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SPECIAL REPORT

Patient Identification Errors

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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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ECRI Institute Undertakes Several Initiatives to Promote Accurate Patient Identification

ECRI Institute Patient Safety Organization's *Deep Dive: Patient Identification* (Volume 1) summarizes an analysis of more than 7,600 wrong-patient events occurring between January 2013 and August 2015 and reported to the PSO event report database. Based on the findings, recommendations and mitigating strategies are provided. The report is available for members at https://www.ecri.org/components/PSOcore/Pages/DeepDive0816_Patient ID.aspx.

ECRI Institute's Health Technology Assessment Information Service's report *Patient Identification: Literature Review* (Volume 2) is an evidence-based review of the clinical literature that addresses key questions about the prevalence and causes of patient identification errors and identifies effective interventions for decreasing wrong-patient mistakes. The report is available for members at https://www.ecri.org/components/SpecialReports/Pages/80816.aspx.

The ***Partnership for Health IT Patient Safety***, a private sector initiative, has assembled a multi-stakeholder workgroup to clarify the role of health information technology (IT) in either mediating or preventing patient identification errors by reviewing the evidence, sharing solutions, identifying challenges and barriers, considering product features and functionality, and creating recommendations for safe practices. Its findings are published in its report *Health IT Safe Practices: Toolkit for the Safe Use of Health IT for Patient Identification*. The *Partnership's* recommendations and Toolkit will be publicly available at https://www.ecri.org/resource-center/Pages/HITPartnership.aspx.

ECRI Institute encourages its members to review these reports. More information is available at http://www.ecri.org/patientid.

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Executive Summary

Patient identification (ID) errors can disrupt care and harm patients in virtually every facet of clinical medicine, including diagnostic testing, medication administration, and even billing. Recognizing the magnitude of this problem, The Joint Commission has named improving the accuracy of patient ID as the most important National Patient Safety Goal since 2014.[1] In 2013, ECRI Institute convened the Partnership for Health IT Patient Safety. In support of ongoing work performed by the Partnership's Patient Identification Workgroup, we performed a literature review to provide an up-to-date understanding of problems and interventions that have been assessed in the literature. Specifically, we addressed the following key questions:

1. What is the prevalence of patient ID errors in clinical care?
2. What are causes of patient ID errors in clinical care?
3. What interventions are effective for decreasing patient ID errors in clinical care?

Methods

A medical librarian performed searches of PubMed, MEDLINE, EMBASE, CINAHL, and the Patient Safety Network to identify relevant studies published from January 2009 to January 2016. We used both medical-subject headings and keywords to address four broad concepts: patient ID, wrong-patient incidents, identity fraud, and biometrics. For Key Question 1 (prevalence), we included studies reporting prevalence of any patient ID error, regardless of study design. If a study described prevalence as part of assessing an intervention, we included these studies under Key Question 3 (effectiveness of interventions). For Key Question 2 (causes), we included studies describing possible factors contributing to ID errors or "near misses," including failure to adhere to patient ID protocols. For Key Question 3, we included only studies that compared the effect of one intervention to another, or to no intervention, or before and after implementation of an intervention. For Key Question 3, we also excluded studies that did not report on actual patient ID errors (e.g., studies reporting adherence to established protocols were excluded). For the identified, relevant systematic reviews, we also included pertinent studies published subsequent to the end search date. Given the broad conceptual and clinical scope of this topic, we limited our description of the literature to Key Questions 2 and 3, which identify factors contributing to errors and comparative studies of interventions to reduce misidentification.

Overall, we identified 106 studies for inclusion: 39 studies described prevalence, 44 described problems contributing to patient ID errors, and 40 assessed interventions.

Results and Discussion

With regard to contributory problems and interventions, five overarching themes emerged:

- Improving design of physical, electronic, and assigned patient identifiers can decrease misidentification
- Providing identification alerts during order entry can decrease wrong-patient orders
- Using new technology and safety checks at automated-systems level can reduce errors and improve monitoring
- Improving registration measures can help protect against identity theft
- Gaining local cultural acceptance of processes is needed to provide feedback, monitor processes, and avoid workarounds

Improving Design of Physical, Electronic, and Assigned Patient Identifiers Can Decrease Misidentification

Confirming patient identity during clinical care fundamentally depends on the accuracy and usability of physical (e.g., wristbands, specimen labels), electronic (e.g., within the electronic health record [EHR], radiology software) and assigned identifiers (e.g., for neonates). Wristbands are particularly critical for ID confirmation in very young or incapacitated patients (e.g., sedated, operating room). However, several studies identified problematic or inadequate aspects of identifier design, including illegibility (small font, or handwritten bands), ink that degraded with exposure to water, bands too narrow to accommodate the printed ID sticker, and lack of a clear covering to protect information from degradation. Notably, one Canadian study found that during surgery, wristbands were often inaccessible or removed, posing risks for this vulnerable population both intra- and postoperatively.[2] Similarly,

specimen labels were often unclear due to small font size along with inadequate demarcation between labels printed for different patients. Notably, the majority of identified design flaws could be addressed with relative ease, and in fact, studies often reported that redesigned wristbands were well received by staff and that increased usability may have contributed to increased adherence to ID protocols.

Interventions for altering electronic or assigned identifiers were similarly somewhat straightforward. We identified studies that reported decreased ID errors after display of patient photographs along with other identifiers in the EHR[3] and radiology films.[4] A new naming convention for neonates designed to be more distinctive also decreased wrong-patient orders.[5] The relative simplicity of these varied interventions (e.g., larger wristband size, using different ink, adding a photograph) suggests that important strides towards reducing identification errors may be achieved with fairly basic, low-technology measures so long as they reflect smart, thoughtful design. If ID protocols are not being followed, institutions should consider seeking feedback from staff, and minor alterations in design may prove helpful.

Providing Identification Alerts during Order Entry Can Decrease Wrong-patient Orders

Identification alerts during order entry can decrease wrong-patient orders. Two studies identified (1) provider distraction and fatigue[6] and (2) having two or more charts simultaneously open[7] as problems that contribute to wrong-patient orders. However, we identified four studies, including one well-designed prospective, randomized controlled trial suggesting that ID verification alerts can significantly reduce wrong-patient orders.

Although such alerts can decrease errors, healthcare staff may perceive addition of another alert as cumbersome. Studies suggest providers already override between 49% and 96% of alerts that arise during order entry.[3] Creating another alert may simply add to "alarm fatigue" in which users are inundated with system notifications and routinely tune them out. Furthermore, given the time constraints many staff work under, adding a new alert that users must address inevitably has an opportunity cost. Although one study reported this additional alert required only an additional 6.6 seconds per ordering session, in the aggregate, authors noted this would represent roughly 3,300 hours annually at one institution alone.[8] Future studies should assess whether reductions in wrong-patient orders are significant enough to warrant this addition, perhaps by assessing what proportion of wrong orders are not detected by other safety mechanisms (i.e., pharmacy review) and reach the patient. Such studies could also explore whether such alerts could be targeted for particular "high risk" populations or providers.

Using New Technology and Automated Systems-level Safety Checks Can Reduce Errors and Improve Monitoring

New technology and automated-systems level safety checks can reduce errors and improve monitoring. Bar-coding systems and radiofrequency identification (RFID) tags can decrease misidentification and allow real-time monitoring and user feedback. Several studies, including a well-designed observational controlled study by Poon et al.,[9] concluded that bar-coding technology can significantly reduce wrong-patient medication administration errors. We also found reports of RFID systems successfully used to track units of blood[10] and pathology samples.[11] Several validation studies also assessed automated algorithms that detect ID errors by comparing new-patient data with prior radiologic or hematologic data. For instance, Lamb et al.,[12] developed an algorithm that compared landmarks from x-rays routinely taken immediately before administering radiation therapy to the patient's prior computed tomography scans acquired during the planning process. Within transfusion medicine, policies requiring a confirmatory second sample for blood typing and use of a centralized database function similarly, confirming patient ID by comparison with prior data.

If more widely implemented, these interventions could function as automated-systems level safety checks that are far less reliant on human adherence to protocols. Many of these new technologies (bar coding, RFID) and algorithms also inherently allow for real-time data collection and objective error measurement, all crucial for ongoing improvement. Such algorithms are promising for automating the process of identity confirmation and mitigating the risks of human error.

Improving Registration Measures Can Help Protect Against Identity Theft

Improved institutional registration processes are needed to address identity theft. A recent report suggested that medical identity theft in the United States is rising, with 2.32 million adult victims in 2014, a 21.7% increase over

the prior year.[13] Detection is challenging because victims may not report a theft or may willingly allow another person to use their credentials;[13] institutions may not report discrepancies because of concerns about losing reimbursement.[14] A report from the Ponemon Institute found that 60% of thefts were unreported by victims because of beliefs that law enforcement would not be helpful (55%) and reluctance to report on someone they knew (47%).[13] To address identity theft, institutions should consider requiring photo identification at registration, educating registration staff to identity suspicious documents, and standardizing a reporting process for when such suspicious documents are encountered.[14] Also, institutions should help to protect important patient identifiers such as Social Security numbers by ensuring, for instance, that they are not routinely printed with all patient records.[15] Although biometric identifiers represent an important potential solution, uptake of these technologies has been slow, perhaps because of concerns about patient acceptance and implementation costs.

Gaining Local Cultural Acceptance of Processes is Needed to Provide Feedback, Monitor Processes, and Avoid Workarounds

Local cultural acceptance of processes is needed to provide feedback, monitor processes, and avoid workarounds. Although various technologies can reduce ID errors and newer technologies are emerging, thorough and lasting changes to practice will also require the support of local healthcare staff. We note that workarounds continued to pose a problem for many interventions, including technologies such as bar-coding systems. One study found that 20% of medications continued to be given without scanning bar code, despite an institutional policy requiring medications be scanned and linked to an electronic medication record.[9] Another study of a safety checklist for patients undergoing surgery found that staff routinely certified completion of the final steps of the protocol before the patient had even entered the building.[16] In some contexts, such as the neonatal intensive care unit (NICU), the unit's local culture also contributed to the widespread practice of placing wristbands on adjoining equipment instead of patients themselves. These examples from varied settings underscore the importance of involving local staff in acknowledging problems and engaging in proposed interventions. In fact, buy-in and participation by healthcare staff may itself lead to better interventions. Sustainable long-term improvements are likely to require ongoing engagement and feedback from staff, to improve intervention designs and promote a better local culture of patient safety.

Conclusions

Proper patient ID confirmation at every step of clinical care is vital to patient safety. However, despite the priority placed on addressing this issue by The Joint Commission and others, significant problems persist. Studies have assessed a variety of interventions, aimed at reducing patient ID errors across wide range of clinical contexts. Although the evidence base has significant gaps, we conclude that patient ID errors can be avoided through improving usability of physical, electronic, and assigned patient identifiers; use of well-designed ID alerts during order entry; and technologies and automated algorithms that function as systems-level safety checks. Given the increasing problem of identity theft, improvements in institutional registration processes are needed. However, while each of these measures can provide significant reductions, sustained improvements will likely require a combination of good design, smart technology, local cultural acceptance by staff, and measurement of outcomes to determine what combination of approaches work best and in which clinical scenarios.

Introduction

Patient identification (ID) errors can disrupt care and harm patients in virtually every facet of clinical medicine, from diagnostic testing to medication administration and even billing. Recognizing the magnitude of this problem, The Joint Commission has named improving the accuracy of patient ID as the most important National Patient Safety Goal since 2014.[1] In recent years, awareness of the increased prevalence of identity theft and its potential clinical and financial ramifications has exposed additional challenges to confirming patient identity.

Steady implementation of computerized order entry (CPOE) systems, electronic health records (EHRs), and bar coding systems has allowed for increased detection and tracking of near misses and actual patient ID errors; it has also highlighted the role health information technology (IT) can play in preventing, but also contributing to ID errors. Such assessments have underscored the complexity of the problem because errors can be introduced by myriad factors at any step of medical care. For instance, mistakes leading to serious medication errors arise during each step of clinical workflow with one-third occurring during order entry, one-third during transcription/dispensing, and one-third during administration.[9] Studies suggest providers override between 49% and 96% of alerts that arise during order entry.[3] Given the demanding pace of work many healthcare staff face, designing effective interventions will require attention to impact on workflow.

In 2013, ECRI Institute convened the Partnership for Health IT Patient Safety and its component, single-topic focused workgroups. The Patient ID workgroup is a multistakeholder workgroup of 45 providers, researchers, information technology experts, healthcare and patient safety organizations, vendors, and a patient safety advocate. In November 2015, the workgroup began to consider how best to address patient ID errors, beginning with a review of all reported ID events. In conjunction with the workgroup initiative, we performed a literature review, to provide an up-to-date understanding of problems and interventions that have been assessed in the literature. Specifically, we addressed the following key questions:

Key Questions

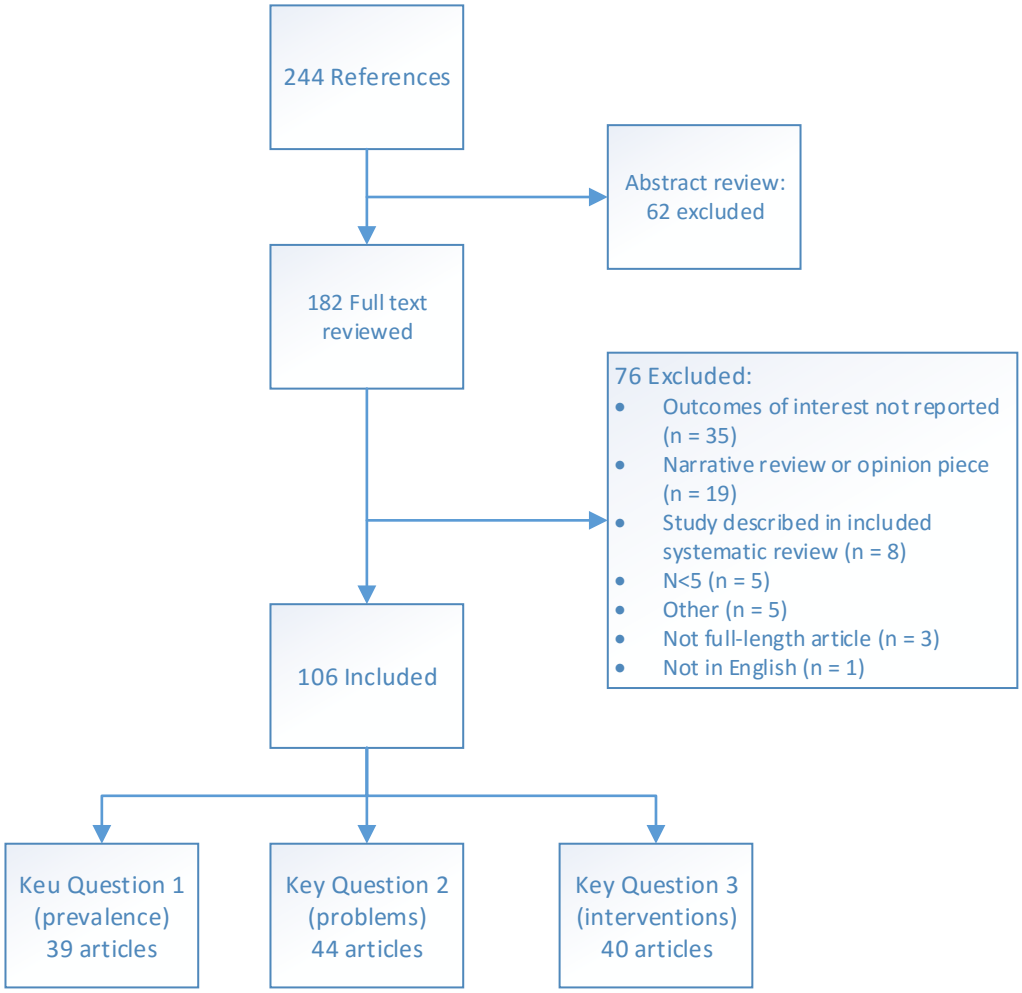
1. What is the prevalence of patient ID errors in clinical care?
2. What are causes of patient ID errors in clinical care?
3. What interventions are effective for decreasing patient ID errors in clinical care?

Methods

An ECRI Institute master's level medical librarian conducted searches of PubMed, MEDLINE, EMBASE, CINAHL, and the Patient Safety Network (PS Net) to identify studies published from January 2009 to January 2016. We used both medical-subject headings and keywords to address four broad concepts: patient ID, wrong-patient incidents, identity fraud, and biometrics. The search strategies we used are available upon request.

Two clinician analysts screened all article abstracts independently. Figure 1 shows the number of studies screened, included, and excluded. We included only published English language studies meeting the following inclusion criteria. For Key Question 1 (prevalence), we included studies reporting prevalence of any patient ID error, regardless of study design. If a study described prevalence as part of assessing an intervention, we included these studies under Key Question 3 (effectiveness of interventions). For Key Question 2 (causes), we included studies describing possible factors contributing to ID errors or "near misses," including failure to adhere to patient ID protocols. For Key Question 3, we included only studies that compared the effect of one intervention to another, or to no intervention, or before and after implementation of an intervention. For Key Question 3, we also excluded studies that did not report on actual patient ID errors (e.g., studies reporting adherence to established protocols were excluded). For the identified, relevant systematic reviews, we also included pertinent studies published subsequent to the end search date. Given the broad conceptual and clinical scope of this topic, we limited our description of the literature to Key Questions 2 and 3, which identify factors contributing to errors and comparative studies of interventions to reduce misidentification. Finally, although we did not formally assess strength of evidence, for Key Question 3, we offer discuss strengths and weaknesses of this evidence base.

Figure 1. Search Results, Study Identification, and Included and Excluded Articles



Results

Overall, we included 106 studies: 39 studies described prevalence, 44 described problems contributing to patient ID errors, and 40 assessed interventions (some studies were included for more than one key question).

Prevalence

We identified 39 studies describing prevalence. These studies reported prevalence in four ways: (1) population prevalence, (2) as a proportion of reported errors, (3) as a proportion of cases in which concerns were raised about patient ID errors, and (4) as respondent surveys regarding event frequency. For some clinical settings, such as transfusion medicine and order entry, prevalence was studied using direct observation, while for other contexts, such as wrong-patient surgeries, prevalence was evaluated only using surveys and voluntary incident-reporting data. The wide range of study designs and clinical settings precludes providing an overall estimate of prevalence for patient identification errors. However, a summary table of prevalence for various clinical contexts is provided in Table 1. More detailed information about each included study can be found in Appendix A, Evidence Table 1.

