diagnosed AF in the study period and 226 patients with confirmed newly diagnosed AF in the control period **Inclusion Criteria:** Notification system was applied to hospitalized patients newly diagnosed with AF, not already on anticoagulation, not in a cardiac ward. **Exclusion Criteria:** Hospitalization on a cardiac ward, ambulatory services, or patient already on anticoagulation. **Study Methods:** We conducted a cohort study with historical controls among patients at a tertiary care hospital. We developed a decision rule to identify newly diagnosed atrial fibrillation, automatically notify providers, and direct them to online evidence-based management guidelines. Authors tracked all notifications from December 2009 to February 2010 (notification period) and retrospectively applied the same decision rule to all patients from December 2008 to February 2009 (control period).	**Intervention:** Investigators developed a decision rule to identify newly diagnosed AF, automatically notify providers, and direct them to online evidence-based management guidelines. The system used included MayoExpert (computer based knowledge resource integrated into the EMR), MUSE (GE Healthcare, Seattle, Washington, USA) for EKG interpretation, and Centricity Enterprise (GE Healthcare) and its integrated expert rule, engine, Blaze Advisor (Fair Isaac Corp., Minneapolis, Minnesota, USA) as its EMR infrastructure. Rules for notification (developed with cardiology input): 1. AF present on the final EKG interpretation; 2. AF not listed on the patient's EMR problem list; 3. AF not present on any EKG in the past 5 years; 4. Recent (within the past 2 months) INR <2, or no recent INR available, or current heart rate >100; 5. Not hospitalized on a cardiology or cardiac surgery service. Historic control: retrospectively applied the same decision rule to all patients from December 2008 to February 2009 (control period). **Outcomes:** Accuracy of notification (confirmed through chart review) Prescription of warfarin within 30 days or appropriate medication	Number/Accuracy of notifications (confirmed through chart review) During the notification period, 604 notifications were triggered, of which 268 (44%) were confirmed as newly diagnosed AF. The notifications not confirmed involved patients with no recent EKG at the institution but who had a previous AF diagnosis. Prescription of warfarin within 30 days/or appropriate medication use Number of high-risk (CHADS2 ≥2) patients with newly diagnosed AF eligible for warfarin (no active bleeding and no use of warfarin at hospital admission) who received a warfarin prescription within 30 days: Among 125 high-risk warfarin-eligible patients in the notification group, 34 (27%) received a prescription for warfarin within 30 days of diagnosis, compared with 34/94 (36%) in the control group (OR, 0.66; 95% CI, 0.37 to 1.17); p not significant). Appropriate medication use (prescription of warfarin within 30 days/or aspirin in low risk patients) An appropriate medication was prescribed for 109/244 (45%) warfarin-eligible patients in the notification period, compared with 85/196 (43%) in the control period (OR, 1.05; 95% CI, 0.72 to 1.54); p = not significant). Time delay between warfarin prescription and alert: Among all warfarin-eligible patients (n = 440) the time to warfarin prescription was virtually identical in the notification and control periods, p not significant. Reasons for not prescribing warfarin to warfarin eligible patients: Of the

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
			151 high-risk warfarin-eligible patients with newly diagnosed AF who were not prescribed warfarin (60 in the pre-notification period, and 91 during the notification period), common reasons for not prescribing included surgical intervention planned (22% and 23%, respectively), choice to use aspirin instead (17% and 19%), frequent falls (13% and 7%), and sinus rhythm on subsequent EKG (13% and 7%). In 16 cases total the clinical team documented that the patient was (or should be) receiving warfarin while the EMR medication record did not.

Appendix B. Evidence Tables – Validation Studies

Table B-1. Validation Studies

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
Reference: Murphy et al. 2017[38] **Study Design:** Diagnostic accuracy **Purpose:** To evaluate the performance of electronic trigger algorithms to detect delays in hematuria follow-up. **Quality Rating:** Fair The trigger was based on >50 red blood cells per high-powered field and some institutions used a range, so the study authors ended up including some records in which 50 was in the range reported in the clinical record but the patient wasn't necessarily >50. Chart review was performed in duplicate. Again, there was no formal data presented on all cases (even ones not identified by the trigger).	**Diagnostic Test:** Hematuria **Setting:** Department of Veterans Affairs (VA) national database repository was reviewed. **Number of Patients:** Randomly selected patient records were identified by the trigger as having a delay in follow-up (400 patient records) or not having a delay in follow-up (100 patient records) from a dataset of 310,331 patients (of whom 5,857 had hematuria). Patients were seen between January 2012 and December 2014. **Age (Years):** Of the 400 randomly selected triggered records as having a delay mean age was 68.5 (SD 13.6); NR for 100 trigger negative records **Gender:** Of the 400 randomly selected triggered records as having a delay, 92% were male; NR for 100 trigger-negative records **Inclusion Criteria:** Data from patients from 6 Midwest regional hospitals and affiliated clinics within the VA database. All unique patients with hematuria (>50 red blood cells per high-powered field). **Exclusion Criteria:** Patients with hematuria not requiring follow-up action: previously-diagnosed bladder cancer, terminal illness or palliative care, previously performed cystoscopy, patient with stones or a urologic procedure during the past 3 months known to cause hematuria, active urinary tract infection within 7 days, or patients <35 years old, for whom the likelihood of cancer is low.	**Intervention:** Trigger embedded in the EMR **Outcomes:** ■ Sensitivity ■ Specificity ■ Positive predicative value (PPV) ■ Negative predicative value (NPV)	Of the 5,857, the trigger excluded 4,840 due to a legitimate clinical exclusion reason and another 522 with evidence of completed follow-up (no delay—follow-up occurred within 60 days of hematuria positive test), leaving 495 with delayed follow-up. **PPV** 400/495 with delayed follow-up were manually reviewed. Based upon manual review, 232/400 were found to have a delay in follow-up (true positive, PPV of 58% [95% CI, 53% to 63%] so just over ½ of patients identified by the trigger had a delay. 67/232 (28.9%) patients with delayed follow-up (>60 days) received subsequent follow-up action within 2 years. Of all patients who experienced a delay (>60 days), 14 were diagnosed with bladder or renal cancer within 2 years after the abnormal urinalysis. In 78% of patient records with a delay (>60 days), there was a lack of documentation that the positive hematuria test result trigger was ever reviewed. False positives included patients with noncancer causes of hematuria such as urinary tract infection (UTI), the patient received care from an outside facility but that information was available only in the free-text progress note, or the patient refused further follow-up.