Table 1. Frequency of Patient Identification Errors, by Clinical Context

Clinical Context, Prevalence	References
Registration	
At Massachusetts General Hospital, 120 duplicate patient charts were created per month and 14 patients received care under a wrong medical record number (MRN).	Judson et al.[14]
In a multisite, single-laboratory study in Spain, chart review of 161,097 laboratory registrations over 1 year found patient identification (ID) error rates of 0.04% (electronic registration) and 0.075% (manual registration).	Salinas et al.[17]
Wristband Accuracy and Use	
At a single institution in Brazil, audit of 385 patient wristbands found 8.67% contained incomplete, wrong, and or misspelled names. Wristband MRN did not match the patient's electronic health record (EHR) MRN for 4.33% of patients.	Hoffmeister and de Moura[18]
In the U.S. Veterans Health Administration (VA) setting, of 182 confirmed laboratory medicine errors due to patient misidentification, 4.4% (8) were due to a patient receiving another patient's wristband.	Dunn and Moga[19]
Order Entry and Charting	
At a single U.S. institution's emergency department, 97% of clinicians (66 of 68) reported charting or entering orders on the wrong patient within the prior 3 months.	Yamamoto[20]
At the University of Pittsburgh Medical Center, of more than 1 million inpatient orders placed over 5 years, 0.064% were likely placed on a misidentified patient.	Levin et al.[6]
In a U.S. multisite study, review of 11,760 anesthesia records found 57 instances of wrong patient charts being opened during procedures requiring anesthesia.	Rebello et al.[21]
At the University of Illinois, alerts firing during order entry for selected drugs over 6 years identified 32 wrong-patient orders, which were intercepted.	Galanter et al.[7]
In the VA setting, root cause analyses of 182 patient ID errors in laboratory medicine over 8 years found 17.1% (31) involved orders placed in the wrong chart.	Dunn and Moga[19]
Medication Administration	
At a Malawi hospital, 34% (32 of 95) of staff reported knowledge of 1 or more patients receiving blood or medication intended for another patient over the prior year.	Latham et al.[22]
In a Swedish study, of 60 errors identified over a 12-year period involving cytotoxic drug administration, 8.3% involved a wrong-patient administration.	Fyhr and Akselsson[23]
In a French study of a single inpatient pharmacy, of all medications dispensed over a 9-month period, 0.38% (37 of 9,719) were dispensed to the wrong patient and accounted for 5.2% of all medication errors described in the study.	Bohand et al.[24]
At a single institution in Switzerland, 23 instances of breast milk administration to the wrong infant in the neonatal intensive care unit (NICU) over 6 years were identified through voluntary reporting, corresponding to an event rate of 0.14 events per 1,000 feedings.	Zeilhofer et al.[25]
Using a theoretical model of outpatient pharmacy errors, study authors estimated 1.22 per 1,000 warfarin prescriptions are dispensed to the wrong patient in the outpatient pharmacy context.	Cohen et al.[26]
In an Australian study, of 487 patient ID errors reported over 4 years, 25.7% (125) involved medication administration.	Thomas et al.[27]
Surgery	
In the VA setting, of 101 surgical incidents reported over 3 years, 30% involved wrong-patient surgeries.	Neily et al.[28]

Clinical Context, Prevalence	References
In a report from multiple U.S. institutions, of 484 root cause analysis reports, 1.86% (9) involved wrong-patient surgeries.	Paull et al.[29]
In a study of a U.S. insurance database, 0.9% (25) of 27,370 adverse events captured involved wrong-patient procedures.	Stahel et al.[30]
In a U.S., multi-institution survey, of 917 orthopedic surgeons respondents, only 1 reported knowledge of a wrong-patient surgery (unclear whether the respondent was involved with care or simply aware of the error).	Wong et al.[31]
Radiology and Procedures	
In a study at a single institution with two large U.S. academic hospitals, a keyword search of 1.7 million radiology reports from over about 4.5 years, found 0.004% (67) contained the phrases "wrong patient" or "wrong dictation."	Sadigh et al.[32]
In a U.S. multi-institution survey, of 225 emergency room (ER) physicians questioned about ER procedures, 4% reported awareness of a wrong-patient procedure and 2% recalled an instance in which a time-out would have prevented a patient ID event.	Kelly et al.[33]
Laboratory and Pathology Medicine	
In a single institution in India, assessment of 600,000 general laboratory specimens processed over 2 years found a patient ID error rate of 0.005%.	Sindhulina and Joseph[34]
In a single institution in Italy, of 8,547 test requests, 0.22% (19) had flawed patient ID.	Carraro et al.[35]
In a single institution in India, 0.35% of 135,808 specimen samples over 1 year were rejected due to mislabeling.	Upreti et al.[36]
In a single institution at the University of Utah, patient name errors over 18 months occurred in 0.275% of 29,479 pathology samples evaluated.	Layfield and Anderson[37]
In a U.S. study of 69 hospitals, of 60,501 pathology cases over 3 months, 2.9% had patient ID defects (wrong patient identifiers and missing information).	Bixenstine et al.[38]
At various institutions, 11.6% to 36% of clinical laboratory errors involved patient ID errors; 7.9% of pathology specimen labeling errors involve patient ID defects.	Upreti et al.[36] Lichenstein et al.[39] Snydman et al.[40]
At a single institution in Australia, of 14 pathology cases (23 total samples) reported as suspicious for specimen labeling error over 3 years, 23.1% (6) were true errors involving a mix-up of patient samples.	Bell et al.[41]
At a single institution in South Africa, of 472 directly observed telephone calls reporting laboratory results over 1 month, 7% (36) involved a patient name or MRN error. These 36 patient identification errors accounted for 70.8% of the 51 errors observed during clinical laboratory result reporting.	Rensburg et al.[42]
In the VA setting, root cause analyses over 8 years revealed 182 laboratory medicine adverse events due to patient misidentification. Of these errors, 132 were pre-analytic, 37 analytic, and 13 post-analytic.	Dunn and Moga[19]
Transfusion Medicine	
At various institutions, reported wrong blood in tube (WBIT) rates ranged from 0.0018% to 0.04%.	Sindhulina and Joseph[34] Vuk et al.[43] Varey et al.[44] Delaney et al.[45] Grimm et al.[46] Askeland et al.[47] Ferrera-Tourenc[48]

Clinical Context, Prevalence	References
At various institutions, rates of specimen mislabeling for blood transfusion ranged from 0.016% to 1.12%.	Grimm et al.[46] Askeland et al.[47] Pagliaro et al.[49] Elhence et al.[50]
In a centralized database containing data from 16 hospitals, an automated data query revealed 16 instances of specimen mismatches. Of these, 25% were due to a misla beled specimen and 50% due to patient misidentification.	MacIvor[51]
At a single U.S. institution, the rate of mislabeled cord blood units was 0.2%.	McCullough et al.[52]
At a single institution in Malawi, 22% of 95 health staff surveyed recalled an instance in which a patient received blood intended for a different patient.	Latham et al.[22]
In the VA setting, of 182 root cause analyses of ID errors over 8 years, 2.7% (5) involved WBIT errors.	Dunn and Moga[19]

Problems

We identified 44 studies assessing or describing factors contributing to patient ID errors. These studies are described below and summarized in Table 2. More detailed information can be found in Appendix A, Evidence Table 2.

Institutional Identification Protocols

Three general problems play important roles for institutions and may contribute to potential patient ID errors: (1) absence of formal institutional policies, (2) failure to follow existing policies, and (3) inadequate design of existing policies. In a survey of clinical risk staff from 154 UK hospitals, Sevdalis et al. (2009)[53] found that, before the 2005 Safer Practice Notice on inpatient wristbands from the UK's National Patient Safety Agency (NPSA), 58% of hospitals lacked a formal patient ID policy. Even when policies exist, compliance may be poor. A survey by Ortiz et al. (2009)[54] of 80 representative staff at 3 Florida hospitals found 49% of staff ID errors were caused by failure to follow existing policies. Notably, low compliance was not related to concerns about an arduous protocol; only 7% felt ID procedures were too complex. Instead, the most frequent contributory factor was time constraints (62%), a theme echoed by others.[55] Other factors included language barriers and use of Yes/No questions (e.g., asking "Is your name ____" instead of "What is your name?") Notably, staff may also consider repeatedly asking a patient for his or her name and date of birth (DOB) to be unprofessional and counterproductive for establishing rapport.[55]

Finally, existing protocols may not be sufficient to prevent errors. Ortiz et al. noted 52% of staff reported being directly or indirectly involved with errors in which a patient responded positively to the wrong name or DOB. In a small study (n = 33), Henneman et al. (2010)[56] noted that 15% (5) of staff failed to recognize ID errors despite completing the verification protocol. Existing protocols may also be inadequate if staff employ workarounds such as completing safety checklists ahead of time.[16]

Registration

Several aspects of current registration processes may create opportunities for misidentification. First, many institutions do not require photo ID, and those that do often have highly variable implementation across different sites. For example, a survey of 82 Chief Medical Information Officers (CMIOs) by Mancilla and Moczygemba (2009)[15] found that only 83.3% used photo ID, and face-to-face confirmation of identity was required in only 70.9% (56) of facilities. Although moving to a biometric identifier was considered desirable, there were significant concerns about patient acceptance and implementation costs.

Second, Mancilla and Moczygemba noted that registration for non-emergency room admissions poses distinct challenges. For instance, patients arriving for inpatient admission are often instructed not to bring anything with them, and may interpret this to include leaving identifying documents at home. Third, in direct observation of registration processes, the authors noted that in outpatient encounters, EHRs did not allow efficient access to photo ID, requiring clerks to navigate through several screens.

Finally, identity theft is an increasing problem. A report from the Ponemon Institute (2015)[13] estimated that 2.32 million U.S. adults were victims of medical identity theft in 2014, a 21.7% increase from the prior year. While 35% reported that the theft occurred without consent, 25% of respondents willingly allowed their credentials to be used, citing the other person's lack of insurance (91%), inability to pay for treatment (86%), and a medical emergency (65%). Sixty percent did not report thefts, citing beliefs that police would not be helpful (55%) and not wanting to report someone they knew (47%). Mancilla and Moczygemba noted that suspicious documents may not be detected by registration staff, who are often unskilled in detecting falsified documents and under significant time constraints. Because social security numbers (SSNs) are highly valuable to thieves, study authors highly recommended increasing protection of this identifier for patients; basic steps could include avoiding use of SSNs as an identifier and not printing this information on reports.[15]

Wristband Accuracy and Use

Several studies identified problems with wristband use and accuracy. Wristbands were often missing (e.g., not on the patient), or had incomplete or inaccurate information.[57,58] Furthermore, poor wristband design, such as inappropriate size (for children), degradation with use/water exposure (e.g., ink smudging), illegibility (e.g., handwritten) limited wristband use and acceptability.[59-61]

Missing Wristband

Missing wristbands are particularly problematic for children and neonatal intensive care units (NICUs).[57-59] Phillips et al. (2012)[57] performed regular audits of wristband use for more than 11,000 patients at 6 U.S. children's hospitals for a year, identifying 957 wristband errors. The most common error was a missing wristband (90.4%; 865 of 957), followed by inaccurate information (4.7%), illegible information (3.6%), wrong patient (0.3%) and other (1%). Common reasons cited for a missing wristband included the following: band fell off patient, was placed on another object, was removed by patient/parent or by staff, was never initially placed, and got in the way of care. Wristband "failure" was highest in NICUs because of the accepted practice of placing bands on the isolette or intravenous tubing attached to the patient. In a second large study of wristband use in 4,556 patients aged 18 months or older at a children's hospital, Walley et al. (2013)[58] found 73.6% of patients were missing the wristband. Tase et al. (2015)[59] found that only 55% of newborn wristbands in a U.S. hospital complied with institutional protocols and only 44% were in good condition.

Missing wristbands were also noted to be problematic in the context of surgery, where bands may be removed (e.g., to facilitate line placement) and not replaced before the patient arrives in the recovery area.[2,60] Studies identifying this problem are further described in section below on ID errors involving transfusion.

Wristband Design

Six studies described problematic aspects of wristband design. In bands lacking a clear covering, printed information can wash off or become illegible.[57,58] Inappropriate sizing of the band also causes problems with patient comfort or use by staff. For instance, nurses noted difficulty in affixing the patient's ID sticker on narrow wristbands. Some institutions may incorporate color coding into wristband design to signify important clinical information (e.g., a medication allergy); however, lack of standardization of what the colors signify may create staff confusion.[62] Finally, wristbands may not highlight the patient information staff consider most useful. Sevdalis et al. (2009)[62] found that UK healthcare staff considered first/last name, hospital number, and date of birth as most important, with 86% to 88% reporting finding these identifiers useful. Interestingly, only 37% considered the unique National Health Service (NHS) patient identifier as useful.

Studies reported on wristband use and design in settings outside of the United States, specifically, Malawi,[22] Brazil,[63] the UK[61] and Canada.[2] Healthcare staff in Malawi noted that DOB is a problematic identifier for their patients, for whom this date may be unknown.[22]

Order Entry and Charting

Three studies described problematic factors associated with order entry and charting.[6,7,64] Two of these studies described two factors promoting wrong-patient orders: the context of the ordering provider (e.g., distraction, fatigue) and having more than one patient chart simultaneously open.[6,7] A 6-year study at the University of Illinois (Galanter et al. 2012[7]) identified 32 intercepted wrong-chart orders (i.e., confirmed near misses). In nearly all cases (31 of

32), patients were being cared for by the same provider, and in 59% of cases, both patient charts were simultaneously open. Provider type (resident vs. attending) and similar patient last names did not play a role.

Similarly, Levin et al. (2012)[6] studied retracted medication orders that were quickly reordered on a different patient (by the same provider) over five years and reached similar conclusions. Comparing 644 identified cases to controls, authors found only one patient factor (similar last name spelling) associated with errors. Multivariate analysis found that factors associated with higher error rates included young age (newborn, children), day of week (Friday), two-letter overlap in last name, patient proximity, and timing of order (6 p.m. to midnight). When surveyed, CMIOs and physicians agreed that having more than one chart simultaneously open was a significant problem. Distraction and fatigue were cited by physicians as the biggest contributing factors. The authors concluded, "it is the context of the order entry process, more than the characteristics of the patient names themselves which are associated with patient ID errors." A systematic review of EHR-associated patient safety risks by Virginio and Ricarte (2015)[65] also cited two or more charts open as problematic, along with display of a high volume of information.

Finally, issues related to software function and design also contribute to errors. Magrabi et al. (2011)[64] reviewed all health IT events in the Manufacturer and User Facility Device Experience (MAUDE) database of the U.S. Food and Drug Administration (FDA) over roughly 1.5 years. The MAUDE database contains mandatory and voluntarily submitted reports pertaining to medical device–related errors and recalls. Software issues accounted for more than 40% of reported health IT events, with patient misidentification representing the most common problem. In particular, characteristic problems were noted with Picture Archiving and Communication Systems (PACS), which store and retrieve radiology images and reports. Reported problems included issues with inputting information, such as storing images under the wrong patient's folder or exchanging one patient's images with another. For example, in one case, a portable chest x-ray study was stored in the system under the wrong name, leading to subsequent intubation that may have contributed to the patient's death. Significant problems with information output from PACS were also reported. These problems included (1) displaying the wrong patient header for an image, (2) displaying the wrong patient's images when users switched from display to edit mode for a radiology report, and (3) caches in the browser causing the incorrect image to display (e.g., display of cached images from the previous patient).

Medication Administration

We identified six studies[26,64,66-69] focused primarily on characterizing potential causes of medication administration errors. A majority (5 of 6 studies) focused on errors in the inpatient setting, including low adherence to ID protocols, cumbersome protocols, and bar-code system glitches. A Finnish study observed 32 nurses administering medication and found poor adherence to patient ID protocols.[66] Hospital protocol required use of either name and DOB or wristband (for patients with impaired mental status). However, patient name was confirmed for only 21.5% of administrations (95 of 441). Confirmation using date of birth (0.2%) and wristband (0.7%) was even lower. Adherence was significantly higher for newer nurses (less than 4 years of experience) and when a high number of distractions were present (e.g., time constraints, discussion with relatives, crowded medicine room). Authors speculated nurses may follow the protocol primarily when they perceive they need help (e.g., nurses with less professional experience or when distractions are clearly present).

A small study by Marquard et al. (2011)[68] tracked the eye movements of 28 nurses administering medications in a simulated setting to 3 actor-patients, in which ID information for the medication label and ID band were mismatched for the third patient. Based on a post-hoc analysis, authors speculated nurses were more likely to identify the error if they confirmed one identity component at a time (e.g., compared name on both wristband and medication, then DOB) instead of "batching" multiple components to check at a time.

Steele and Bixby (2014)[67] used root cause analysis to identify problems leading to breast milk administration errors. Important contributory problems included (1) a cumbersome and unclear process for the bedside nurse and (2) inadequate double checks at key points, such as when mothers are provided with labels for milk or when a nurse is preparing milk, often combining multiple bags.

Although bar-code technology systems have often been implemented to reduce medication administration errors, system malfunctions may themselves cause problems. Magrabi et al. (2011)[64] identified reports in FDA's MAUDE database of bar-code readers corrupting patient data and causing the wrong medication to be dispensed. Similarly,

Snyder et al. (2010)[69] described factors that may impair bar-code reader function such as low batteries, artifacts on printed labels, and scanning difficulty because wristbands curve around the wrist.

Finally, medication dispensing in the outpatient pharmacy setting presents a different set of challenges. Cohen et al. (2012)[26] used data from 22 community pharmacies across the United States to create a model simulating pharmacy dispensing errors and near misses for outpatient pharmacies. The study estimated the incidence of point-of-sale errors (in which a drug [e.g., warfarin] was given to the wrong patient) to be 1.2 in 1,000, or 4.6 million per year. These errors were caused by pharmacists (1) placing a drug in the wrong patient's bag, or (2) giving the wrong bag to the patient. Factors contributing to these errors include working on more than one patient's medications during verification or bagging and flawed or absent process for confirming patient identity. Inpatient protocols for verification may not translate well to the outpatient context since medications are frequently picked up by family or friends who may not know the patient's DOB and may pick up medications for multiple family members sharing a last name and address.

Diagnostic Care

Radiology and Surgery

Communication errors and system problems were the primary root causes identified for wrong-site/wrong-patient surgeries in a study of a large insurance database. Stahel et al. (2010)[30] analyzed 6.5 years of data and identified 25 confirmed cases of wrong-patient surgeries. Of these cases, 56% were due to errors during the diagnostic process, such as misidentified medical records, radiographs, or laboratory or biopsy samples. Five of 25 patients experienced significant harm or functional impairment. In one case, a vitrectomy was performed on the wrong patient because of confusion created by two patients with identical names in the ophthalmologist's office. A high proportion of errors could have been averted by formal "readbacks" by the surgical team.

However, despite safety protocols and checklists, workarounds can thwart safety gains. For instance, Danaher et al. (2011)[16] found that "final" checks of patient identity mandated for radiology procedures were often performed and certified before the patient's arrival at the hospital.

Laboratory Medicine, Transfusion, and Pathology

Studies suggest the majority of patient ID problems for laboratory, transfusion, and surgical-specimen processing arise during the "preanalytic" phase of specimen collection and labeling. (Dunn et al.'s [2010][19] analysis of 227 root cause analyses of patient misidentification events at Veterans Health Administration [VA] hospitals concluded that 72% of errors were due to mislabeled specimens.) Problematic factors included missing patient wristbands, failure to follow ID confirmation protocols at collection,[70-72] mislabeling due to "batching" of multiple samples, centralized printing of labels,[19,73] poor label design, use of handwritten forms, and poor handling/disposal of labels.[19]

Mislabeling of specimens occurred for many reasons including (1) "batched" labeling (specimens from multiple patients labeled at once), and (2) allowing non-laboratory staff (e.g., registration clerks) to help phlebotomists with labeling. A large study by Grimm et al. (2010)[46] assessed all labeling errors associated with blood transfusion over a 30-day period at 122 (primarily U.S.) institutions. Although all institutions required first and last name confirmation at collection, only 72% required DOB confirmation as well. The overall combined mislabeling rate was 1.12% (1 in 89 samples). Allowing labeling and collection by non-laboratory personnel was significantly associated with higher mislabeling rate ($p = 0.001$), while requiring DOB confirmation and gender on outpatient labels was associated with lower error rates ($p = 0.05$ and $p = 0.007$, respectively). These factors were also associated with rates of wrong-blood-in-tube (WBIT): labeling by non-laboratory personnel ($p = 0.008$) was associated with higher WBIT rates, requiring DOB on requisition forms and phlebotomist ID on sample labels was associated with lower rates.