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
	Study Methods: Case-control study based on a retrospective chart review of a subset of patients included in the VA database.		**NPV** Of the 100 trigger-negative records with hematuria, 97 (NPV, 97%; 95% CI, 91% to 99%) were identified by manual review to truly have no delay. **Sensitivity** (using extrapolated results just reported to the full dataset of 5,857 patient records): 64% (95% CI, 59% to 68%) **Specificity** (using extrapolated results just reported to the full dataset of 5,857 patient records): 96% (95% CI, 96% to 97%)
Reference: Murphy et al. 2016[40] **Study Design:** Diagnostic accuracy **Purpose:** To test the application of a trigger to big data as a first step in creating a large-scale surveillance system to identify and enable action on delays in care in patients with abnormal lung imaging results. **Quality Rating:** Good A percentage of charts were blinded, double reviewed, and interrater agreement was high (kappa 0.74). Again, there was no formal data presented on all cases (even ones not identified by the trigger).	**Diagnostic Test:** Cases that a radiologist marked with a numeric code indicating "suspicious for malignancy." Trigger then excluded cases not requiring follow-up, including patients with terminal illness or in whom follow-up had already occurred (within 30 days). Comparator is human review. **Setting:** VA national database repository was reviewed. **Number of Patients:** Cases were flagged by the trigger as having a delay in follow-up (400 cases, trigger-positive) or not having a delay in follow-up (100 cases, trigger-negative) **Inclusion Criteria:** VA's national database of electronic health record (EHR) data with a specific focus on patients seen at a large VA network of 7 hospitals and associated clinics in the midwestern United States. The trigger was applied to 208,633 patients seen at the seven sites between January 1, 2012, and December 31, 2012, and the authors identified 40,218 chest imaging tests performed. A total of 1,847 results were flagged by radiologists with a numerical "suspicious for malignancy" code; 655 (35%) were trigger-positive after clinical and expected follow-up exclusions. Of these, 400 records were	Intervention: Trigger identified cases that a radiologist marked with a numeric code indicating "suspicious for malignancy." Trigger then excluded cases not requiring follow-up, including patients with terminal illness or in whom follow-up had already occurred (within 30 days). Comparator is human review. **Outcomes:** ■ Sensitivity ■ Specificity ■ PPV (percentage of trigger-positive records with an actual delay) ■ NPV (percentage of trigger-negative cases that truly did not have a delay in diagnostic evaluation) **Follow-up outcomes:** Any of the following within 30 days of abnormal imaging: ■ Repeat chest radiograph or chest computed tomography (CT) scan ■ Specificity ■ Position emission tomography (PET) or PET/CT scan ■ Multidisciplinary tumor board conference	**Sensitivity** 99% (95% CI, 96.2% to 99.7%) **Specificity** 38% (95% CI, 32.1% to 44.3%) **PPV** 242/400 (PPV, 61%; 95% CI, 55.5% to 65.3%) records were identified for which follow-up diagnostic evaluation was not performed within 30 days. **NPV** Of the randomly selected 100 trigger-negative records (suspicious imaging results but follow-up detected or not needed), 97 were found to truly not require follow-up (NPV, 97%; 95% CI, 90.8% to 99.2%). **Follow-up outcomes** False-negative cases: 3 Of the 158 false-positive cases, the most common cause was that the suspicious finding was not located within the lungs (51%) Of the 242 with no detected follow-up, 158 (65%) had no documented plan in the chart and 84 had a documented plan for future action. Of the 84 with a plan for the future, 22

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
	randomly selected for manual review. 100 trigger-negative charts were also reviewed. **Exclusion Criteria:** NR **Study Methods:** Case-control study. Trigger was pilot tested with 20 cases and then iteratively with an additional 10 cases after each modification. Once the individual criteria were individually validated, the full trigger was applied to a 1-year set of data in the warehouse. The final trigger algorithm was applied to all patient records in which a chest radiograph or computed tomography (CT) scan was performed during the 1-year study ("the validation cohort"). Clinician reviewers, blinded to the trigger status, manually reviewed a randomly selected sample of 400 trigger positive and 100 trigger-negative records (i.e., patients with abnormal imaging results with no evidence of delays detected by the trigger) and classified whether each record truly experienced a delay. Each reviewer evaluated 240 trigger-positive and 60 trigger-negative records, such that there was a 10% overlap to enable calculation of interrater reliability.	■ Pulmonary visit ■ Cardiothoracic surgery visit ■ Any of the following within 30 days prior to and 30 days after the abnormal imaging result: ▪ Bronchoscopy ▪ Lung biopsy ▪ Lung surgery	did not receive follow-up in 30 days and 62 did. At the 2 year follow-up, 93% of trigger- positive patients with a documented plan on record received follow-up, while only 79% of patients without a documented plan did; p statistically significant Median time to action for those who received follow-up was 107 days and was not dependent on whether a plan was documented; p not significant.
Reference: Meyer et al. 2016[27,28,39,41] Note: multiple publications; most recent publication extracted **Study Design:** Original study was a randomized controlled trial (RCT) comparing intervention (email, phone call, clinic director contact) to usual care (not described in this article). However, this secondary analysis compares the effectiveness of the various communication methods applied in the intervention group.	**Diagnostic Test:** Electronic algorithms identified patients with delays in follow-up (>30 days) from EHRs. Physicians were then contacted about the delayed follow-up via email. If the physician did not follow up (conducting a diagnostic evaluation or documenting why no diagnostic follow-up was performed, for example, because watchful waiting was employed) in 1 week, either the physician or his/her nurse was contacted by phone (up to 3 telephone calls). If no one could be reached by phone, the clinic director was notified. The 3 methods of communication (email vs. phone vs. clinic director) were compared, as was the effectiveness of phone calls to the physician vs. the nurse.	**Intervention:** Main study: Stepped communication vs. usual care Secondary analysis: email vs. phone vs. clinic director and physician phone contact vs. nurse phone contact **Outcomes:** ■ Time to diagnostic evaluation	**Main Study Findings** **Time to diagnostic evaluation** **Intervention vs. usual care** Colorectal cancer: median 104 and 200 days, respectively; p statistically significant Prostate cancer: 40% of patients received evaluation at 144 days versus 192 days, respectively; p statistically significant Lung cancer: median 65 versus 93 days, respectively; p not significant At final review (7 months after the initial red flag finding): received diagnostic evaluation 73% vs. 52%, respectively; p statistically significant

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
Purpose: To assess the effectiveness of different communication strategies for alerting physicians to delays in follow-up for potential cancer-related red flag results. **Quality Rating:** Secondary analysis—Poor, because all 3 strategies were not presented as the initial contact.	**Setting:** A large urban VA facility and a private health system, both located in Houston, Texas, USA **Number of Patients:** Secondary analysis: 72 primary care physicians from 2 sites (a large urban VA facility and a private health system) responsible for 369 patients who received a red flag indicating follow-up was warranted for possible lung, colorectal, or prostate cancer but for whom follow-up was still needed. Main study: Patient population—364 patients requiring follow-up for physicians assigned to the control group and 369 patients requiring follow-up for physicians in the stepped intervention group. **Inclusion Criteria:** Patients were seen between April 2011 and July 2012 and their EHR was red flagged for possible cancer. **Exclusion Criteria:** NR **Study Methods:** Secondary analysis of an RCT that compared usual care to communications presented in escalating steps. This secondary analysis evaluates which communication method was most effective for getting physicians to do a diagnostic follow-up evaluation.		At final review (7 months after the initial red flag finding): cancer diagnosis was confirmed in 10 and 13 patients respectively; p not significant Secondary analysis of communication methods (email vs. phone vs. clinic director) Emails led to follow-up in 11% of cases (41 of 369). Telephone calls led to follow-up in 69% of cases where this escalation occurred (225/328) or in 71.0% of cases in which a provider could be reached (225/317). Lastly, contacting clinic directors led to follow-up in 5 of the 11 cases where communication escalated to the highest level. Cumulatively, this led to 11%, 72%, and 73% response rates for the respective communication attempts. There were between-site differences in follow-up rates after phone calls to physicians, but similar follow-up rates across sites in response to emails. Secondary analysis of communication methods (phone call to physician vs. nurse): 68% (133/223) and 70% of cases (92/146), respectively; p not significant.
Reference: Meyer et al. 2017[37] **Study Design:** Tool validation **Purpose:** To develop and test an EHR-based trigger algorithm to identify instances of delayed follow-up of abnormal thyroid-stimulating hormone (TSH) results in patients being treated for hypothyroidism. **Quality Rating:** Single reviewer; did not review records not triggered	**Diagnostic Test:** EHR-based trigger algorithm to identify instances of delayed follow-up of abnormal TSH results in patients being treated for hypothyroidism **Setting:** EHR-based trigger was applied to patients seen on an outpatient basis at 1 of 2 large VA networks cumulatively encompassing 17 medical centers and associated clinic across 12 states. All patient visits occurred in 2011. **Number of Patients:** 645,555 patients seen in outpatient setting (293,554 patients had at least 1 TSH result) **Age (Years):** NR **Gender:** NR	**Intervention**: EHR-based trigger algorithm to identify instances of delayed follow-up of abnormal TSH results in patients being treated for hypothyroidism vs. human review (gold standard). Gold standard was applied as follows: trigger-positive patient records were reviewed by a physician using a manual data collection instrument. The reviewer evaluated whether a delay was truly experienced by the patient, collected reasons for false-positive results, and determined patient and provider characteristics that potentially affected delays. **Outcomes**:	Of the patients with a TSH result, 5,230 patients (1.8%) had a TSH result higher than 10 mIU/L. The trigger algorithm excluded 3,980 patients based on new hypothyroidism diagnoses (elevated TSH results in patients with no prior hypothyroidism diagnosis), recent hospitalizations (due to artificially abnormal TSH results in acute illness), age, or hyperthyroidism diagnoses, leaving 1,250 patients for whom follow-up action was needed. Of these, the trigger identified expected follow-up action in 979 records and flagged 271 records as having potential follow-up delays (21.7% of all TRT-treated patients with known