In some cases, patient labels were printed in one centralized location, but demarcation between sets of patients labels was poor. Phlebotomy staff would often mistakenly grab labels left from the prior patient and mislabel the specimen at the bedside.[19,73] Separating labels for different patients by inserting a label printed with large X's was helpful to address this error. Small, hard-to-read labels also contributed to labeling errors in surgical pathology specimens.[74] In studying VA adverse events, Dunn et al. found that non-user-friendly electronic forms led to routine

use of manual forms, user-entry errors, and subsequent transfusion events.[19] Errors were also caused by similar patient last names, or similar SSNs (the last 4 digits of the SSN are used as identifiers).[19]

Poor handling and disposal of labels also contributed to errors. Dunn et al. noted that the presence of printed labels from multiple patients in common areas of the emergency department, operating rooms (ORs), and nursing units were all connected to labeling errors, some resulting in serious patient harm.[19] In one case, a fine-needle aspiration biopsy was mistakenly labeled using labels left in the OR from the previous patient. This resulted in an unnecessary lung resection for one patient and delayed diagnosis and treatment for the second.[19] Askeland et al. (2009)[47] also noted that inadvertent scanning of a bar code from a previous patient's label led to near misses for transfusion errors in the operating room.

Blood Transfusion Specific

Three institutional factors may play a particular role in blood transfusion errors: failure to implement a two-sample confirmatory policy for ABO typing, lack of a centralized database, and identity theft. Requiring a confirmatory second sample for blood typing decreases the probability of a labeling error or identity theft leading to transfusing incompatible blood. However, Grimm et al. (2010)[46] reported that only 60% of institutions required two-sample confirmatory typing for non-emergent cases; only 45% required photo ID at registration. Two studies, one French[48] one U.S.,[45] concluded that using a regional centralized database of patient blood types that spans multiple institutions can also help prevent transfusion errors. Notably, Ferrera-Tourenc et al. (2015)[48] reported 61% of patient ID errors (19 of 31) were believed to be due to identity theft. Without a confirmatory second-sample policy in place, 61% of patients with ID errors would have received non-compatible blood.

Distinctive challenges for safe transfusion in the intraoperative or postoperative setting can arise due to wristband removal or inaccessibility during the procedure. Burrows et al. (2009)[2] assessed wristband accessibility in patients undergoing elective surgery. Intraoperatively, only 44.6% (190 of 426) of patients had accessible ID bands. Furthermore, no identity confirmation using an ID band was performed for any of the 77 units of blood transfused, a clear violation of the institution's policy. In 6.3% (27 of 426) of cases, wristbands had been removed to facilitate line placement.

If removed wristbands are not replaced before the patient leaves the OR, patients (likely to have impaired mental status while recovering from anesthesia) may arrive in postoperative recovery areas without wristbands. Burrows et al. (2009)[2] found that 2 (of 426) patients tracked in the study arrived in the recovery area without a wristband. Participants in the QUEST study (Heddle et al. [2012][60]), a qualitative study of transfusion staff from five countries, including the United States, also flagged patients returning from surgery without wristbands as a significant problem for performing pre-transfusion identity checks. To address this problem, staff suggested all surgery patients should be required to have two wristbands.[60] Other challenges to safe transfusion practices included (1) delivery of multiple units of blood for several patients at the same time, (2) wristbands that become illegible with water exposure, and (3) language barriers between the nurse and patient.

Finally, failure to promptly dispose of unused blood products can also lead to transfusion errors. Assessing "near misses" at a large U.S. healthcare system over a 46-month period, Askeland et al. (2009)[47] identified four events in which blood left in the OR from a prior surgery would have been administered to the wrong patient if the error had not been detected using a bar-coding system.

Table 2. Contributing Factors, Patient Identification Errors

Problems	Reference
General Problems, Institutional Policies	
No institutional patient identification (ID) policy	Sevdalis et al. (2009)[53]
Non-compliance with existing ID protocols (staff time constraints, language barriers, use of Yes/No questions, concerns about repetitive confirmation of name/date of birth as unprofessional)	Phipps et al. (2012)[55] Ortiz et al. (2009)[54]

Problems	Reference
Existing protocols are not adequate to prevent ID errors (e.g., due to patient confusion or staff workarounds)	Danaher et al. (2011)[16] Henneman et al. (2010)[56] Ortiz et al. (2009)[54]
Registration	
No requirement for photo ID	Ponemon Institute (2015)[13] Mancilla and Moczygemba (2009)[15]
Registration not performed face to face	
Identity theft (registration staff face time constraints, not trained to flag suspicious documents); outpatient electronic health records not designed to facilitate photo ID at registration; health systems provide inadequate security for social security numbers	
Non-emergency room patients may not bring identifying documents	
Wristband Accuracy and Use	
Missing wristband (particularly for neonates, children, and in the operative/postoperative setting) Never placed, or removed by patient/staff, or placed on surrounding equipment No policy for wristband replacement Removed and not replaced intraoperatively Inaccurate/Incomplete information Poor wristband design Inappropriate size Illegibility (handwritten, ink smudging, small print) Degradation with use (water exposure) Lack of consistency for color coding	Tase et al. (2015)[59] Walley et al. (2013)[58] Phillips et al. (2012)[57] Burrows et al. (2009)[2] Sevdalis et al. (2009)[62]
Order Entry and Charting	
Provider fatigue, distraction 2 charts open simultaneously PACS (picture archiving and communication system) software misfiles images, displays images for wrong patient	Virginio and Ricarte (2015)[65] Levin et al. (2012)[6] Galanter et al. (2013)[7] Magrabi et al. (2011)[64]
Medication Administration	
Inpatient Low adherence to ID protocols Overly complex ID protocol Factors interfering with bar-code technology performance	Härkänen et al. (2014)[66] Steele and Bixby (2014)[67] Snyder et al. (2010)[69] Magrabi et al. (2011)[64]
Outpatient Patient dispensed wrong medication (due to pharmacist placing medication in wrong bag, or giving wrong bag to patient) Less rigorous process for ID confirmation	Cohen et al. (2012)[26]
Radiology and Surgery	
Communication and system errors, primarily during diagnostic processes (misidentified records, images, laboratory/biopsy samples)	Stahel et al. (2010)[30]

Problems	Reference
Laboratory Medicine, Transfusion, and Surgical Pathology Specimen	
Mislabeling Missing wristbands Failure to have or follow protocols Labeling of samples by non-laboratory personnel "Batched" labeling of multiple specimens at once Centralized label printing Poor handling/disposal of labels	Schmidt et al. (2013)[74] Rees et al. (2012)[73] Dunn and Moga (2010)[19] Grimm et al. (2010)[46]
Transfusion-Specific Problems	
Lack of 2 sample confirmation, centralized database for blood typing, and identity theft Intra/post-operative inaccessible or missing wristbands Failure to dispose of unused blood products in the operating room	Ferrera-Tourenc et al. (2015)[48] Delaney et al. (2013)[45] Heddle et al. (2012)[60] Askeland et al. (2009)[47] Burrows et al. (2009)[2]

Interventions

Overall, we identified 40 studies for inclusion on the question of interventions used: 4 systematic reviews and 36 original comparative studies. These studies addressed potential patient ID problems across the care spectrum: specifically, studies assessed interventions for problems associated with systems-level patient matching, registration, accurate patient wristbands, order entry and charting, medication or breast milk administration, point-of-care testing, radiology, and laboratory medicine, including transfusion and pathology.

Patient Matching (Systems Level)

Lee et al. (2015)[75] developed a naturalistic patient-matching algorithm for detecting the same patients within and between health information systems that integrated elements of deterministic and probabilistic algorithms. Deterministic algorithms require exact matches, while probabilistic algorithms allow for typos and small differences. Study authors created a hybrid algorithm incorporating both deterministic and probabilistic elements and validated it using a large dataset of Health Level 7 (HL7) messages.

HL7 messages are a widely used standard of communication for electronic data between health information systems and contain demographic data in pre-specified formats. A large dataset of 137,470 HL7 messages were stripped of system-generated, unique patient identifiers; remaining demographic data included DOB, SSN, name, and address. Using these demographic data, the naturalistic algorithm was asked to determine which messages belonged to the same patient. Overall, the algorithm reported matches correlating with unique identifiers for 19,788 patients, a 99.65% agreement with the source database on unique patient identifiers. The new algorithm identified 56 patients that manual review confirmed had incorrectly been assigned separate unique identifiers in the original dataset.

In 13 instances, the naturalistic algorithm concluded messages belonged to 2 separate patients, while the original dataset indicated a single patient. For 1 of 13 cases, the original dataset was demonstrated to be inaccurate (e.g., 1 identifier had mistakenly been used for 2 separate patients). However, the remaining 12 cases were potential false negatives in which the algorithm potentially inaccurately concluded that there was no match. Authors noted that data quality affected the ability of the naturalistic algorithm to link patient records.

To further test record matching between systems, study authors used the naturalistic algorithm to match laboratory data from a different geographic area with the original dataset. As patient overlap between two geographic regions should be minimal, matching between systems was expected to be low. The algorithm was highly successful, with no false positives or false negatives. Only two patient matches were identified, and manual review revealed that these were the same patients seen in both locations.

Registration

Judson et al. described an initiative at Massachusetts General Hospital to improve the registration process by identifying encounters suspicious for identity fraud.[14] The Verify Everyone's Identity (VERI) Safe Patient Care initiative created a notification tree for standardized reporting of "red flags" suggesting a possible mistaken identity including: (1) patient was seen by provider under a different name, (2) patient received bill for care he or she did not receive, and (3) identity documents appear forged. Administrators at patient-intake sites, registration staff, and specific providers received education including geographic distribution of SSNs and sample scripts to prompt patients for clarification; they were asked to comment in the system when core demographic information (e.g., name, gender, DOB) were changed. Registration staff were required to document whether photo ID was requested; if ID was not available, staff were required to document why and ask the patient to bring it to the next visit. Additionally, a follow-up verification question was asked: "When was the last time you were seen and by which doctor?" Since 2006 when data collection began, the number of red-flag incidents steadily increased to more than 80 incidents in 2010. After implementation of VERI Safe Patient Care in 2011, incidents steadily decreased to 40 incidents in 2013.

Accuracy of Patient Identification Wristbands

Two studies described quality-improvement initiatives aimed at improving the accuracy and use of patient ID wristbands.[57,76] Phillips et al. (2012)[57] described a collaborative quality-improvement initiative among six children's hospitals during which failure data were collectively shared on monthly conference calls along with a broad educational campaign for staff, parents, and families regarding the importance and proper use of wristbands. Also ID band verification was incorporated into handoffs between nurses. Monthly ID band audits were conducted on 11,377 patients over 13 months. At baseline, the combined overall failure rate was 17% (ranges among hospitals 4.9% to 52%). Thirteen months after implementation, ID band failures fell from 17% to 4.1%, a 77% relative reduction ($p < 0.001$).

Hain et al. (2010)[76] described a quality initiative at Monroe Carell Jr. Children's Hospital at Vanderbilt to improve use and accuracy of pediatric ID wristbands. After input from multiple units and staff, an initiative was launched consisting of educational programs for ancillary providers (e.g., transport, dietary, and radiology technicians), unit-specific improvement plans, and regular audits of ID band use. Notably, the baseline failure rate of 20.4% dropped to 6.5% after audits were begun but before implementation of other parts of the plan. By 4 months after implementation of action plans, the rate dropped further to 2.6%. A staff survey identified the most common barriers to proper use as (1) improper fit and (2) the perception that the band impedes care.

Order Entry and Charting

We identified five studies[3,5,8,77,78] that assessed three interventions (ID verification alerts, addition of photo ID, new neonatal naming convention) for decreasing wrong-patient orders during order entry.

Four studies assessed use of verification alerts to improve order and charting accuracy. Adelman et al. (2012)[8] performed a large, single-institution, prospective randomized controlled trial (RCT) comparing ID verify alert, ID re-entry function, and control. The ID verify alert required a single click to confirm patient name, gender, and age, while ID re-entry required re-entry of patient initials, gender, and age. As a surrogate measure for wrong-patient orders, authors measured the retract and reorder (RAR) events, defined as retraction of orders in 10 minutes or less that are subsequently reordered by the same provider for another patient within 10 minutes. Authors validated RAR with semi-structured interviews of providers and determined the positive predictive value (PPV) of RAR events to be 76%.[8] At 6 months, both interventions showed significant decreases in RAR events, and the magnitude of improvement was larger for ID re-entry (odds ratio, 0.60; 95% confidence interval [CI] 0.50 to 0.71) than for ID verify (odds ratio 0.94). Users required an additional 0.5 seconds for ID verify and 6.6 seconds for ID re-entry.

Green et al. (2014)[77] reported on five New York emergency rooms (ERs) that assessed the impact of alerts displayed at the outset of each ordering session. A dialogue box with name, gender, DOB, and medical record number (MRN), chief complaint, and recent medication orders with a forced 2.5 second delay, required users to confirm identity before moving on. A special warning appeared when another patient in the ER had the same name. Overall, 5,637 RAR events were identified, corresponding to an estimated error rate of 1.63 per 1,000 orders (estimated using a PPV of 76%). Overall, this intervention was associated with significant reduction in wrong-patient

orders at four months and two years. After adjusting for confounders, the adjusted odds ratio was 0.72 (95% CI, 0.64 to 0.80) at 4 months; the decrease was sustained at 2 years (risk ratio 0.76; 95% CI, 0.69 to 0.83). During the first 4 months, 5.3% of orders were cancelled, with 0.4% of cancellations due to wrong-patient orders.

Wilcox et al. (2011)[78] evaluated a pop-up window displaying name and MRN before completion of each note at a single institution (Columbia University Medical Center). Authors measured the rate of "clinician discovered mismatches," defined as discovery of one patient's note found in a different patient's chart. Compared to 1 year prior, the mismatch rate decreased by 40% (0.0003 vs. 0.0005, p <0.004). However, despite this large relative reduction, the authors noted that the actual prevalence of these events remains very low. Finally, a fourth single-center study by Hyman et al. (2012)[3] assessed whether a verification alert with patient name and other core demographic information along with a patient photo could decrease wrong-patient orders for pediatric patients. At baseline, orders placed in the wrong patient chart comprised 24% of self-reported patient ID events. However, in the 15 months after implementation of this verify alert, no patient whose picture was in the EHR was reported to receive unintended care due to wrong-order placement.

To address the potential for misidentification in newborns—who are often assigned temporary names and lacking distinctive features to make a photo ID useful—Adelman et al. (2015)[5] assessed whether a new naming convention (incorporating the mother's name, e.g., Wendysgirl) decreased wrong-patient orders (by measuring RAR rate). The RAR rate decreased from 59.5 to 37.9 per 100,000 orders, with a significant decrease in RAR events (odds ratio 0.64; 95% CI, 0.42 to 0.97). Improvement was most pronounced for house staff (odds ratio 0.48; 95% CI, 0.24 to 0.93), with no change for attending physicians.

Medication/Breast Milk Administration Errors

We identified one systematic review[79] and six comparative studies[9,67,80-83] describing two interventions (bar-code technology and pre-administration protocols) to prevent ID errors for medication or breast milk administration.

Bar-code Technology

A systematic review by Young et al.[79] (2010) assessed the impact of bar-coding technology on medication administration errors (MAEs) and included six comparative studies. Five of 6 studies reported overall changes in MAEs:

- 3 studies found significant decreases in overall MAEs in the medical intensive care unit (MICU), surgical ward, and inpatient units (relative decreases of 56%, 39%, and 54% respectively)
- 1 NICU study reported a 15% increase (69.5 to 79.9 per 1,000 doses, p <0.001) in overall MAEs
- 1 study reported no effect

Notably, clear descriptions of how measured MAEs correspond to the "five rights" of medication administration were missing for many studies. Only two of six studies described how often medications were administered to the right patient: both studies found a decrease in wrong-patient errors, but this reduction was significant for only one study (Skibinski et al., cited in Young et al. [2010][79]) in which the error rate decreased from 0.7% to 0.63%, p = 0.003).

Four studies published subsequent to this review also described the impact of bar-code technology on MAEs[9,81] and breast milk administration. A large study by Poon et al. (2010)[9] assessed the impact of a bar-code medication–administration system on MAEs at Brigham and Women's hospital. MAEs were identified through direct observation by trained research nurses before implementation and four to nine weeks afterwards. Overall, 14,041 medication administrations for 1,726 patients were observed, primarily on weekday nursing shifts. The bar-code system decreased non-timing errors (e.g., transcription and dosing errors) by 41% (11.5% to 6.8%, p <0.001). Of note, the rate of potential adverse drug reactions due to non-timing errors also significantly decreased, from 3.1% to 1.6% (p <0.001). Overall, wrong-medication errors decreased by 57%, wrong-dose errors by 42%, and administration documentation errors decreased by 80%. Reductions were seen across surgical units, intensive care units (ICU), and medical units, although reductions for medical units were not significant, likely because of low baseline rates. Notably, the authors speculated that the errors persisted, in part, because 20% of medications continued to be administered without scanning the bar code.

Two studies also reported changes after bar-code system implementation. A retrospective study by Sakushima et al. (2015)[80] assessed MAEs five years before and four years after implementation. Wrong-patient errors significantly decreased from 17.4 to 4.5 errors per year ($p < 0.05$). Another study by Higgins et al. (2010)[81] evaluated use of bar-code scanning along with a quality improvement initiative. Although the total errors (near misses plus errors reaching the patient) significantly increased over the study period, medication errors reaching the patient significantly decreased (73% reduction, $p < 0.05$). Both Sakushima et al. and Higgins et al. relied on voluntary reporting to identify near misses and errors.

Steele and Bixby (2014)[67] described a two-step intervention to improve accurate delivery of breast milk at a single children's hospital: the intervention consisted of a new protocol followed by bar code implementation. At baseline, 45 breast-milk handling errors (including 3 wrong-milk-administered errors) were reported over 2 years. After introducing a new protocol that required dual confirmation of label accuracy by staff, 7 errors were captured over 10 months, with no wrong-patient errors. With introduction of a bar-code system, only 5 errors over 6 months (no wrong-patient errors) were detected, along with 55 near misses.

Protocols/Checklists

Two studies[82,83] described changes to pre-administration checklists for chemotherapy administration. A Canadian study by White et al. (2010)[82] assessed whether changes, including an ID band check for MRN and name into a chemotherapy administration checklist, could decrease wrong-patient errors. In a simulated chemotherapy suite, 10 nurses were observed administering infusions to "cancer patients" played by actors (who were instructed to create distractions). Each nurse used both old and new checklists. Using the new checklist resulted in a significantly higher detection of the 20 ID errors (80% vs. 15%, $p < 0.01$). A study by Spruill et al. (2009)[83] described the impact of a new protocol requiring a bedside ID check by two chemotherapy-competent nurses before chemotherapy administration. No errors were detected either before or 6 months after protocol implementation, although all staff agreed this bedside check was an improvement in practice.