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
	Inclusion Criteria: Patients with an existing hypothyroidism diagnosis who were currently receiving therapy **Exclusion Criteria:** Patients with newly elevated TSH **Study Methods:** Pilot-tested the tool on 50 patients identified by the trigger as having an abnormal test results and delayed follow-up who were seen at 1 study site in 2009 then did full validation study with larger sample as described above. Pilot test led to refinement of the tool, which now allowed 60 days for repeat TSH testing as opposed to the initial 30 days. Validation of a tool with human (single) review as the gold standard. The trigger was designed first to identify adult patients with elevated TSH values (>10 mIU/L) who were receiving thyroid replacement therapy (TRT) before the date of the TSH result. When multiple elevated TSH values occurred in a patient, the authors used the earliest elevated TSH in the study period. The trigger then excluded instances where TRT would not be appropriate or expected, including (1) a diagnosis of hyperthyroidism on the problem list, (2) where evidence of hospitalization, emergency room, or urgent care visit was detected within 24 hours before the elevated TSH (because acute illnesses can skew thyroid testing), and (3) patient nonadherence to therapy within 30 days after the elevated TSH. Finally, the trigger excluded records containing evidence of expected follow-up, which included orders for new prescriptions for TRT within 30 days or repeat TSH testing performed within 60 days after the elevated TSH result.	■ True-positive cases (patient records in which the reviewing physician could not identify any of the following types of follow-up action: TRT adjustment within 30 days, repeat TSH testing within 60 days, or a plan to delay action). ■ False-positive cases (patient records where, although the trigger identified no follow-up action, the reviewing physician identified a follow-up action, a documented plan to delay follow-up, or some other reason why follow-up should not have been expected [e.g., patient saw an external provider]). ■ PPV (the number of true-positive cases confirmed by physician chart review divided by the total number of records identified by the EHR trigger).	hypothyroidism). No nonadherence codes were identified by the trigger. **True Positive Cases/PPV** The physician reviewer confirmed delayed follow-up in 163 of the 271 triggered patients with elevated TSH, yielding a PPV of 60.1% (95% CI, 54.0% to 66.0%), meaning that 13.0% of all TRT-treated patients in this population with known hypothyroidism had confirmed delayed follow-up. In most instances (126/163, 77.3%), records lacked any clinician documentation regarding the abnormal TSH result. This relatively high PPV translates to an average of 1.7 records needing to be reviewed after trigger application to benefit 1 patient. **False Positive Cases** The most common reasons for false-positive findings (n=108) were free-text documentation (which is not interpretable by the computer algorithm) in the progress note that patients failed to take medications as instructed (n=58; 53.7%), that appropriate follow-up in the form of an increase in medication dose occurred (n=21; 19.4%), or that deliberate plans were made to follow up within a time period longer than 60 days (n=7; 6.5%).
Reference: Lakhani et al. 2011[36] **Study Design:** Diagnostic accuracy	**Diagnostic Test:** Text-mining algorithm was compared to gold standard, which was human review	**Intervention:** Text-mining algorithm **Outcomes:** ■ Precision, which was the percentage of radiology reports selected by the	**Precision, recall, and the F statistic, respectively** Acute appendicitis: 99.0%

Study Details	Patients/Interventions	Intervention/Treatment	Outcomes/Results
Purpose: To develop and validate text-mining algorithms to automatically identify radiology reports containing critical results, including tension or increasing/new large pneumothorax, acute pulmonary embolism, acute cholecystitis, acute appendicitis, ectopic pregnancy, scrotal torsion, unexplained free intraperitoneal air, new or increasing intracranial hemorrhage, and malpositioned tubes and lines. **Quality Rating:** Fair No test of reliability performed	**Setting:** University of Pennsylvania, (Philadelphia, USA) and regional affiliates; inpatient/outpatient NR **Number of Patients:** For final algorithms, 100 and 500 to 2,000 new random reports were analyzed for each algorithm to determine precision, recall, and the F statistic. **Age (Years):** NR **Gender:** NR **Inclusion Criteria:** A subset of new radiology reports from 1988 to 2011 **Exclusion Criteria:** Reports used in the process of refining the final algorithms **Study Methods:** Once the algorithm for each clinical condition could not be refined anymore (no significant improvement between iterations), algorithm accuracy was determined using precision, recall, and F-measure by analyzing 100 and 500 to 2,000 new random reports for each algorithm, respectively.	algorithm that actually contained the critical result ■ Recall, which represented the percentage of radiology reports selected by the algorithm of all possible reports in the database positive for that critical value. This number was estimated by selecting only reports from relevant modalities and exam types for the critical value in question. As an example, for new or worsening intracerebral hemorrhage, only head CT or brain magnetic resonance imaging (MRI) examinations were selected. Of these studies, a subset of reports excluded by the query algorithm was selected, and the frequency of critical findings in this subset was determined. ■ F statistic (or overall accuracy), which was a harmonic-weighted mean of precision and recall, using equal weighting between the 2 values.	(95% CI, 97.1% to 100.0%), 89.0% (CI, 83.0% to 95.8%), and 94% Acute cholecystitis: 96.0% (CI, 92.2% to 100.0%), 88.6% (CI, 82.5% to 95.7%), and 92.3% Ectopic pregnancy, 98.0% (CI, 94.1% to 100.0%), 94.8% (CI, 86.1% to 100.0%), and 96.4% Unexpected free intraperitoneal air: 87.0% (CI, 80.4% to 93.6%), 93.7% (CI, 80.3% to 100.0%), and 90.4% New or increasing intracranial hemorrhage, 94.0% (CI, 87.3% to 97.5%), 68.0% (CI, 59.7% to 79.0%), and 81.0% Large or tension or new/increasing large pneumothorax: 96.0% (CI, 92.2% to 99.8%), 84.2% (CI, 75.3% to 95.4%), and 90.1% Acute pulmonary embolism: 99.0% (CI, 97.1% to 100.0%), 97.8% (CI, 81.4% to 100.0%), and 98.9% Acute scrotal torsion: 96.0% (CI, 88.3% to 100.0%), 100.0% (CI, 96.8 to 100.0%), and 98.0% Malpositioned nasogastric, feeding, and endotracheal tubes: 98.0% (CI, 95.3% to 100.0%), 100% (CI:,92.2% to 100.0%), and 99.0%

Appendix C. Study Quality Assessment

Table C-1. Risk-of-bias assessment and Quality Ratings for Randomized Controlled Trials

Study Author	Randomization Described	Concealed Randomization	High Attrition	Validated or Objective Outcome?	Blinded Outcome Assessors?	Intervention clearly defined?	More than 100 patients?	Rating	Comment
El-Kareh et al. 2012[14]	Yes	NR	No	Yes	Yes	Yes	Yes	Good	—
Dalal et al. 2014[13]	Method NR; however, method changed midway through trial	NR	Yes	No	NR	Yes	Yes	Fair	23.5% of patients excluded, not randomized because study personnel unavailable; method of randomization changed midway through trial; further partial sampling performed mid-trial; primary outcome was self-reported physician awareness of tests (both indirect and subjective)
Filice 2017[17]	NR	NR	No	No	NR	Yes	Yes	Poor	Outcome depended on radiologist recall
Humphrey et al. 2011[25]	Yes	NR	Yes	Yes	NR	Yes	Yes	Fair	—
Murphy et al. 2015[27]	Yes	NR	No	Yes	Yes	Yes	Yes	Good	—