Point-of-Care Testing

Alreja et al. (2011)[84] described introduction of bar-code-enabled glucometers for point-of-care glucose testing at Baystate Health System. Before the intervention, staff would scan the ID wristband and manually enter a nine-digit MRN before testing glucose; after acquiring results from multiple patients, information would be downloaded from the device and only then, checked against the system database of patient IDs for errors. By contrast, the new glucometer required scanning the patient's ID wristband and entering DOB followed by verification of the patient's ID with the central system, *before* unlocking the glucometer to allow testing. Patient ID errors for old and new glucometers were compared over two months. Error rates for the new glucometers were significantly lower than for the old glucometers (0.319% vs. 0.015%, $p = 0.002$). The majority of errors with new glucometers were due to transient ID numbers created for unregistered ER patients (before ID wristbands are issued).

Radiology Acquisition

We identified 10 studies[4,12,16,85-91] describing 4 interventions to improve accuracy of patient ID when acquiring radiological images: (1) new safety protocols, (2) a DICOM system, (3) automated algorithm to check patient ID at acquisition, and (4) displaying photographic patient ID along with radiology images.

Safety Protocols

Two studies[16,85] assessed new safety protocols for reducing ID errors for patients undergoing radiology studies. Rubio et al. (2015)[85] assessed whether implementing a two-person verification protocol, "Rad Check" decreased wrong-patient/wrong-study errors at a children's hospital. Rad Check required two health care staff to read name and MRN (from patient armband) and study to be performed (from the paper/electronic order) before acquisition of every study. The authors included errors in which a clinician ordered the wrong study or cases in which studies were filed under the wrong patient. Forty-five wrong-patient/wrong-study errors were identified over 6 years: 36 errors before implementation, and 9 errors after implementation. This corresponded to a significant decrease in the error rate from 9.4 to 2.9 (per 100,000 examinations, $p = 0.001$). Roughly two-thirds of errors (64%) were wrong-study errors, and 36%, of errors involved a study performed on the wrong patient. In 20% of cases, patients received unnecessary radiation.

Danaher et al. (2011)[16] described use of a three C's-based protocol (correct patient, correct site, and correct procedure) to prevent wrong-side/wrong-site radiology errors at three Australian hospitals. Although error rates decreased after introduction of the new protocol, rates increased after a new web-based error reporting system replaced a paper-based system midway through the study. In addition to these flaws with outcome reporting, the study authors also acknowledged that staff were quite open about workarounds to circumvent the protocol (e.g., signing a "final check" before the arrival of a patient).

Implementing a DICOM System

Pandit et al. (2015)[86] assessed whether implementing a DICOM workflow for ophthalmologic studies (e.g., visual field testing) could reduce the number of misfiled studies. DICOM was developed as a universal, non-proprietary standard; DICOM image files include embedded information regarding image acquisition parameters and more than 2,000 demographic and medical attributes. Individual diagnostic machines in the ophthalmology department were integrated into the centralized patient registration system, allowing technicians to choose from a drop-down menu of patients, instead of entering information manually. Although many challenges arose, compared to pre-implementation, the DICOM system decreased the misfiled image rate by 76% (9.2% to 2.2%, p <0.01). Also, at 18 months after integration, more encounters had the correct demographics available to the technician than were available 3 months after integration, although the results did not reach statistical significance (80% vs. 73%, p = 0.08).

Displaying Photo Identification with Study Image

Three studies[4,87,88] assessed whether displaying patient ID photographs alongside chest radiographs could decrease mismatches in patient ID. All three studies were performed by the same team and used the same set of base images, although test subjects and study design changed among studies. In all three studies, pairs of chest radiographs (a mixture of correctly paired and mismatched pairs) were presented to newly trained radiologists. Participants were blinded regarding the intent of the study and asked to simply read the films. Two of these studies[4,88] used a crossover study design in which 5 or 10 radiologists were asked to interpret pairs of chest radiographs. Study participants were asked to read 20 pairs without photographs, followed by 20 pairs in which a patient photo ID was part of the identifying information for each image. Up to 4 mismatched pairs were included in each set of films. In the first study, detection of mismatched pairs improved from 0/20 to 17/18 (94.4%) after addition of patient photographs. A second study also found that detection of mismatched pairs improved after addition of photographs (3/24 [12.5%] vs. 16/25 [64%]). In the third study, 90 radiologists reviewed 10 pairs of films either with or without patient photographs. Without photographs, the radiologists identified 9/29 (31%) mismatched pairs. However, adding photographs significantly improved identification of mismatches to 23/30 (77%) mismatched pairs, corresponding to an odds ratio of 7.3 (95% CI, 2.29 to 23.18).

Automated Algorithms

Two studies[12,89] investigated automated algorithms to confirm patient ID and proper positioning for radiation therapy. Both studies were prospective and used intentionally mismatched films to validate the algorithm. Lamb et al. (2013)[12] compared two system-acquired planar radiographs taken immediately before therapy (via planning computed tomography [CT] scan) to confirm patient ID and proper positioning. Images from 100 patients undergoing cranial therapy and 100 patients receiving prostate therapy were used to test patient matching. The number of mismatched images included in the dataset was not reported. The algorithm produced no false positives or false negatives for cranial therapy patients; for prostate patients there were two false positives and no false negatives.

Jani et al. (2015)[89] used a similar process to detect patient ID and positioning errors using a planning CT scan and setup CT scan for patients receiving radiation therapy to the head and neck, pelvis, and spine. The algorithm performed well, detecting patient mismatches with high sensitivity and specificity. Of the two brands of imaging systems tested, the system with better image quality had better results.

Identifying Misfiled Radiology Images

We identified two studies[90,91] using distinguishing radiographic "markers" to investigate misfiled or mismatched chest radiographs. Toge et al. (2013)[90] developed a "fingerprint" using 5 weighted biologic markers, which was tested using a database of 200 randomly selected misfiled images. This weighted fingerprint correctly

automatically refiled 87.5% of misfiled images and identified another 5% with similarity significant enough to warrant manual review. This process produced no false positives.

Kao et al. (2013)[91] developed an automated patient-matching algorithm using 6 biologic markers to generate a similarity score (range 0 to 6, with 6 being most similar). This algorithm was tested on 1,000 matched and 999,000 mismatched image-pairs developed from a base set of 1,000 matched image-pairs. Correctly matched image-pairs had an average similarity score of 4.53 (± 0.84) and incorrectly matched image-pairs had a similarity score of 1.90 (± 1.18). Using a threshold-of-similarity score of 4.5 or more for matching, the algorithm yielded a false-positive rate of only 1.1% (e.g., only 1.1% of mismatched pairs were determined to be accurate).

Laboratory Studies

We identified one systematic review[92] and six studies[93-98] assessing interventions to decrease patient ID errors in the laboratory.

Bar Coding

A 2012 systematic review by Snyder et al. (2012)[92] assessed the effects of bar-coding systems for tracking laboratory specimens; the review also assessed bar-coding systems for point-of-care testing. Ten large observational studies assessing bar-coding systems for laboratory specimen tracking in large U.S. hospitals were included. Eight studies were performed in clinical pathology laboratories and two in surgical/anatomic pathology laboratories. Study settings were diverse, spanning inpatient, outpatient, emergency department, and pediatric settings. All studies tracked more than 1,000 specimens and all except two studies followed more than 10,000 specimens for both comparative groups. Meta-analysis of nine studies concluded that barcoding systems were associated with significant improvement in rates of ID error identification (odds ratio, 4.39; 95% CI, 3.05 to 6.32) and had strong consistency in results across studies.

In the Snyder systematic review, seven included studies assessed point-of-care glucose testing (two published, five unpublished). With one exception (Rao, 2005, cited in Snyder et al. [2012]), included studies were large, with more than 10,000 tests included. Authors concluded that point-of-care test bar-coding systems produce substantial and consistent improvement in identification of ID errors compared with results of non-bar-coding systems; a meta-analysis of seven studies found a summary effect of odds ratio of 5.93 (95% CI, 5.28 to 6.67), favoring barcoding.[92]

Snyder and co-authors noted that bar-coding technologies do not eliminate errors. For instance, scanners may misread patient ID barcodes because of low print quality, degradation of print quality over time and use, and incompatible print sizes or low battery power; narrow wrist curvature on pediatric patients may also cause scanners to misread. Lastly, bar-coding systems cannot address the problem of inaccuracies on ID wristbands. Benefits include decreased phlebotomy and misidentification for patients, but also the ability to track errors to allow for performance improvement.[92]

Optical Character Recognition (OCR)

Hawker et al. (2014)[98] compared optical character recognition (OCR) to routine quality assurance measures for detecting mislabeled laboratory specimens from 2006 to 2013. Specimen tubes were lifted using vacuum suction and then photographed by four cameras, yielding a 360-degree photo of the specimen label. All OCR information was reviewed by laboratory personnel to confirm accuracy of patient information. Of 1,009,830 specimens processed, OCR detected 121 labeling errors, of which only 71 were detected by routine quality assurance measures. While OCR produced no false negatives (e.g., no problematic labels were missed), study authors found an extremely high rate of false positives. Of 266,852 specimens flagged as problematic, only 121 were true patient ID errors and an additional 148 were discrepancies in spelling for patient names on labels compared to the laboratory system.

Automated Algorithms

Miller (2015)[93] assessed the validity of an automated algorithm based on the composite complete blood cell count (CCD) to detect mislabeled complete blood count (CBC) specimens at Rush University Medical Center. Study authors developed an algorithm to detect fluctuations in a variety of CBC parameters (such as mean cell hemoglobin [MCH] which is not affected by hydration/dialysis) to identify potential instances of misidentification.

The CCD algorithm was optimized using samples of 49 patients with a combined more than 2,000 multiple sequential blood tests (with most acquired within 2 days). On this sample, the algorithm was found to have high sensitivity and specificity (92.5% and 97.6%, respectively). After optimization, the algorithm was used to assess 11,193 CBC results over 2 weeks, 52% of which had prior CBC values to permit assessment. Of the 110 values flagged as potential ID errors, 8% (9) were found to be mislabeled; the remaining causes for "false positives" were interim transfusion (49%), no error (36%), and failure due to another problem (7%).

Doctor and Strylewicz (2010)[96] used a Bayesian network to detect mismatches between glucose and $HgbA_{1C}$ data using a large dataset with randomly and intentionally mismatched values. The study compared a Bayesian network to standard error detection software and human observers for error detection. Compared with another automated system, given a pre-determined specificity of 95%, the Bayesian network had higher sensitivity for detecting mismatches than the comparative system (area under the curve [AUC] 0.65 vs. 0.55, respectively; p <0.0001). Neither system was as successful at detecting clinically insignificant errors. Of note, the standard error-detection system was designed to use more data for determining mismatches than was provided in this study. The authors also compared the Bayesian network to human observers. Study participants were asked to report likelihood of error using a Likert scale. The Bayesian network had higher accuracy than 7 of 11 participants and was not worse than the remaining 4 participants.

Two Sample Protocol

A single-center UK study by Thomas et al. (2014)[94] evaluated whether implementation of a two-sample protocol decreased wrong blood in tube (WBIT) errors. No change in WBIT tube rates from 2010 to 2013 (0.22 to 0.25 per 1,000 samples) was observed, despite implementation of the new policy in August 2011. Notably, the study failed to report how errors were measured. Observation and survey of 160 staff found that 15% reported not labeling samples at the bedside, 26% had not completed appropriate training, and 28% reported not identifying patients according to correct procedures.

Multicomponent Intervention

Seferian et al. (2014)[95] described a multicomponent quality improvement initiative implemented over 24 months and aimed at decreasing the error rate of specimen labeling at Cedars-Sinai Medical Center. The study measured labeling errors for inpatient blood and body fluid specimens defined as either (1) any mismatch between specimen and requisition, (2) inaccurate patient identifiers, or (3) unlabeled specimens; all errors were confirmed by a multidisciplinary team.

The intervention consisted of staff engagement, data transparency with monthly reporting, event reviews/root cause analyses, and process changes; components were introduced in a stepwise fashion. Specifically, process changes included ID label redesign (increasing font and boldness of MRN), two-person verification, incorporation of patients into verification process, removing extra labels from ORs after cases, bar-code scanning of point-of-care tests, and highlighting of patient ID and MRN in the ICU and ER. Compared with baseline rates (6 months before intervention) the ID error rate decreased from 4.39 to 1.97 per 10,000 over 2 years. Improvements in error rates were seen across all settings except for labor and delivery and OR/post-anesthesia care unit. The most effective components were initial label redesign and patient engagements in ID verification.

Rizk et al. (2014)[97] found a significant reduction in incomplete chemistry laboratory requisition forms (1.02% vs. 0.24%, p = 0.001) after an educational initiative for nurses, technicians, and secretaries involved with handling specimens.

Blood Transfusion

We identified two systematic reviews[10,99] and one study[100] describing interventions focused on decreasing ID errors for blood transfusion.

A review by Cottrell et al. (2013)[99] identified interventions used to decrease WBIT errors in transfusion. The review included five studies on single interventions and four studies on multicomponent interventions. Single-intervention studies evaluated diverse interventions, including changes in specimen labeling (e.g., incorporating a handwritten component, introducing an electronic transfusion system), weekly incidence reporting, and confirmatory blood-grouping samples. All studies found a reduction in WBIT after intervention. Studies of multicomponent interventions

used combinations of education, changes to labeling and consent policies, confirmatory grouping, and additional nurse training. These studies also reported decreased WBIT with each intervention, although one study in the review (Gallagher-Swann, 2011) noted that the improvement did not persist two years after intervention.

A subsequent retrospective study by Nuttall et al. (2013)[100] described patient ID errors after introduction of bar-coding systems at the Mayo Clinic. Before the systems were implemented, patient ID was verified by ID number, and errors were voluntarily reported by staff administering blood. Compared with baseline (errors over 3 years prior), there was no significant decrease in erroneous transfusions 3 years after implementation (6 events vs. 1 event, p = 0.14); the post-implementation transfusion error rate was 0.3 per 100,000 transfusions. The single wrong-transfusion error after implementation occurred because the unit of blood was not scanned until *after* administration. Forty-three near misses were identified by the bar-coding system: nine were attributed to merged clinic numbers for the correct patient (ID number updated after order for blood was placed); the remainder were deemed "true" near misses.

Radiofrequency Identification (RFID)

Coustasse et al. (2015)[10] performed a review describing RFID use to improve tracking in blood transfusion. The review included 56 case reports of RFID implementation, but only 2 studies reported on changes in clinical outcomes. One of the included studies, Porcella and Winter (2005), implemented RFID in an Iowa hospital system for transfusion medicine; an initial pilot study in 5 hospital units found that detection of misidentified patients/blood products increased from 3% to 10%. When implemented system-wide, the detection rate increased to 30%. Another included study, Change et al. (2008), found that detection of misidentified products increased by 19% after implementing RFID at a blood center.

Drawing on the experience of numerous case reports of RFID implementation, the authors note that RFID offers significant potential benefits for blood bank supply-chain management including the following:

- Ability to scan items without being in close proximity
- Ability to simultaneously scan multiple items
- Reusability of tags
- Ability to ensure proper storage and handling throughout the supply chain
- Automation of reconciliation and inventory check-in
- Ability to track tainted blood
- Ability to monitor temperature and age of samples (factors that can contribute to degradation)

However, RFID can also pose unique challenges. For example, high-powered RFID readers may interfere with other medical devices, even causing failure. Readability of RFID can be affected by read range and existence of multiple tagged objects. Privacy concerns include the possibility that chips could be read by unauthorized readers, compromising sensitive health information. Also, concerns have been raised by the American Association of Blood Blanks that tags may have biochemical or morphologic effects on blood products. Finally, implementation cost may prove a barrier: tags may cost 10 to 15 times more than traditional bar-coding systems, and RFID systems range in cost from $20,000 to more than $1 million.

Pathology Specimens

Three studies[11,101,102] described interventions addressing ID errors for non-blood specimens.

Francis et al. (2009)[11] compared rates of unlabeled, wrong-site or wrong-patient errors before and after introducing an RFID system in endoscopy suite specimens at Mayo Clinic. Use of paperless requisitions and dual provider confirmation (by endoscopist and nurse) of site and procedure were also initiated at the same time. More than 10,000 specimens were processed during the 2 study periods. Error rates significantly decreased from 7 (0.09%) to 2 (0.02%), p = 0.001 after implementation; both post-implementation errors were detected and corrected before specimen processing.

Marberger et al. (2011)[101] described the use of DNA profiling to detect ID errors in prostate biopsy samples as part of the REDUCE study, a clinical trial spanning 800 sites in 42 countries. After discovering two mismatches in the second year of the trial, an intervention consisting of education for staff on specimen handling, visual inspection, and a bar-coding system was initiated. Errors were measured by DNA testing that compared each biopsy to a blood sample. If potential mismatches were identified, other biopsy and blood samples were tested until the correct source of the mismatch was confirmed. After the intervention, the biopsy mismatch rate (determined by DNA testing) decreased from 0.4% to 0.02%.

Meyer et al. (2009)[102] assessed the impact of altering Papanicolaou (Pap) slide labeling on ID error rates. At baseline, placement of labels covered handwritten patient identifiers. To confirm the patient ID on the label, cytotechnologists were typically required flip the slide over to identify the handwritten identifier through the back of the slide. The study intervention changed the placement of the ID label to the "top" of the slide, allowing technologists to simply compare the label on the "top" with handwritten identifiers on the "bottom" of the slide. Over a baseline period of 1 month, 17 of 2,844 Pap smears were mislabeled (e.g., patient identifiers on label did not match handwritten information). However, after the intervention, no errors were found of the 34,335 slides processed. Notably, the errors tracked included only erroneous slides presented to cytotechnologists or discovered during 10% quality improvement audits.

Table 3. Summary of Interventions and Study Characteristics

Clinical Context and Interventions	References	Study Design	Objective Outcome Measure
Patient Matching (Systems Level)			
Naturalistic matching algorithm	Lee et al. (2015)[75]	Validation	Yes
Improving Registration Process			
Standardized reporting of "red flags" for mistaken identity	Judson et al. (2014)[14]	Pre/Post	Not reported (NR)
Accuracy and Proper Use of Patient Identification (ID) Wristbands			
Quality improvement initiative	Phillips et al. (2012)[57] Hain et al. (2010)[76]	Pre/Post Pre/Post	No No
Order Entry and Charting			
ID verify alert / ID re-entry	Adelman et al. (2013)[8]	Randomized controlled trial	Yes*
ID alert + 2.5 second delay	Green et al. (2014)[77]	Pre/Post	Yes*
ID alert	Wilcox et al. (2011)[78]	Pre/Post	Yes
ID alert + photograph	Hyman et al. (2012)[3]	Pre/Post	No
New newborn naming convention	Adelman et al. (2015)[5]	Pre/Post	Yes*
Medication and Breast Milk Administration Errors			
Bar-coding technology (medication administration)	Young et al. (2010)[79] Poon et al. (2010)[9] Sakushima et al. (2015)[80] Higgins et al. (2010)[81]	Systematic Review (SR) Observational, controlled Pre/Post Pre/Post	Not applicable (N/A) Yes No No
Bar-coding technology + protocol change (breast milk administration)	Steele and Bixby (2014)[67]	Pre/Post	NR
Protocols/Checklists	White et al. (2010)[82]	Controlled, crossover	Yes

Clinical Context and Interventions	References	Study Design	Objective Outcome Measure
	Spruill et al. (2009)[83]	Pre/Post	NR
Point-of-Care Testing (Glucose)			
Bar-coding technology	Alreja et al. (2011)[84]	Pre/Post	NR
Radiology Acquisition and Procedures			
Protocols/checklists	Rubio and Hogan (2015)[85] Danaher et al. (2011)[16]	Pre/Post Pre/Post	No No
Implementing DICOM workflow	Pandit et al. (2015)[86]	Pre/Post	No
Displaying patient photograph with images	Tridandapani et al. (2015)[4] Tridandapani et al. (2013)[88] Tridandapani et al. (2014)[87]	Controlled, crossover Controlled, crossover Validation	Yes Yes Yes
Automated algorithms to identify ID errors before radiation therapy	Jani et al. (2015)[89] Lamb et al. (2013)[12]	Validation Validation	Yes Yes
Identifying Misfiled Radiology Images			
Creation of biologic "fingerprint" using biologic markers	Toge et al. (2013)[90] Kao et al. (2013)[91]	Validation Validation	Yes Yes
Laboratory Medicine (General)			
Bar-coding technology	Snyder et al. (2012)[92]	Systematic review (SR)	N/A
Optical character recognition (OCR)	Hawker et al. (2014)[98]	Validation	Yes
Automated algorithms (complete blood count, HgA_{1c}/glucose)	Miller et al. (2015)[93] Doctor and Strylewicz (2010)[96]	Validation Validation	Yes Yes
Protocol (two sample)	Thomas et al. (2014)[94]	Pre/Post	NR
Multicomponent quality improvement initiative	Seferian et al. (2014)[95]	Pre/Post	Yes
Education	Rizk et al. (2014)[97]	Pre/Post	NR
Transfusion Medicine			
Labeling changes, electronic transfusion system, regular incidence reporting, confirmatory blood grouping, education	Cottrell et al. (2013)[99]	SR	N/A
Bar-coding technology	Nuttall et al. (2013)[100]	Pre/Post	No
Radiofrequency identification (RFID)	Coustasse et al. (2015)[10]	SR	N/A
Pathology			
RFID (endoscopy specimens)	Francis et al. (2009)[11]	Pre/Post	NR
Education, protocols, and bar-coding (prostate biopsy)	Marberger et al (2011)[101]	Pre/Post	Yes
Labeling changes (Papanicolaou smears)	Meyer et al. (2009)[102]	Pre/Post	No

*Although three studies used an objective outcome measure (the retract and reorder rate), this is only a surrogate measure for order-entry errors due to patient misidentification; in Adelman et al. (2012)[8] the study also included validation data regarding what proportion

of captured retract and reordered events were likely to be true misidentification events; however, this information is not reported in Green et al. (2014)[77] or Adelman et al. (2015)[5]

Evidence Base Quality Issues

The methodologic quality of intervention studies was highly variable, and many studies had significant flaws. Overall, two aspects of study design were particularly problematic: lack of true control groups and lack of objective study outcome measures. Although we required all intervention studies to be comparative for inclusion in this review, more than half (22 of 40) used a pre/post (before and after) study design and therefore lacked a parallel control group. Only one study (assessing ID alerts for improving the accuracy of order entry) was a randomized controlled trial (RCT; Adelman et al. [2012][8]). This large proportion of pre/post studies reflects the fact that many studies were reports of institutional quality improvement initiatives, many of which were retrospective. Inferring efficacy from such studies is problematic because the many variables that could affect outcomes are not controlled for. Thus, it is not possible to know with certainty whether a quality control intervention was actually responsible for the effects observed in the study. Furthermore, the Hawthorne effect, in which behavior changes when people know they are being observed, could also have distorted results. In one study of wristband use, when staff became aware that audits would be performed, the problem rate dropped from 20.4% to 6.5% even before introduction of the "intervention," the study's primary focus.[76] This effect may lead studies to overestimate an intervention's efficacy.

A second significant problem was a lack of objective outcome measures. Of 22 pre/post studies, 10 lacked objective outcome measures, and 7 did not report how the study outcome was measured. To measure ID errors, many studies relied on voluntary reporting, which is known to be unreliable. For instance, staff may not report errors due to fear of punitive actions (for themselves or others), and pragmatic barriers, such as lack of time or inconvenience of the reporting process itself. Notably, Danaher et al. (2011)[16] reported a significant increase in reported events after implementing an online reporting system that was easier to use. Without objective outcome measures, reliability of results may also be compromised by variation in how measurements were performed. For example, the self-audits used to capture wristband errors in Phillips et al. (2012)[57] were performed differently at each participating institution.

Discussion

Overall, we identified a large evidence base encompassing a wide variety of interventions and spanning a broad range of clinical contexts. Because we examined only the past six years of literature, this review does not represent a comprehensive picture, but reflects more recent technologies and interventions on this important patient safety topic. With regard to contributory problems and interventions, five overarching themes emerged:

- Improving design of physical, electronic, and assigned patient identifiers can decrease misidentification
- Providing identification alerts during order entry can decrease wrong-patient orders
- Using new technology and safety checks at automated-systems level can reduce errors and improve monitoring
- Improving registration measures can help protect against identity theft
- Gaining local cultural acceptance of processes is needed to provide feedback, monitor processes, and avoid workarounds

Table 4. Selected Problems and Solutions

Theme	Problems	Potential Solutions
Design can be improved for physical, electronic, and assigned patient identifiers	Physical (wristbands): Illegible (handwriting or font too small) Ink that degrades with water exposure Too small to accommodate identification (ID) sticker	 Larger fonts Nonsoluble ink, or clear protective covering Resize wristbands

Theme	Problems	Potential Solutions
	Inaccessible or removed during surgery	Two wristbands on patients undergoing procedures
	Physical (specimen labels): Inadequate demarcation between labels printed for consecutive patients	Separating labels for each patient with a label printed with large "X"s
	Electronic/Assigned (patient identifiers used in electronic health record [EHR]): Wrong orders placed in EHR	New neonatal naming convention to create more distinctive identifiers Display patient photograph along with other identifiers
Identification alerts during order entry can decrease wrong-patient orders	Provider distraction and fatigue More than 1 chart simultaneously open	ID verification alerts Allowing only 1 open patient chart at a time
New technology and automated- systems level safety checks can reduce errors and improve monitoring	Medication or transfusion errors Mislabeling of laboratory or pathology specimens (including wrong blood in tube)	Bar-coding technology systems Radiofrequency identification (RFID) systems 2 sample confirmations for blood typing Automated algorithms for serial laboratory results
	Misidentification of patients undergoing radiation therapy	Automated radiologic algorithms to verify identity prior to radiation
Improved institutional registration processes are needed to address identity theft	Inadequate registration processes (e.g., no photo ID requirement)	Require photo ID with patient registration
	Registration staff are not trained to recognize suspicious documents	Educate registration staff to recognize suspicious documents
	No standardized process for reporting	Standardize a process for reporting suspicious encounters
	Valuable patient identifiers (e.g., Social Security number [SSN]) may not be adequately protected	Avoid regularly printing identifiers like SSN on patient records
Local cultural acceptance is needed for providing feedback and ongoing monitoring and avoiding workarounds	Workarounds Adherence to existing ID protocols	Engage staff regarding their perception of problems and possible interventions Incorporate stakeholder feedback into intervention design

Improving Design of Physical, Electronic, and Assigned Patient Identifiers Can Decrease Misidentification

Confirming patient identity during clinical care fundamentally depends on the accuracy and usability of physical (e.g., wristbands, specimen labels), electronic (e.g., within EHR, radiology software) and assigned identifiers (e.g., for neonates). However, several studies identified problematic or inadequate aspects of identifier design, such as illegibility (small font or handwritten), ink that degraded with exposure to water, bands too narrow to accommodate the printed ID sticker, and lack of a clear covering to protect information from degradation. Notably, the majority of these design flaws can be addressed with relative ease, and in fact, studies often reported that redesigned wristbands were well received by staff and the increased usability may have contributed to increased adherence to ID protocols.

Interventions for altering electronic or assigned identifiers were similarly straightforward, such as displaying a patient photograph along with other identifiers in the EHR[3] and radiology films,[4] or using a new naming convention for neonates to produce more distinctive names.[5] The relative simplicity of these varied interventions (e.g., larger wristband size, using different ink, adding a photograph) suggests that important strides towards reducing

identification errors may be achieved with fairly basic, low-technology measures, as long as they reflect smart, thoughtful design. If ID protocols are not being followed, institutions should consider seeking feedback from staff, and minor alterations in design may prove helpful.

Providing Identification Alerts during Order Entry Can Decrease Wrong Patient Orders

Evidence from several studies suggests pop-up ID verification alerts can significantly reduce wrong-patient orders. However, although successful in a study context, implementing ID alerts more widely may present important challenges. Although such alerts can decrease errors, healthcare staff may perceive addition of another alert as cumbersome. Studies suggest providers already override between 49% and 96% of alerts that arise during order entry.[3] Creating another alert may simply add to "alarm fatigue," in which users are inundated with system notifications and routinely tune them out. Furthermore, given the time constraints many staff work under, adding a new alert that users must address inevitably has an opportunity cost. Adelman et al. (2013)[8] reported that attending to this additional alert required an additional 6.6 seconds per ordering session. Although this duration may seem trivial, the authors noted that in the aggregate, this would represent roughly 3,300 hours annually at their institution alone. Future studies should assess whether reductions in wrong-patient orders are significant enough to warrant this addition, perhaps by assessing what proportion of wrong orders fail to be detected by other safety mechanisms (i.e., pharmacy review) and reach the patient. Such studies could also explore whether such alerts could be targeted for particular "high risk" populations or providers.

Using New Technology and Automated Systems-level Safety Checks Can Reduce Errors and Improve Monitoring

Although any technological intervention to promote proper patient identification can be sidestepped by human error, technologies such as bar-coding systems and RFID can substantively increase error detection and allow for real-time monitoring in a wide variety of clinical contexts, from medication administration to tracking of blood and pathology samples.[9-11] Several validation studies also assessed automated algorithms developed to detect potential ID errors by comparing new patient data with prior data using hematologic and radiologic data.[12] Such algorithms are promising in that they automate the process of identity confirmation and can act as a systems-level surveillance for human errors. For transfusion medicine, policies requiring a confirmatory second sample for blood typing and use of a centralized database to track prior results function similarly. Aside from bar-coding systems and two sample/central database use for transfusion, these interventions do not appear to have been widely adopted. However, if implemented, such automated algorithms and policies could provide another level of automatic surveillance for errors that does not rely on human adherence to protocols. Furthermore, many of these interventions (bar coding, RFID) involve real-time data collection and allow for objective measurement of error rates, all crucial for ongoing quality improvement initiatives.

Improved institutional registration processes are needed to address identity theft. A recent report suggested that medical identity theft in the United States is rising, with 2.32 million adult victims in 2014, a 21.7% increase over the prior year's results.[13] Detection is challenging because victims may not report a theft or may willingly allow another person to use their credentials;[13] institutions may not report discrepancies because of concerns about losing reimbursement.[14] Institutions should proactively meet this challenge by strengthening the fidelity of the registration process. Measures to improve this process could include requesting photographic ID for all registering patients, educating registration staff about characteristics of documents that should raise suspicion for ID theft, and finally, creating a standardized reporting process for when suspicious documents are encountered.[14] Also, institutions should work to protect important patient identifiers such as Social Security numbers by ensuring, for instance, that such information is not routinely printed with all patient records.[15] Obviously, in some emergency contexts, obtaining photo ID is not feasible. Biometric identifiers (i.e. fingerprints, vein mapping, retina scan matching) represent an attractive potential future solution, but uptake of these technologies may continue to be slow due to concerns about patient acceptance and implementation costs.

Gaining Local Cultural Acceptance of Processes is Needed to Provide Feedback, Monitor Processes, and Avoid Workarounds

Local cultural acceptance of processes is needed to be able to provide feedback, monitor processes, and avoid workarounds. Although various technologies can reduce ID errors and newer technologies are emerging, thorough

and lasting changes to practice will also require the support of local healthcare staff. We note that workarounds continued to pose a problem for many interventions, even for technologies such as bar-coding systems. One study found that 20% of medications continued to be given without scanning the bar code, despite an institutional policy requiring medications be scanned and linked to an electronic medication record.[9] Another study of a safety checklist for patients undergoing surgery found that staff routinely certified completion of the final steps of the protocol before the patient had even entered the building.[16] In some contexts such as the NICU, the unit's local culture also contributed to the widespread practice of placing wristbands on adjoining equipment instead of patients themselves. These examples from varied settings underscore the importance of involving local staff in acknowledging problems and being engaged in proposed interventions. In fact, buy-in and participation by healthcare staff is may itself lead to better interventions. Sustainable long-term improvements are likely to require ongoing engagement and feedback from staff to improve intervention designs and promote a better local culture of patient safety.

Conclusions

Proper patient ID confirmation at every step of clinical care is vital to patient safety. However, despite the priority placed on addressing this issue by The Joint Commission and others, significant problems persist. Studies have assessed a variety of interventions aimed at reducing patient ID errors across a wide range of clinical contexts. Although the evidence base has significant gaps, we conclude that patient ID errors can be avoided by improving usability of physical, electronic, and assigned patient identifiers; using well-designed ID alerts during order entry; and employing technologies and automated algorithms for systems-level safety checks. Given the increasing problem of identity theft, improvements in institutional registration processes are needed. Although each of these measures can provide significant reductions, sustained improvements will likely require a combination of good design, smart technology, local cultural acceptance by staff of the processes to be used, and measurement of outcomes to determine what combination of approaches works best and in which clinical scenarios.

References

1. National Patient Safety Goals. [Web site]. Oakbrook Terrace (IL): The Joint Commission; [accessed 2016 Apr 12]. Available: http://www.jointcommission.org/standards_information/npsgs.aspx.

2. Burrows JM, Callum JL, Belo S, Etchells E, Leeksma A. Variable pre-transfusion patient identification practices exist in the perioperative setting. Can J Anaesth. 2009 Dec;56(12):901-7. Also available: http://dx.doi.org/10.1007/s12630-009-9180-0. PMID: 19816751.

3. Hyman D, Laire M, Redmond D, Kaplan DW. The use of patient pictures and verification screens to reduce computerized provider order entry errors. Pediatrics. 2012 Jul;130(1):e211-e219. Also available: http://dx.doi.org/10.1542/peds.2011-2984. PMID: 22665415.

4. Tridandapani S, Olsen K, Bhatti P. Improvement in detection of wrong-patient errors when radiologists include patient photographs in their interpretation of portable chest radiographs. J Digit Imaging. 2015 Dec;28(6):664-70. Also available: http://dx.doi.org/10.1007/s10278-015-9808-2. PMID: 26123980.

5. Adelman J, Aschner J, Schechter C, Angert R, Weiss J, Rai A, Berger M, Reissman S, Parakkattu V, Chacko B, Racine A, Southern W. Use of Temporary Names for Newborns and Associated Risks. Pediatrics. 2015 Aug;136(2):327-33. Also available: http://dx.doi.org/10.1542/peds.2015-0007. PMID: 26169429.

6. Levin HI, Levin JE, Docimo SG. "I meant that med for Baylee not Bailey!": a mixed method study to identify incidence and risk factors for CPOE patient misidentification. AMIA Annu Symp Proc. 2012;1294-301. PMID: 23304408.

7. Galanter W, Falck S, Burns M, Laragh M, Lambert BL. Indication-based prescribing prevents wrong-patient medication errors in computerized provider order entry (CPOE). J Am Med Inform Assoc. 2013 May 1;20(3):477-81. Also available: http://dx.doi.org/10.1136/amiajnl-2012-001555. PMID: 23396543.

8. Adelman JS, Kalkut GE, Schechter CB, Weiss JM, Berger MA, Reissman SH, Cohen HW, Lorenzen SJ, Burack DA, Southern WN. Understanding and preventing wrong-patient electronic orders: a randomized controlled trial. J Am Med Inform Assoc. 2013 Mar-Apr;20(2):305-10. Epub 2012 Jun 29. Also available: http://dx.doi.org/10.1136/amiajnl-2012-001055. PMID: 22753810.

9. Poon EG, Keohane CA, Yoon CS, Ditmore M, Bane A, LevtzionKorach O, Moniz T, Rothschild JM, Kachalia AB, Hayes J, Churchill WW, Lipsitz S, Whittemore AD, Bates DW, Gandhi TK. Effect of bar-code technology on the safety of medication administration. N Engl J Med. 2010 May 6;362(18):1698-707. Also available: http://dx.doi.org/10.1056/NEJMsa0907115. PMID: 20445181.

10. Coustasse A, Meadows P, Hall RS, Hibner T, Deslich S. Utilizing Radiofrequency Identification Technology to Improve Safety and Management of Blood Bank Supply Chains. Telemed J E Health. 2015 Nov;21(11):938-45. Also available: http://dx.doi.org/10.1089/tmj.2014.0164. PMID: 26115103.

11. Francis DL, Prabhakar S, Sanderson SO. A quality initiative to decrease pathology specimen-labeling errors using radiofrequency identification in a high-volume endoscopy center. Am J Gastroenterol. 2009 Apr;104(4):972-5. Also available: http://dx.doi.org/10.1038/ajg.2008.170. PMID: 19259073.

12. Lamb JM, Agazaryan N, Low DA. Automated patient identification and localization error detection using 2-dimensional to 3-dimensional registration of kilovoltage x-ray setup images. Int J Radiat Oncol Biol Phys. 2013 Oct 1;87(2):390-3. Also available: http://dx.doi.org/10.1016/j.ijrobp.2013.05.021. PMID: 23849694.

13. Ponemon Institute LLC. Fifth annual study on medical identity theft. Sponsored by the Medical Identity Fraud Alliance with support from: Kaiser Permanente, ID Experts, Experian Data Breach Resolution and Identity Finder, LLC. Traverse City (MI): Ponemon Institute LLC; 2015 Feb. 38 p. Also available: http://medidfraud.org/wp-content/uploads/2015/02/2014_Medical_ID_Theft_Study1.pdf.

14. Judson T, Haas M, Lagu T. Medical identity theft: prevention and reconciliation initiatives at Massachusetts General Hospital. Jt Comm J Qual Patient Saf. 2014 Jul;40(7):291-5. PMID: 25130011.

15. Mancilla D, Moczygemba J. Exploring medical identity theft. Perspect Health Inf Manag. 2009;6:1e.

16. Danaher LA, Howells J, Holmes P, Scally P. Is it possible to eliminate patient identification errors in medical imaging? J Am Coll Radiol. 2011 Aug;8(8):568-74. Also available: http://dx.doi.org/10.1016/j.jacr.2011.02.021. PMID: 21807351.

17. Salinas M, Lopez-Garrigos M, Lillo R, Gutierrez M, Lugo J, Leiva-Salinas C. Patient identification errors: the detective in the laboratory. Clin Biochem. 2013 Nov;46(16-17):1767-9. Epub 2013 Aug 16. Also available: http://dx.doi.org/10.1016/j.clinbiochem.2013.08.005. PMID: 23958395.

18. Hoffmeister LV, de Moura GM. Use of identification wristbands among patients receiving inpatient treatment in a teaching hospital. Rev Lat Am Enfermagem. 2015 Jan-Feb;23(1):36-43. Also available: http://dx.doi.org/10.1590/0104-1169.0144.2522. PMID: 25806629.