Table C-2. Risk-of-Bias Assessment and Study Quality for Pre/Post Studies

Study	For important factors, were characteristics of patients who entered the study the same as for those who completed the study to time point of interest?	All suitable patients (i.e., consecutive patients or randomized sample enrolled) within time period?	Study prospectively planned?	Independent (>1), blinded outcome assessors, or efforts to verify accuracy of data abstraction?	Objective outcome of interest? (primary outcome)	85% or more of patients completed the study?	Overall rating	Comment
Bell et al. 2012[32]	NR	Yes	No	NR	Yes	N/A	Good	—
Browning et al. 2013[21]	NR	Yes	No	NR	Yes, but different for pre/post	N/A	Fair	Outcome differed for pre-intervention compared to post-intervention
Cadwallader et al. 2012[9]	NR	Yes	Yes	Yes	Yes	N/A	Good	—
Cook et al. 2015[35]	Yes (see comment)	Yes	No	Yes	Yes	N/A	Good	Before and after groups differed with respect to congestive heart failure and diabetes; however, this was not believed to be directly relevant to the primary outcome.
Dibble et al. 2017[22]	NR	Yes	No	NR	Yes	N/A	Good	—
Dupuis et al. 2010[30]	NR	Yes	No	NR	Yes	N/A	Good	—
Gilliam et al. 2017[10]	NR	Yes (random sample)	Yes	NR	Yes	N/A	Fair	Although small number of patients was studied (total=90), random samples were taken at various points.
Kantor et al. 2014[11]	NR	Yes	Yes	NR	Yes	N/A	Fair	—
Lacson et al. 2014, 2015[18,19]	NR	Yes (random sample)	Yes	Yes	Yes		Good	—
Larson et al. 2009[26]	NR	Yes	No	NR	Yes	N/A	Good	—
Laxmisan et al. 2012[29]	NR	Yes (random sample)	No	NR	Yes	N/A	Good	—

Study	For important factors, were characteristics of patients who entered the study the same as for those who completed the study to time point of interest?	All suitable patients (i.e., consecutive patients or randomized sample enrolled) within time period?	Study prospectively planned?	Independent (>1), blinded outcome assessors, or efforts to verify accuracy of data abstraction?	Objective outcome of interest? (primary outcome)	85% or more of patients completed the study?	Overall rating	Comment
Lin et al. 2011[31]	NR	Yes	No	NR	Yes	N/A	Good	—
O'Connor et al. 2012[20]	NR	Yes (random sample)	No	Yes	Yes	N/A	Good	—
Pham-Thomas et al. 2014[16]	NR	Yes	No	NR	Yes	N/A	Fair	—
Saha et al. 2017[15]	NR	Yes	Yes	NR	Yes	N/A	Fair	—
Schiff et al. 2017[34]	N/A	Unclear	Yes	Yes	Yes	N/A	Fair	Sampling strategy was unclear: an "enriched sample" of patients with 1 of the specified abnormal laboratory tests was identified for each site; if there were <20 abnormal results for each test type (per site), "oversampling" or other lab abnormalities was performed.
Singh et al. 2009[23]	NR	Yes (random sample)	No	Yes	Yes	N/A	Good	—
Singh et al. 2009[24]	NR	Yes	No	NR	Yes	N/A	Good	—
Watkins et al. 2014[12]	NR	Yes	No	NR	Yes	N/A	Fair	—

Note: For pre/post studies, studies were considered Good quality if they (1) enrolled a representative sample (either consecutive patients or a randomized sample); (2) used an objective outcome measure; and (3) either blinded outcome assessors or took measures to verify the accuracy of data (i.e., independent review of 10% of data).

Appendix D. Search Strategy

We conducted a systematic literature search of PubMed, MEDLINE, EMBASE, CINAHL, and Scopus, using a search strategy developed by a medical librarian. The search strategy identified studies published from January 2009 to May 2017 and used a combination of medical subject headings and keywords. Several broad concepts were initially addressed: electronic medical records, diagnostics tests, communication, and the outpatient setting. Follow-up searches were conducted to include discontinued medications and allergic reactions in electronic medical records. Specific search strategies available upon request.