19. Dunn EJ, Moga PJ. Patient misidentification in laboratory medicine: a qualitative analysis of 227 root cause analysis reports in the Veterans Health Administration. Arch Pathol Lab Med. 2010 Feb;134(2):244-55. Also available: http://dx.doi.org/10.1043/1543-2165-134.2.244. PMID: 20121614.

20. Yamamoto LG. Reducing emergency department charting and ordering errors with a room number watermark on the electronic medical record display. Hawaii J Med Public Health. 2014 Oct;73(10):322-8. PMID: 25337450.

21. Rebello E, Kee S, Kowalski A, Harun N, Guindani M, Goravanchi F. Reduction of incorrect record accessing and charting patient electronic medical records in the perioperative environment. Health Inform J. 2015 Oct 14; Also available: http://dx.doi.org/10.1177/1460458215608901. PMID: 26470715.

22. Latham T, Malomboza O, Nyirenda L, Ashford P, Emmanuel J, M'baya B, Bates I. Quality in practice: implementation of hospital guidelines for patient identification in Malawi. Int J Qual Health Care. 2012 Dec;24(6):626-33. PMID: 22833617.

23. Fyhr A, Akselsson R. Characteristics of medication errors with parenteral cytotoxic drugs. Eur J Cancer Care (Engl). 2012 Sep;21(5):606-13. Also available: http://dx.doi.org/10.1111/j.1365-2354.2012.01331.x. PMID: 22335508.

24. Bohand X, Aupee O, Le Garlantezec P, Mullot H, Lefeuvre L, Simon L. Medication dispensing errors in a French military hospital pharmacy. Pharm World Sci. 2009 Aug;31(4):432-8. Epub 2009 Mar 21. Also available: http://dx.doi.org/10.1007/s11096-009-9290-3. PMID: 19306071.

25. Zeilhofer UB, Frey B, Zandee J, Bernet V. The role of critical incident monitoring in detection and prevention of human breast milk confusions. Eur J Pediatr. 2009 Oct;168(10):1277-9. Also available: http://dx.doi.org/10.1007/s00431-008-0917-5. PMID: 19148678.

26. Cohen MR, Smetzer JL, Westphal JE, Comden SC, Horn DM. Risk models to improve safety of dispensing high-alert medications in community pharmacies. J Am Pharm Assoc. 2012 Sep-Oct;52(5):584-602. Also available: http://dx.doi.org/10.1331/JAPhA.2012.10145. PMID: 23023839.

27. Thomas MJ, Schultz TJ, Hannaford N, Runciman WB. Mapping the limits of safety reporting systems in health care--what lessons can we actually learn? Med J Aust. 2011 Jun 20;194(12):635-9. PMID: 21692720.

28. Neily J, Mills PD, Eldridge N, Carney BT, Pfeffer D, Turner JR, Young-Xu Y, Gunnar W, Bagian JP. Incorrect surgical procedures within and outside of the operating room: a follow-up report. Arch Surg. 2011 Nov;146(11):1235-9. Also available: http://dx.doi.org/10.1001/archsurg.2011.171. PMID: 21768408.

29. Paull DE, Mazzia LM, Neily J, Mills PD, Turner JR, Gunnar W, Hemphill R. Errors upstream and downstream to the Universal Protocol associated with wrong surgery events in the Veterans Health Administration. Am J Surg. 2015 Jul;210(1):6-13. Also available: http://dx.doi.org/10.1016/j.amjsurg.2014.10.030. PMID: 25873162.

30. Stahel PF, Sabel AL, Victoroff MS, Varnell J, Lembitz A, Boyle DJ, Clarke TJ, Smith WR, Mehler PS. Wrong-site and wrong-patient procedures in the universal protocol era: analysis of a prospective database of physician self-reported occurrences. Arch Surg. 2010 Oct;145(10):978-84. Also available: http://dx.doi.org/10.1001/archsurg.2010.185. PMID: 20956767.

31. Wong DA, Herndon JH, Canale ST, Brooks RL, Hunt TR, Epps HR, Fountain SS, Albanese SA, Johanson NA. Medical errors in orthopaedics. Results of an AAOS member survey. J Bone Joint Surg Am. 2009 Mar 1;91(3):547-57. Also available: http://dx.doi.org/10.2106/JBJS.G.01439. PMID: 19255214.

32. Sadigh G, Loehfelm T, Applegate KE, Tridandapani S. JOURNAL CLUB: Evaluation of Near-Miss Wrong-Patient Events in Radiology Reports. AJR Am J Roentgenol. 2015 Aug;205(2):337-43. Also available: http://dx.doi.org/10.2214/AJR.14.13339. PMID: 26204284.

33. Kelly JJ, Farley H, O'Cain C, Broida RI, Klauer K, Fuller DC, Meisl H, Phelan MP, Thallner E, Pines JM. A survey of the use of time-out protocols in emergency medicine. Jt Comm J Qual Patient Saf. 2011 Jun;37(6):285-8. PMID: 21706988.

34. Sindhulina C, Joseph NJ. Addressing sample identification errors in a multispecialty tertiary care hospital in Bangalore. Vox Sang. 2014 Aug;107(2):153-7. Also available: http://dx.doi.org/10.1111/vox.12139. PMID: 24602024.

35. Carraro P, Zago T, Plebani M. Exploring the initial steps of the testing process: frequency and nature of pre-preanalytic errors. Clin Chem. 2012 Mar;58(3):638-42. Also available: http://dx.doi.org/10.1373/clinchem.2011.175711. PMID: 22205692.

36. Upreti S, Upreti S, Bansal R, Jeelani N, Bharat V. Types and frequency of preanalytical errors in haematology lab. J Clin Diagn Res. 2013 Nov 10;7(11):2491-93. Also available: http://dx.doi.org/10.7860/JCDR/2013/6399.3587.

37. Layfield LJ, Anderson GM. Specimen labeling errors in surgical pathology: an 18-month experience. Am J Clin Pathol. 2010 Sep;134(3):466-70. Also available: http://dx.doi.org/10.1309/AJCPHLQHJ0S3DFJK. PMID: 20716804.

38. Bixenstine PJ, Zarbo RJ, Holzmueller CG, Yenokyan G, Robinson R, Hudson DW, Prescott AM, Hubble R, Murphy MM, George CT, D'Angelo R, Watson SR, Lubomski LH, Berenholtz SM. Developing and pilot testing practical measures of preanalytic surgical specimen identification defects. Am J Med Qual. 2013 Jul-Aug;28(4):308-14. Epub 2013 Jan 15. Also available: http://dx.doi.org/10.1177/1062860612469824. PMID: 23322909.

39. Lichenstein R, O'Connell K, Funai T, Blumberg S, Shaw K, Ruddy R, Mahajan PV, Chamberlain JM. Laboratory errors in a pediatric emergency department network: an analysis of incident reports. Pediatr Emerg Care. 2015 Apr 1;Epub ahead of print. Also available: http://dx.doi.org/10.1097/PEC.0000000000000414. PMID: 25834966.

40. Snydman LK, Harubin B, Kumar S, Chen J, Lopez RE, Salem DN. Voluntary electronic reporting of laboratory errors: an analysis of 37,532 laboratory event reports from 30 health care organizations. Am J Med Qual. 2012 Mar-Apr;27(2):147-53. Also available: http://dx.doi.org/10.1177/1062860611413567. PMID: 21918013.

41. Bell CG, Wood DR, Cheong SJ, Kwan E, Sinosich M, Delprado W, Baumgart KW. Molecular confirmation of pathological specimen integrity in Australasia. Pathology (Phila). 2009;41(3):280-3. Also available: http://dx.doi.org/10.1080/00313020902756311. PMID: 19291541.

42. Rensburg MA, Nutt L, Zemlin AE, Erasmus RT. An audit on the reporting of critical results in a tertiary institute. Ann Clin Biochem. 2009 Mar;46(Pt 2):162-4. Also available: http://dx.doi.org/10.1258/acb.2008.008182. PMID: 19225027.

43. Vuk T, Cipek V, Hecimovic A, Jukic I. Wrong blood in tube error: first study on donor blood samples. Transfusion. 2014 Apr;54(4):1200-2. Also available: http://dx.doi.org/10.1111/trf.12549. PMID: 24724790.

44. Varey A, Tinegate H, Robertson J, Watson D, Iqbal A. Factors predisposing to wrong blood in tube incidents: a year's experience in the North East of England. Transfus Med. 2013 Oct;23(5):321-5. Also available: http://dx.doi.org/10.1111/tme.12050. PMID: 23808358.

45. Delaney M, Dinwiddie S, Nester TN, Aubuchon JA. The immunohematologic and patient safety benefits of a centralized transfusion database. Transfusion. 2013 Apr;53(4):771-6. Also available: http://dx.doi.org/10.1111/j.1537-2995.2012.03789.x. PMID: 22803792.

46. Grimm E, Friedberg RC, Wilkinson DS, AuBuchon JP, Souers RJ, Lehman CM. Blood bank safety practices: mislabeled samples and wrong blood in tube--a Q-Probes analysis of 122 clinical laboratories. Arch Pathol Lab Med. 2010 Aug;134(8):1108-15. Also available: http://dx.doi.org/10.1043/2009-0674-CP.1. PMID: 20670129.

47. Askeland RW, McGrane SP, Reifert DR, Kemp JD. Enhancing transfusion safety with an innovative bar-code-based tracking system. Healthc Q. 2009;12 Spec No Patient:85-9. PMID: 19667783.

48. Ferrera-Tourenc V, Lassale B, Chiaroni J, Dettori I. Unreliable patient identification warrants ABO typing at admission to check existing records before transfusion. Transfus Clin Biol. 2015 Jun 1;22(2):66-70. Also available: http://dx.doi.org/10.1016/j.tracli.2015.03.004.

49. Pagliaro P, Turdo R, Capuzzo E. Patients' positive identification systems. Blood Transfus. 2009 Oct;7(4):313-8. Also available: http://dx.doi.org/10.2450/2009.0001-09. PMID: 20011643.

50. Elhence P, Shenoy V, Verma A, Sachan D. Error reporting in transfusion medicine at a tertiary care centre: a patient safety initiative. Clin Chem Lab Med. 2012 Nov;50(11):1935-43. Also available: http://dx.doi.org/10.1515/cclm-2012-0212. PMID: 23093085.

51. MacIvor D, Triulzi DJ, Yazer MH. Enhanced detection of blood bank sample collection errors with a centralized patient database. Transfusion. 2009 Jan;49(1):40-3. Also available: http://dx.doi.org/10.1111/j.1537-2995.2008.01923.x. PMID: 18798804.

52. McCullough J, McKenna D, Kadidlo D, Maurer D, Noreen HJ, French K, Brunstein C, Wagner JE. Mislabeled units of umbilical cord blood detected by a quality assurance program at the transplantation center. Blood. 2009 Aug 20;114(8):1684-8. Also available: http://dx.doi.org/10.1182/blood-2009-02-205047. PMID: 19487257.

53. Sevdalis N, Norris B, Ranger C, Bothwell S, Wristband Project Team. Closing the safety loop: evaluation of the National Patient Safety Agency's guidance regarding wristband identification of hospital inpatients. J Eval Clin Pract. 2009 Apr;15(2):311-5. Also available: http://dx.doi.org/10.1111/j.1365-2753.2008.01004.x. PMID: 19335490.

54. Ortiz J, Amatucci C. A case of mistaken identity: staff input on patient ID errors. Nursing Manage. 2009 Apr;40(4):37-41. Also available: http://dx.doi.org/10.1097/01.NUMA.0000349689.98615.6d. PMID: 19346924.

55. Phipps E, Turkel M, Mackenzie ER, Urrea C. He thought the "lady in the door" was the "lady in the window": a qualitative study of patient identification practices. Jt Comm J Qual Patient Saf. 2012 Mar;38(3):127-34. PMID: 22435230.

56. Henneman PL, Fisher DL, Henneman EA, Pham TA, Campbell MM, Nathanson BH. Patient identification errors are common in a simulated setting. Ann Emerg Med. 2010 Jun;55(6):503-9. Also available: http://dx.doi.org/10.1016/j.annemergmed.2009.11.017. PMID: 20031263.

57. Phillips SC, Saysana M, Worley S, Hain PD. Reduction in pediatric identification band errors: a quality collaborative. Pediatrics. 2012 Jun;129(6):e1587-93. Also available: http://dx.doi.org/10.1542/peds.2011-1911. PMID: 22566421.

58. Walley SC, Berger S, Harris Y, Gallizzi G, Hayes L. Decreasing patient identification band errors by standardizing processes. Hospital Pediatrics. 2013 Apr;3(2):108-17. PMID: 24340411.

59. Patient identification systems in obstetric units, and wristband conformity. Acta Paul Enfermagem. Jul/Aug 2015;28(4):374-81. Also available: http://dx.doi.org/10.1590/1982-0194201500063.

60. Heddle NM, Fung M, Hervig T, Szczepiorkowski ZM, Torretta L, Arnold E, Lane S, Murphy MF, BEST Collaborative. Challenges and opportunities to prevent transfusion errors: a Qualitative Evaluation for Safer Transfusion (QUEST). Transfusion. 2012 Aug;52(8):1687-95. Also available: http://dx.doi.org/10.1111/j.1537-2995.2011.03514.x. PMID: 22229518.

61. Smith AF, Casey K, Wilson J, Fischbacher-Smith D. Wristbands as aids to reduce misidentification: an ethnographically guided task analysis. Int J Qual Health Care. 2011 Oct;23(5):590-9. Also available: http://dx.doi.org/10.1093/intqhc/mzr045. PMID: 21828067.

62. Sevdalis N, Norris B, Ranger C, Bothwell S, Wristband Project Team. Designing evidence-based patient safety interventions: the case of the UK's National Health Service hospital wristbands. J Eval Clin Pract. 2009 Apr;15(2):316-22. Also available: http://dx.doi.org/10.1111/j.1365-2753.2008.01026.x. PMID: 19335491.

63. Quadrado ER, Tronchin DM. Evaluation of the identification protocol for newborns in a private hospital. Rev Lat Am Enfermagem. 2012 Jul-Aug;20(4):659-67. PMID: 22990150.

64. Magrabi F, Ong MS, Runciman W, Coiera E. Using FDA reports to inform a classification for health information technology safety problems. J Am Med Inform Assoc. 2012 Jan-Feb;19(1):45-53. PMID: 21903979.

65. Virginio LA, Ricarte IL. Identification of Patient Safety Risks Associated with Electronic Health Records: A Software Quality Perspective. Studies in Health Technology and Informatics. 2015;216:55-9. PMID: 26262009.

66. Harkanen M, Kervinen M, Ahonen J, Turunen H, Vehvilainen-Julkunen K. An observational study of how patients are identified before medication administrations in medical and surgical wards. Nursing & health sciences. 2015 Jun;17(2):188-94. Epub 2014 Jul 8. Also available: http://dx.doi.org/10.1111/nhs.12158. PMID: 25040901.

67. Steele C, Bixby C. Centralized breastmilk handling and bar code scanning improve safety and reduce breastmilk administration errors. Breastfeed Med. 2014 Nov;9(9):426-9. Also available: http://dx.doi.org/10.1089/bfm.2014.0077. PMID: 25243824.

68. Marquard JL, Henneman PL, He Z, Jo J, Fisher DL, Henneman EA. Nurses' behaviors and visual scanning patterns may reduce patient identification errors. J Exp Psychol Appl. 2011 Sep;17(3):247-56. Also available: http://dx.doi.org/10.1037/a0025261. PMID: 21942314.

69. Snyder ML, Carter A, Jenkins K, Fantz CR. Patient misidentifications caused by errors in standard bar code technology. Clin Chem. 2010 Oct;56(10):1554-60. Also available: http://dx.doi.org/10.1373/clinchem.2010.150094. PMID: 20702784.

70. Cottrell S, Davidson V. National audit of bedside transfusion practice. Nurs Stand. 2013 Jun 26-Jul 2;27(43):41-8. Also available: http://dx.doi.org/10.7748/ns2013.06.27.43.41.e7067. PMID: 23987720.

71. Spain D, Crilly J, Pierce J, Steele M, Scuffham P, Keijzers G. Can a barcode scanner for blood collection improve patient identification integrity in the emergency department? A prospective before-and-after study. EMA - Emergency Medicine Australasia. 2015 Feb;27(1):47-54. Also available: http://dx.doi.org/10.1111/1742-6723.12334. PMID: 25594877.

72. Hijji B, Parahoo K, Hossain MM, Barr O, Murray S. Nurses' practice of blood transfusion in the United Arab Emirates: an observational study. J Clin Nurs. 2010 Dec;19(23-24):3347-57. Also available: http://dx.doi.org/10.1111/j.1365-2702.2010.03383.x. PMID: 20955481.

73. Rees S, Stevens L, Mikelsons D, Quam E, Darcy T. Reducing specimen identification errors. J Nurs Care Qual. 2012 Jul-Sep;27(3):253-7. Also available: http://dx.doi.org/10.1097/NCQ.0b013e3182510303. PMID: 22446504.

74. Schmidt RL, Messinger BL, Layfield LJ. Internal labeling errors in a surgical pathology department: a root cause analysis. Lab Med. Spring 2013;44(2):176-85. Also available: http://dx.doi.org/10.1309/LMIENKGRN0AE39NG.

75. Lee ML, Clymer R, Peters K. A naturalistic patient matching algorithm: Derivation and validation. Health Inform J. 2015 Oct 11; Also available: http://dx.doi.org/10.1177/1460458215607080. PMID: 26460103.

76. Hain PD, Joers B, Rush M, Slayton J, Throop P, Hoagg S, Allen L, Grantham J, Deshpande JK. An intervention to decrease patient identification band errors in a children's hospital. Qual Saf Health Care. 2010 Jun;19(3):244-7. PMID: 20364035.

77. Green RA, Hripcsak G, Salmasian H, Lazar EJ, Bostwick SB, Bakken SR, Vawdrey DK. Intercepting wrong-patient orders in a computerized provider order entry system. Ann Emerg Med. 2015 Jun;65(6):679-686.e1. Epub 2014 Dec 18. Also available: http://dx.doi.org/10.1016/j.annemergmed.2014.11.017. PMID: 25534652.

78. Wilcox AB, Chen YH, Hripcsak G. Minimizing electronic health record patient-note mismatches. J Am Med Inform Assoc. 2011 Jul-Aug;18(4):511-4. Also available: http://dx.doi.org/10.1136/amiajnl-2010-000068. PMID: 21486875.

79. Young J, Slebodnik M, Sands L. Bar code technology and medication administration error. J Patient Saf. 2010 Jun;6(2):115-20. Also available: http://dx.doi.org/10.1097/PTS.0b013e3181de35f7. PMID: 22130354.

80. Sakushima K, Umeki R, Endoh A, Ito YM, Nasuhara Y. Time trend of injection drug errors before and after implementation of bar-code verification system. Technol Health Care. 2015 Jun 10;23(3):267-74. Also available: http://dx.doi.org/10.3233/THC-150897. PMID: 25669212.

81. Higgins T, Heelon M, Siano B, Douglass L, Liebro P, Spath B, Kudler N, Kerr G. Medication safety improves after implementation of positive patient identification. Appl Clin Inform. 2010;1(3):213-20. Also available: http://dx.doi.org/10.4338/ACI-2010-02-RA-0011. PMID: 23616837.

82. White RE, Trbovich PL, Easty AC, Savage P, Trip K, Hyland S. Checking it twice: an evaluation of checklists for detecting medication errors at the bedside using a chemotherapy model. Qual Saf Health Care. 2010 Dec;19(6):562-7. Also available: http://dx.doi.org/10.1136/qshc.2009.032862. PMID: 20724398.

83. Spruill A, Eron B, Coghill A, Talbert G. Decreasing patient misidentification before chemotherapy administration. Clin J Oncol Nurs. 2009 Dec;13(6):716-7. Also available: http://dx.doi.org/10.1188/09.CJON.716-717. PMID: 19948470.

84. Alreja G, Setia N, Nichols J, Pantanowitz L. Reducing patient identification errors related to glucose point-of-care testing. J Pathol Inform. 2011;2:22. Also available: http://dx.doi.org/10.4103/2153-3539.80718. PMID: 21633490.

85. Rubio EI, Hogan L. Time-out: it's radiology's turn-incidence of wrong-patient or wrong-study errors. AJR Am J Roentgenol. 2015 Nov;205(5):941-6. Also available: http://dx.doi.org/10.2214/AJR.15.14720. PMID: 26496541.

86. Pandit RR, Boland MV. Impact of digital imaging and communications in medicine workflow on the integration of patient demographics and ophthalmic test data. Ophthalmology. 2015 Feb;122(2):227-32. Also available: http://dx.doi.org/10.1016/j.ophtha.2014.08.036. PMID: 25439603.

87. Tridandapani S, Ramamurthy S, Provenzale J, Obuchowski NA, Evanoff MG, Bhatti P. A multiobserver study of the effects of including point-of-care patient photographs with portable radiography: a means to detect wrong-patient errors. Acad Radiol. 2014 Aug;21(8):1038-47. Also available: http://dx.doi.org/10.1016/j.acra.2014.03.006. PMID: 25018076.

88. Tridandapani S, Ramamurthy S, Galgano SJ, Provenzale JM. Increasing rate of detection of wrong-patient radiographs: use of photographs obtained at time of radiography. AJR Am J Roentgenol. 2013 Apr;200(4):W345-52. Also available: http://dx.doi.org/10.2214/AJR.12.9521. PMID: 23521477.

89. Jani SS, Low DA, Lamb JM. Automatic detection of patient identification and positioning errors in radiation therapy treatment using 3-dimensional setup images. Pract Radiat Oncol. 2015 Sep-Oct;5(5):304-11. Also available: http://dx.doi.org/10.1016/j.prro.2015.06.004. PMID: 26215586.

90. Toge R, Morishita J, Sasaki Y, Doi K. Computerized image-searching method for finding correct patients for misfiled chest radiographs in a PACS server by use of biological fingerprints. Radiol Phys Technol. 2013 Jul;6(2):437-43. Also available: http://dx.doi.org/10.1007/s12194-013-0221-6. PMID: 23771325.

91. Kao EF, Lin WC, Jaw TS, Liu GC, Wu JS, Lee CN. Automated patient identity recognition by analysis of chest radiograph features. Acad Radiol. 2013 Aug;20(8):1024-31. PMID: 23830608.

92. Snyder SR, Favoretto AM, Derzon JH, Christenson RH, Kahn SE, Shaw CS, Baetz RA, Mass D, Fantz CR, Raab SS, Tanasijevic MJ, Liebow EB. Effectiveness of barcoding for reducing patient specimen and laboratory testing identification errors: a Laboratory Medicine Best Practices systematic review and meta-analysis. Clin Biochem. 2012 Sep;45(13-14):988-98. Also available: http://dx.doi.org/10.1016/j.clinbiochem.2012.06.019. PMID: 22750145.

93. Miller I. Development and evaluation of a logical delta check for identifying erroneous blood count results in a tertiary care hospital. Arch Pathol Lab Med. 2015 Aug;139(8):1042-7. Also available: http://dx.doi.org/10.5858/arpa.2014-0494-OA. PMID: 26230597.

94. Thomas W, Davies J, Asamoah A, Scott-Molloy C, Sansom V, Kerr J. Two samples for blood transfusion: single centre experience. Transfus Med. 2014 Aug;24(4):209-12. Also available: http://dx.doi.org/10.1111/tme.12122. PMID: 24779632.

95. Seferian EG, Jamal S, Clark K, Cirricione M, Burnes-Bolton L, Amin M, Romanoff N, Klapper E. A multidisciplinary, multifaceted improvement initiative to eliminate mislabelled laboratory specimens at a large tertiary care hospital. BMJ Qual Saf. 2014 Aug;23(8):690-7. Also available: http://dx.doi.org/10.1136/bmjqs-2014-003005. PMID: 24915540.

96. Doctor JN, Strylewicz G. Detecting 'wrong blood in tube' errors: Evaluation of a Bayesian network approach. Artif Intell Med. 2010 Oct;50(2):75-82. Also available: http://dx.doi.org/10.1016/j.artmed.2010.05.008. PMID: 20566275.

97. Rizk MM, Zaki A, Hossam N, Aboul-Ela Y. Evaluating laboratory key performance using quality indicators in Alexandria University Hospital Clinical Chemistry Laboratories. J Egypt Public Health Assoc. 2014 Dec;89(3):105-13. Also available: http://dx.doi.org/10.1097/01.EPX.0000453262.85383.70. PMID: 25534174.

98. Hawker CD, McCarthy W, Cleveland D, Messinger BL. Invention and validation of an automated camera system that uses optical character recognition to identify patient name mislabeled samples. Clin Chem. 2014 Mar;60(3):463-70. Also available: http://dx.doi.org/10.1373/clinchem.2013.215434. PMID: 24366726.

99. Cottrell S, Watson D, Eyre TA, Brunskill SJ, DorÃ©e C, Murphy MF. Interventions to reduce wrong blood in tube errors in transfusion: a systematic review. Transfus Med Rev. 2013 Oct;27(4):197-205. Also available: http://dx.doi.org/10.1016/j.tmrv.2013.08.003. PMID: 24075096.

100. Nuttall GA, Abenstein JP, Stubbs JR, Santrach P, Ereth MH, Johnson PM, Douglas E, Oliver WC. Computerized bar code-based blood identification systems and near-miss transfusion episodes and transfusion errors. Mayo Clin Proc. 2013 Apr;88(4):354-9. Also available: http://dx.doi.org/10.1016/j.mayocp.2012.12.010. PMID: 23541010.

101. Marberger M, McConnell JD, Fowler I, Andriole GL, Bostwick DG, Somerville MC, Rittmaster RS. Biopsy misidentification identified by DNA profiling in a large multicenter trial. J Clin Oncol. 2011 May 1;29(13):1744-9. Also available: http://dx.doi.org/10.1200/JCO.2010.32.1646. PMID: 21444877.

102. Meyer E, Underwood RS, Padmanabhan V. Patient misidentification in Papanicolaou tests: a systems-based approach to reducing errors. Arch Pathol Lab Med. 2009 Aug;133(8):1297-300. Also available: http://dx.doi.org/10.1043/1543-2165-133.8.1297. PMID: 19653729.

103. Lichtner V, Galliers JR, Wilson S. A pragmatics' view of patient identification. Qual Saf Health Care. 2010 Oct;i13-9. Also available: http://dx.doi.org/10.1136/qshc.2009.036400. PMID: 20513792.

104. Strong Sean, Evans Kathryn, McNally Janet. The name game. BMJ: British Medical Journal (Overseas & Retired Doctors Edition). 2012 Aug 18;345(7870):45-6.

105. Jo J, Marquard JL, Clarke LA, Henneman PL. Re-examining the requirements for verification of patient identifiers during medication administration: No wonder it is error-prone. IIE Trans Healthc Syst Eng. 2013;3(4):280-91. Also available: http://dx.doi.org/10.1080/19488300.2013.862329.

106. Karim F, Moiz B, Shamsuddin N, Naz S, Khurshid M. Root cause analysis of non-infectious transfusion complications and the lessons learnt. Transfus Apher Sci. 2014 Feb;50(1):111-7. Also available: http://dx.doi.org/10.1016/j.transci.2013.10.004. PMID: 24239270.

107. Miller K, Akers C, Magrin G, Whitehead S, Davis AK. Piloting the use of 2D barcode and patient safety-software in an Australian tertiary hospital setting. Vox Sang. 2013 Aug;105(2):159-66. Also available: http://dx.doi.org/10.1111/vox.12034. PMID: 23600799.

108. Tinegate HN, Davies T, Elshaw RJ, Jane G, Lyon M, Norfolk DR, Plews DE, Troy CB, Watson D. When and why is blood crossmatched? A prospective survey of transfusion laboratory practice in two regions in the north of England. Vox Sang. 2010 Aug 1;99(2):163-7. Also available: http://dx.doi.org/10.1111/j.1423-0410.2010.01317.x. PMID: 20202181.

Appendix

Evidence Table 1. Key Question 1. What is the prevalence of patient identification errors in the clinical care setting?

Metadata	Country, Setting	Institution	Clinical Setting	Prospective	Recruitment	Method of Measurement	Duration	Results	Sampling Classification
Askeland et al. (2009)[47]	Not reported (NR)	Single institution	Transfusion	Yes	All patients	Automated data collection	2005-2008 (46 months)	0.15% of sample collections had prevented identification errors (PIEs) 0.17% of distributions had PIE 0.03% of administrations had PIE	
Bell et al. (2009)[41]	Australia	Single institution	Pathology	No	All suspected cases of mix-ups	Manual testing of specimens with forensic ABI Identifier kit (DNA testing)	2005 to 2007 (3 years)	6/23 samples discordant (indicating mix-up) (23.1%) 1/14 cases unable to be tested	14 cases, 23 patients (some cases had more than 1 patient)
Bixenstine et al. (2013)[38]	U.S.	Multi-institution (69 hospitals)	Pathology	Yes	Voluntary reporting	Performance measure reporting	2010 (3 months)	15.5% of container defects, 7.6% of requisition defects involved patient name or numeric identifier	60,501 surgical cases; 81,656 sample containers; 61,245 requisitions
Bohand et al. (2009)[24]	France	Single institution	Medication administration	Yes	All oral medications dispensed	Review of medication cassettes by pharmacist	April to December 2006 (9 months)	Overall error rate of 0.80% 37 wrong-patient administrations 5.2% of medication errors 0.38% of medication dispenses	9,719 medication dispenses

Metadata	Country, Setting	Institution	Clinical Setting	Prospective	Recruitment	Method of Measurement	Duration	Results	Sampling Classification
Carraro et al. (2012)[35]	Italy	Single institution	Clinical laboratory	Yes	All submitted specimens	Direct observation	(1 week) then 6-month study period October 2010 to March 2011	19 patient misidentification events out of the 304 errors reported (352 errors per 1 million orders)	8,547 test requests
Cohen et al. (2012)[26]	U.S.	None	Medication administration	No	Theoretical model	Event tree analysis	Theoretical	Preventable adverse drug events (PADEs) Dispensing warfarin to the wrong patient (1.22/1,000 prescriptions)	NA
Delaney et al. (2013)[45]	U.S.	Multi-institution	Transfusion	No	All samples	Data query for notated samples (reported wrong blood in tube)	2003 to 2009 (6 years) 2010 (1 year)	77/418,333 WBIT events (0.9/1000 samples)	418,333 specimens

Metadata	Country, Setting	Institution	Clinical Setting	Prospective	Recruitment	Method of Measurement	Duration	Results	Sampling Classification
Dunn and Moga (2010)[19]	U.S.	Veterans Health Administration (VA)	Wristband Charting and order entry Clinical laboratory Pathology Transfusion	No	Root cause analysis (RCA) reports	Natural language processing used to extract data from RCA reports (pre-screened)	2000-2008 (8 years)	182/253 adverse events caused by patient misidentification **Preanalytic:** 8/132 wrist bands wrong 31/132 orders placed on wrong patient 35/132 specimen labeling errors **Analytic:** 27/37 pathology labeling errors 10/37 microbiology laboratory errors **Postanalytic:** 8/13 results sent to wrong patient 5/13 wrong blood in tube (WBIT)	253 adverse events from within 227 reports, no baseline number of orders or adverse event error rate

Metadata	Country, Setting	Institution	Clinical Setting	Prospective	Recruitment	Method of Measurement	Duration	Results	Sampling Classification
Elhence et al. (2012)[50]	India	Single institution	Transfusion	Yes	All reported transfusions	Review of error reporting forms	April 2009 to March 2010 (12 months)	**All errors:** Actual events 0.23/1,000 units Near misses 4.49/1,000 units **Near misses:** 68/143 labeling events 1/143 placed on wrong patient **Preanalytic events:** 1 in 303 samples mislabeled (74/80 mislabeling events related to patient identification [ID] errors)	60,309 units (285 events)
Ferrera-Tourenc et al. (2015)[48]	France	Blood issues to Marseille Public Hospital System (4 hospitals)	Transfusion	No	All patient ID errors over 18 months	Query, centralized database	18 months	73 discrepancies (between new ABO typing and centralized database) were detected among 107,380 ABO tests performed—1 : 2,334 error rate	Discrepancy between ABO test and centralized database

Metadata	Country, Setting	Institution	Clinical Setting	Prospective	Recruitment	Method of Measurement	Duration	Results	Sampling Classification
Fyhr and Akselsson (2012)[23]	Sweden	National reporting system	Medication administration	No	All cytotoxic drugs given parenterally inpatient resulting in a medical error From lex Maria (1998-2006) From National Board of Health and Welfare (Sweden) 2006-2008 From other sources (non-systematic)	Manual report review	1996-2008	5/60 medical errors involved wrong patient receiving cytotoxic drug	101 medical errors, 44 met inclusion criteria Another 16 medical errors found from other sites (denominator NR)
Galanter et al. (2013)[7]	U.S.	Single institution	Charting and order entry	Yes	All alerted drug-problem list-check errors	Automated data capture flagged event Chart review used to detect near misses	2006-2012 (6 years)	32 intercepted wrong-patient errors Order entry error rate of 0.25/1,000 drug-problem list alerts	127,320 alerts
Grimm et al. (2010)[46]	U.S.	Multi-institution	Transfusion	Yes + no	Institution reported	Manual review of samples	30-day prospective 12-month retrospective	Mislabeled specimen rate 1.12% Wrong blood in tube (WBIT) rate 0.04% (95% confidence interval, 0.02% to 0.06%)	112,112 samples

Metadata	Country, Setting	Institution	Clinical Setting	Prospective	Recruitment	Method of Measurement	Duration	Results	Sampling Classification
Hoffmeister and de Moura (2015)[18]	Brazil	Single institution	Wristband	Yes	Proportional selection (single observation)	Direct observation	5 days	11.9% of patients had wristbands with errors (including wristband integrity) 32 name errors (8.67%) including incomplete name, misspellings, and wrong names 16 (4.33%) had mismatch between wristband medical record number (MRN) and computer MRN	385 patients
Judson et al. (2014)[14]	U.S.	Single institution	Registration	No	NR	Data integrity dashboard	NR	Estimated 120 duplicate records created each month, 25 related to fraud/identify theft 14 patients treated under wrong MRN each year	No denominator
Kelly et al. (2011)[33]	U.S.	Multiple institutions	Procedure	No	Survey	Questionnaire	Single instance, no time limit on event recall	5 (2%) reported they knew of an instance in which a time-out may have prevented an error 9/225 respondents reported knowledge of wrong-patient procedures within the emergency department (ED)	225 respondents

Metadata	Country, Setting	Institution	Clinical Setting	Prospective	Recruitment	Method of Measurement	Duration	Results	Sampling Classification
Latham et al. (2012)[22]	Malawi	Single institution	Transfusion and medication administration	No	95 participants	Survey	NR	22% reported being able to recall a patient who received blood intended for a different patient 34% reported more than once over the past year a patient might have received blood or medication intended for another patient	NR
Layfield and Anderson (2010)[37]	U.S.	Single institution	Pathology	Yes	All cases reviewed	Manual review	(18 months)	55/75 errors involve patient name (0.275% of cases have errors)	29,479 pathology cases
Levin et al. (2012)[6]	U.S.	Single institution	Charting and order entry	No	Members of AMDIS, a national organization of chief medical information officers (CMIOs) and 100 randomly selected clinicians in the local institution 2. Inpatient medication orders	Survey of physicians and CMIOs Automated data query	January to April 2011 May 2006 to April 2011	CMIOs reported patient misidentification a rare event after the initial electronic medical record (EMR) installation issues Physicians dichotomous in reporting frequent versus infrequent misidentification, but most report making an identification error 644/1,002,901 orders were likely order on misidentified patient (OOMP) 0.064% OOMP rate	1,002,901 orders

Metadata	Country, Setting	Institution	Clinical Setting	Prospective	Recruitment	Method of Measurement	Duration	Results	Sampling Classification
Lichenstein et al. (2015)[39]	U.S.	Multisite research network	Clinical laboratory	No	All incident reports classified as laboratory errors (ED)	Manual review of incident reports	July 2007-July 2008 (12 months)	92/793 were wrong patient (11.6%) Laboratory events occurred at a rate of 3.76 per 1,000 patients	793 laboratory errors From 2,906 incident reports
MacIvor et al. (2009)[51]	U.S.	Multisite institution	Transfusion	No	All ABO mismatches	Automated data query	2005-2007	25% of ABO errors due to mislabeled specimen 50% due to patient misidentification	16 events
McCullough et al. (2009)[52]	U.S.	Single institution	Transfusion	Yes	All cord blood units	Manual testing	January 1, 2002, to December 31, 2007 (6 years)	2/871 cord blood units mislabeled (0.2%)	871 cord blood units
Neily et al. (2011)[28]	U.S.	VA	Procedure	No	All incident reports	Automated database query	2006-2009	30 wrong-patient surgeries out of 101 events Only 2 occurred in operating room (OR); other 28 outside of OR	Proportion of events, absolute number of surgery NR

Metadata	Country, Setting	Institution	Clinical Setting	Prospective	Recruitment	Method of Measurement	Duration	Results	Sampling Classification
Paull et al. (2015)[29]	U.S.	Multisite institution	Surgical time-out	No	All incorrect surgeries	Automated data query from root cause analysis (RCA) database followed by manual review	2004-2013	308/484 RCAs were for wrong-patient or wrong-site surgery Looked for "wrong" event because of upstream/downstream events (i.e., mislabeled specimen resulted in the surgery) 48 cases of wrong surgery met criteria (16% of all 308 wrong-surgery events) 9/48 were wrong patient 6/9 because mislabeled report or specimen led to surgery decision 2/9 because of name similarity/ computerized physician order entry (CPOE) 1/9 because of scheduling error Wrong-patient surgeries at highest risk included prostatectomies and cataract implants Time-outs alone would not have prevented these surgeries	308 RCAs met wrong-surgery criteria 1,288 total events in database