Sources searched:

- **Databases (5):** Pubmed; Embase; Medline; Cinahl, Scopus
- **Websites (4):** AHIMA; AHRQ; AMIA; HIMSS

Ovid Medline Strategy

Set Number	Concept	Search Statement
1	Electronic medical records	exp "Medical Records Systems, Computerized"/ OR exp "Management Information Systems"/ OR exp "Decision Support Systems, Clinical"/ OR ("EHR" OR "EMR" OR "EHRs" OR "EMRs" OR ((computerized OR computer OR electronic$) adj5 record$) OR "electronic notes" OR "electronic note" OR "electronic system" OR "electronic medical" OR "electronic test management"
2	Diagnostic tests	"Diagnostic Techniques and Procedures"/ OR exp "Diagnostic Tests, Routine"/ OR exp "Clinical Laboratory Techniques"/ OR "Diagnostic Imaging"/ OR exp "Diagnostic Techniques, Cardiovascular"/ OR exp "Diagnostic Techniques, Digestive System"/ OR exp "Diagnostic Techniques, Endocrine"/ OR exp "Diagnostic Techniques, Neurological"/ OR exp "Diagnostic Techniques, Obstetrical and Gynecological"/ OR exp "Diagnostic Techniques, Radioisotope"/ OR exp "Diagnostic Techniques, Respiratory System"/ OR exp "Diagnostic Techniques, Surgical"/ OR exp "Diagnostic Techniques, Urological"/ OR exp "Electrodiagnosis"/ OR exp "Pathology, Molecular"/ OR exp "Specimen Handling"/ OR "diagnostic imaging".fs. OR "diagnosis".fs.
3	Communication	exp "Communication"/ OR "Health Information Exchange"/ OR "Medical Record Linkage"/ OR exp "Reminder Systems"/ OR exp "Continuity of Patient Care"/ OR exp "Follow-Up Studies"/ OR exp "Delayed Diagnosis"/ OR ("test tracking" OR "test management" OR "test result" OR "test results" OR "missed result" OR "missed test" OR "missed diagnosis" OR "delayed result" OR "delayed results" OR "delayed diagnosis" OR "follow-up" OR "specimen tracking" OR "specimen routing")
4	Outpatient setting	exp "Ambulatory Care"/ OR exp "Ambulatory Care Facilities"/ OR exp "General Practice"/ OR "Primary Health Care"/ OR "Physicians, Primary Care"/ OR "Physicians, Family"/ OR "General Practitioners"/ OR "Outpatients"/ OR (outpatient$ OR out-patient$ OR ((primary OR tertiary OR ambulatory) ADJ2 care) OR ((community OR health OR satellite OR affiliated) ADJ2 clinic$) OR ((group OR family OR general OR private) ADJ2 practice) OR "community health" OR "neighborhood health")
5	Combine sets	#1 AND #2 AND #3 AND #4
6	Apply limits	#5 with Filters: Publication date from 2009/01/01; English

Ovid Medline Strategy

Set Number	Concept	Search Statement
1	Electronic medical records	exp "Medical Records Systems, Computerized"/ OR exp "Management Information Systems"/ OR exp "Decision Support Systems, Clinical"/ OR ("EHR" OR "EMR" OR "EHRs" OR "EMRs" OR ((computerized OR computer OR electronic$) adj5 record$) OR "electronic notes" OR "electronic note" OR "electronic system" OR "electronic medical" OR "electronic patient" OR patient portal$
2	Medication	exp "Prescriptions"/ OR exp "Medication Systems"/ OR (medication$ OR prescription$).ti,ab.
3	Discontinued	(stop$ OR cancel$ OR discontin$ OR "no longer taken" OR "stop therapy order").ti,ab.
4	Allergic reaction	exp Hypersensitivity/ OR (allerg$ OR hypersensitiv$).ti,ab.
5	Combine sets	#1 AND #2 AND (#3 OR #4)
6	Apply limits	#5 with Filters: Publication date from 2009/01/01; English

Website Search Strategy

	Search Statement
1	"test tracking" OR "test management" OR "results management" OR "test result" OR "test results" OR "missed result" OR "missed test" OR "missed diagnosis" OR "missing results" OR "missing test" OR "delayed result" OR "delayed results" OR "delayed diagnosis" OR "follow-up" OR "specimen tracking" OR "imaging results" OR "laboratory results"
2	("delayed" OR missed OR missing OR "abnormal" OR "incidental") AND ("notification" OR "results" OR "testing" OR "tests" OR "reminders" OR "alerts")