Metadata	Country, Setting	Institution	Clinical Setting	Prospective	Recruitment	Method of Measurement	Duration	Results	Sampling Classification
Rebello et al. (2015)[21]	U.S.	Multisite institution	Charting and order entry	No	All anesthesia procedures	Automated data query	2009-2012	57 occurrences of incorrect chart opening/closing Incremental deployment of bar-coding scanners associated with downtrend in wrong-patient charting during anesthesia 75% of wrong-charting errors occurred at off-site locations	115,760 anesthesia records
Rensburg et al. (2009)[42]	South Africa	Single institution	Clinical laboratory	Yes	All communi-cations monitored	Direct observation	April 2008 (1 month)	51 total errors 3 (5.9%) errors in patient name 33 (64.7%) errors in folder number MRN The rest were related to laboratory results	472 telephone calls
Sadigh et al. (2015)[32]	U.S.	Single health system – two hospitals	Radiology	No	All images	Recognized errors — data search for "wrong patient" or "wrong dictation"	2009-2013 (53 months)	67 out of 1,717,713 (4 per 100,000) radiology reports with recognized patient identification errors	All samples
Salinas et al. (2013)[17]	Spain	Multisite institution, single laboratory	Registration	Yes	All patients	Manual review of registration data	2011-2012 (12 months)	Error rates of: 400/1,000,000 for electronic registration 754/1,000,000 for manual registration	161,097 patients

Metadata	Country, Setting	Institution	Clinical Setting	Prospective	Recruitment	Method of Measurement	Duration	Results	Sampling Classification
Sindhulina and Joseph (2014)[34]	India	Single institution	Clinical lab Transfusion	No	All orders	Reported, bedside blood grouping, delta check logging	2011-2012 (2 years)	General laboratory identification error rate: 48 per 1,000,000 in 2011 45 per 1,000,000 in 2012 Wrong blood in tube (WBIT) error rate baseline (2011) was 0.96 per 1,000.	
Snydman et al. (2012)[40]	U.S.	Multi-institution	Clinical laboratory	No	All reported events	Automated data query	January 2000 to December 2005 (6 years)	Specimens mislabeled 16.3% Incorrect patient ID 4.4%	37,522 events reported
Stahel et al. (2010)[30]	U.S.	Insurance network	Procedure	No, but prospective database	Self-reported adverse events	Automated query with manual review	2002-2008	25 wrong-patient procedures (27,370 adverse events) 5 of these resulted in "serious harm"	Self-reported adverse events
Thomas et al. (2011)[27]	Australia	National system	Multiple	No	All incident reports related to patient ID errors	Database query with manual review	2004-2008	Most common types of patient misidentification: 125 (25.7%) medication administration 74 (15.2%) procedures 34 (7.0%) pathology/radiology order Also reported 43 incident types related to patient ID	487 patient identification errors

Metadata	Country, Setting	Institution	Clinical Setting	Prospective	Recruitment	Method of Measurement	Duration	Results	Sampling Classification
Upreti et al. (2013)[36]	India	Single institution	Clinical laboratory	No	All samples	Automated data query	2011 12 months	1,339 samples with errors 482 (36%) samples rejected due to misidentification	135,808 samples
Varey et al. (2013)[44]	England	Multi-institution (15 hospitals)	Transfusion	Yes	All events	Event reporting	2011-2012 (12 months)	Corrected wrong blood in tube (WBIT) error rate: 1 : 2,717 (95% confidence interval: 1 : 2,122 to 1 : 3,481) Raw 48 WBIT (denominator uncertain)	169,595 repeat samples 237,621 total samples
Vuk et al. (2014)[43]	Croatia	NR	Transfusion	Yes	All samples	Quality control step in transfusion (routine)	2002-2013 (12 years)	Wrong blood in tube (WBIT) was recorded in 34 (0.0018%) samples.	955,218 samples
Wong et al. (2009)[31]	U.S.	Multi-institution	Procedure	No	Survey	Self-report	Single response	53% of survey respondents reported observing a medical error within past 6 months 27 reports of wrong-site surgery including 1 wrong-patient surgery	5,540 surveys sent, 917 returned
Yamamoto (2014)[20]	U.S.	Single institution's ED	Charting and order entry	No	68 participants	Survey	3-month recall	66/68 participants reported making wrong-patient charting or ordering errors Up to 20 errors/month reported by participants (last 3-month recall) Error rate of between 0 and 8.6 errors per 100 patients/clinician	NR

Metadata	Country, Setting	Institution	Clinical Setting	Prospective	Recruitment	Method of Measurement	Duration	Results	Sampling Classification
Zeilhofer et al. (2009)[25]	Switzerland	Single institution	Medication administration	Yes	All breast milk feedings	Voluntary reporting	2001 to 2007	23 events total ~0.14 events/1,000 feedings 75% of misidentifications in evening shift	Denominator NR

Evidence Table 2. Key Question 2. What are causes of patient identification errors in the clinical care setting?

Author (Year)	Country, Context	Clinical Context	Methods	Findings
Phipps et al. (2012)[55]	U.S., single institution	Patient identification (ID) practices	Qualitative survey, 30 residents and nurses full-time at hospital for >1 year	Checking wristband considered domain of nurses, not residents Repeatedly asking a patient his or her name can be viewed as disruptive to relationship or professionalism Being overwhelmed, overworked, or overtired contributes to errors
Henneman et al. (2010)[56]	U.S.	Medication administration, drawing labs, and applying wristbands	Simulated setting	61 emergency healthcare workers (28 nurses, 16 technicians, 17 emergency service associates) 61% of workers (37/61) detected the ID error (61% of nurses, 94% of technicians, 29% of emergency service associates) 15% of staff (5/33) failed to recognize the error even after completing steps to verify patient identity
Lichtner et al. (2010)[103]	UK	Patient ID practices	Qualitative case study of NHS walk-in center in London over 3-month period in 2006	ID errors occur because we often depend on contextual factors to interpret meaning Characteristics such as time of presentation, chief complaint, and personal characteristics were often used to identify patients.

Ortiz and Amatucci (2009)[54]	U.S., 3 Florida hospitals	Institutional ID practice	Survey of 80 staff from 3 Florida hospitals (5 participants randomly selected by manager/ director of 16 clinical areas)	80 staff were surveyed, and 79% responded
				1/3 were nurses, 1/3 were technicians, and 1/3 were other
				• 52% reported having been directly or indirectly involved in an error related to patient's responding positively to the wrong name or date of birth (DOB)
				• 60% had not experienced or observed ID error or near-miss error related to preprinted labels.
				• Only 7% agreed that ID procedures are too complex
				• 65% used open-ended questions more than half the time and most (56%) verified identity with 2 identifiers >75% of the time
				• Most frequent factors contributing to ID errors:
				  ○ Staff in a hurry (62%)
				  ○ Existing ID policy not followed (49%)
				  ○ Language barriers (46%)
				  ○ ID band not on patient (38%)
				  ○ Patient answers to wrong name (38%)

Author (Year)	Country, Context	Clinical Context	Methods	Findings
				○ Staff are careless (35%) ○ Use of "yes or no" identification questions (33%) ○ Staff lacks clinical experience (29%) • 73% felt that staff did not need more training and 51% felt disciplinary procedures did *not* need to be stronger
Sevdalis et al. (2009)[53]	UK	Institutional patient ID policy	Survey of random UK hospitals	Before new recommendations by the National Patient Safety Agency (NPSA), a survey of 50 hospitals found that 58% did not have a patient identification policy. Only 1 of 40 hospitals reported having no policy after the guidance was issued.
Fifth Annual Study of Medical Identity Theft Ponemon Institute (2015)[13]	U.S.	Identity theft	Large sampling frame of adults (49,266) who were victims of identity theft. Of 1,158 respondents, 86% (1,005) were victims of medical identity theft and included. 1,005 medical identity theft victims were included (2% response rate).	Extrapolating from census data suggests that 2.32 million adult Americans (or close family members) were victims of medical identity theft during or before 2014. This represents a 21.7% increase from 1.84 million victims estimated in 2013. Of medical ID theft victims, the following reasons were reported for theft: • 67%: obtain healthcare services/treatments • 61%: obtain prescription drugs or medical equipment • 53%: obtain government aid, including Medicare/Medicaid 35% reported that a family member took personal identification or medical credentials without consent 25% of respondents reported willingly allowing a family member or other person to use their personal identification; reasons provided included no insurance (91%), couldn't afford to pay for treatments (86%), and it was an emergency (65%) Once becoming aware of the theft, 60% did not report it to law enforcement or other authorities: Cases were not reported because the victim (1) did not think the police would be of help (55%) and (2) the victim knew the thief and did not want to report him/her (47%). Average cost for those who had to pay as a result of medical identity theft was $13,453.

Author (Year)	Country, Context	Clinical Context	Methods	Findings
Strong et al. (2012)[104]	UK, single institution	Registration	Searched hospital database for 5 years to determine what proportion of patients admitted to a pediatric surgery center had undergone name changes. Other study methods not reported	Of 457 patients admitted to pediatric surgery unit over 5 years, in 32.4% of admissions, either first name or surname had been changed. Both first and last names were changed in 1.3%.

Mancilla and Moczygemba (2009)[15]	U.S.	Registration	Mixed-methods study of chief compliance officers for acute healthcare facilities
			Objective: To determine whether patient identity is confirmed during admission/registration, and what methods are used to establish patient identity
			Surveyed chief compliance officers who were members of the Health Care Compliance Association
				Web-based survey of 133 chief compliance officers at acute healthcare facilities (12.6% response rate).
				82 participants (representing 226 separate facilities) received follow-up phone call:
				• 78.5% (62) reported patient ID is confirmed at admission/registration
				  ○ 91.9% (57) used driver's license; none used biometric identifier
				  ○ 37% (23) reported using another form of proof
				• Outside of the ED, if patient did not have proof of ID, 59.5% provided care anyway, while 16% rescheduled care; 20.2% handled by another procedure, or unsure how this was handled
				• 70.9% (56) performed ID confirmation face to face, 26.6% did not require face to face, and 2.5% were unsure
				• 83.3% used photo identification; no sites reported biometric confirmation
				Telephone surveys of 25 participants yielded the following themes:
				• Most cases of identity theft occur through ED (where providers are obligated by the Emergency Medical Treatment and Labor Act to provide treatment); drug-seeking behavior and frequent presence of law enforcement may cause patients to commit theft to avoid arrest
				• Some organizations are beginning to implement photo identification in information systems; however, implementation remains highly fragmented across systems
				• Admission/registration staff are typically unskilled in detecting falsified identity documentation and staff are under significant time constraints

Author (Year)	Country, Context	Clinical Context	Methods	Findings
				• Biometrics are "desirable"; however, barriers include cost and consumer acceptance From direct observation, the authors noted: • Patients are often advised not to bring anything for inpatient admissions and may not bring ID • Photo identifications may not represent patient's current appearance • Compliance with requesting photo ID varied, perhaps owing to training and time constraints • Information systems for outpatient care were not designed for efficient use of photo ID, requiring navigation through multiple screens The authors note that widespread use of SSNs should be reconsidered to decrease theft; organizations should avoid using SSN on clinical reports and applications and in information systems because this information is highly valuable to thieves.
Tase et al. (2015)[59]	U.S.	Wristband accuracy and use	Random probabilistic sampling of 800 wristbands on maternity wards	400 maternal and 400 neonatal wristbands were included: Overall, 87.2% of wristbands for pregnant/postpartum women were compliant with wristband protocol and 70% were in good condition (e.g., legible) • 2.3% were missing, 2.7% were present but lacked identifiers, and 7.8% did not match the condition of the mother or postpartum woman Only 55% of wristbands for newborns were compliant with protocol and only 44.% were in good condition.
Walley et al. (2013)[58]	U.S., single children's hospital (Children's of Alabama)	Wristbands	Audits of wristband use over 18-month period Pre/post study with intervention of feedback to nurses after each audit, educational conference	4,556 patients audited over 18 months Most common error was ID band not on patient (73.6% of errors) After assessment of different wristband styles, the following problems were noted: • ID bands lacking a clear covering were eliminated because the cover prevented printed information from washing off • ID bands that were too narrow to easily fit with a sticker label were eliminated.

Author (Year)	Country, Context	Clinical Context	Methods	Findings
Latham et al. (2012)[22]	Malawi, single teaching hospital	Accuracy and use of patient wristbands	Pre/post study Causes of problems: semistructured interviews of hospital staff Educational interventions to improve: Wristband usage Practice change Evaluated request forms/samples from a 1- to 2-day period monthly.	Interviewed 95 hospital staff (81 nurses, 9 medical/clinical staff, 5 students) regarding reasons 2 patient identifiers not used: • 34% inadequate time/heavy workload • 31% DOB unknown • Laziness/negligence: 18% • Nowhere to write identifiers: 16% • Forgetfulness: 14% • Staff attitude (task considered not important): 6% • Not trained how to use identifiers: 5% • Habits: 1% • Confidentiality concerns: 1% **At baseline:** Use of identifiers on laboratory forms: • Only 2% (11/603) of transfusion request forms and 1% (6/537) of laboratory request forms used an identifier in addition to patient name. • <10% used identifier other than name in bedside identity checks or when completing request forms/transfusion forms • 22% reported ≥1 incident in their career in which a patient received blood meant for another patient • 34% reported observing a patient receive medication/blood transfusion meant for another patient in the past year • Only 2 events of serious morbidity/mortality in the prior year **5 months after education**: • Wearing of wristbands and % of wristbands with 2 points of identification significantly improved from 0 to 5 months (from 0% to >80% for wearing wristbands, 0% to >90% for wristbands with 2 points of identification) There were no significant changes in any of the following staff self-reported practices: writing ward ID on request forms, writing DOB; asking for name before drawing blood; wristband check before medication administration; wristband check before blood transfusion.

Author (Year)	Country, Context	Clinical Context	Methods	Findings
Phillips et al. (2012)[57]	U.S., 6-site study: freestanding children's hospitals, children's hospitals with academic centers, community hospitals with pediatric/neonatal inpatient care areas (NICUs)	Improve use and accuracy of patient identification bands	Collaborative quality improvement initiative with monthly conference calls to implement interventions from Monroe Carell Jr Children's Hospital at Vanderbilt initiative: Run charts transparently reported failure data for each hospital ID bands verified at nursing bedside handoff Patient and family engagement in patient ID and purpose of ID band Education for hospitals/units regarding importance of accurate patient ID bands Sense of urgency created by using storytelling Voluntary event reporting systems to catch errors/patients lacking bands Bedside nurse asked about failures and fix occurred immediately Discussion of topic on safety walkrounds and leadership engagement	957 ID band failures identified. **Reasons for ID band failure**: ID band off patient (90.4% [865]) Inaccurate ID information (4.7% [45]) Illegible (3.6% [34]) Other (1% [10]) Wrong patient (0.3% [3]) Most common reason for failure: band not included on patient Common reasons the band was not on patient were band falling off patient (18.4%), placement on another object (16.7%), removal by parent or patient (12.7%), removal by staff (3.2%), never placed (3.2%), gets in the way of care (2.7%) Failure rates highest in NICUs, due to accepted practice of placing band on intravenous tubing attached to patient or taped to isolette.
Quadrado and Tronchin (2012)[63]	Brazil, single institution, NICU	Wristbands	Probability sampling of 540 wristbands over 3-month period in 2010	98.5% of wristbands contained the hospitalization number Only 93.3% of wristbands contained the mother's complete name. Overall, 82.2% of all wristbands met all criteria.

Author (Year)	Country, Context	Clinical Context	Methods	Findings
Smith et al. (2011)[61]	UK	Wristband use	Qualitative study with interviews of healthcare staff and direct observation of wristband use	14 individuals and 1 focus group interviewed; based on interviews and observations, the following problems were identified: • Several scenarios in which wristbands might not be applied were identified: emergency patients, and those who visit the hospital frequently for treatment but are not admitted (e.g., chemotherapy patients). Staff may be less rigorous with ID checking if they feel they recognize a patient over time. • For elective admission, wristbands are prepared ahead of time by clerks and attached to patient's case notes; unclear what training these clerks received; also, preparing these ahead of time increases odds of wristband being swapped before patient's admission. • Staff rarely verified wristband information on first meeting patient; also transport staff rarely checked patient identity • Careless handwriting may confuse numbers and letters
Burrows et al. (2009)[2]	Canada, single institution (Sunnybrook Health Sciences in Toronto)	Intraoperative Accessibility of wristbands, particularly for transfusion	Prospective observational study of patients undergoing elective surgery (excluded patients who were incoherent, sedated, or had cognitive barriers) ID band considered accessible if it could be accessed without unstrapping the patient's arm from the table, disturbing surgical drapes, or asking surgeon to pause, move, or adjust equipment Recruited elective surgery patients from June to August 2008 on nonconsecutive weekdays.	794 patients had preoperative checks of wristbands performed and 3 errors were identified. 426 patients were tracked pre- to postoperatively (due to only 1 study personnel being able to collect data). Intraoperatively, only 44.4% (190/426) had accessible ID bands. • 6.3% of bands removed intraoperatively (27/426), all within the first hour of procedure. 85% (23/27) of removals were for line placement. Remaining removals were to ensure accessibility, replace a soiled band, or because it interfered with procedure. • Once removed, 59.3% were left off for duration of procedure, while others were replaced. • 2 of 426 patients arrived in recovery area without wristband. 77 units of blood were transfused: in most cases, the addressograph card was used to confirm patient identity (never the ID band). This was in violation of the institutional policy. • At time of bedside check, 16.9% of ID bands (13/77) were accessible, but not used.

Author (Year)	Country, Context	Clinical Context	Methods	Findings
				Surgical subspecialties with the most inaccessible intraoperative ID bands: (1) General surgery, (2) urology, and (3) cardiovascular surgery; all rates <20% Authors recommend ensuring that ID bands remain accessible during surgery, and that a new patient ID that is more mobile (i.e., cannot be impaired by surgical procedure) is created to allow for thorough ID checks.
Sevdalis et al. (2009)[62]	UK	Wristband accuracy and use	Survey of clinical risk management staff at UK hospitals	166 responses from 162 hospitals received. 8 excluded for illegible or missing information. 154 ultimately included. Which identifiers on wristband label are the most useful? • First name, last name, hospital number (all 88%) • DOB (86%) • Sex (29%) • National Health System (NHS) number (37%) Issues with applying, checking wristbands: • Routine use of multiple wristbands on the same patient was reported by 71% Problems included; not mutually exclusive): • Information inaccurate, unavailable, or illegible (30) • ID band not put on or removed and not replaced (17) • Time pressure, inadequate staffing, lack of clarity about who is supposed to check ID band (12) Problems with wristband design: • Not waterproof—easily becomes illegible (63) • Bands too small/too large (20; e.g., cannot fit on edematous limb) Also, failure to standardize what color coding represents

Author (Year)	Country, Context	Clinical Context	Methods	Findings
Virginio and Ricarte (2015)[65]	Brazil	EHR design	Systematic review (literature from 2010 to 2014) with narrative synthesis of patient safety risks associated with the electronic health record (EHR)	Only 2 mentions of patient ID problems: • Problems with functional appropriateness and usability can lead to ID problems: • Allowing ≥2 records to be open on the same device • Simultaneous editing by 2 users • Usability: incomplete display of information and high information volume Issues with both functional appropriateness and usability may lead to registration of information to the wrong patient (Sittig and Singh 2012, cited in review)
Galanter et al. (2013)[7]	U.S., single large academic institution (University of Illinois)	Order entry	Indication-based prompts to prevent wrong-patient medication orders For particular medications, if the patient problem list did not include a particular set of problems on the "active" problem list, an alert for the clinician to update the problem list appeared. Events that involved (1) an order started but not completed followed by (2) the same prescriber submitting the same order for a different patient were further reviewed by an experienced clinician to determine whether the incident represented an intercepted wrong-chart error.	Over nearly 6 years (April 2006 to February 2012), 127,320 alerts fired. • Location: inpatient (42%) versus outpatient (38%), ED (14%), and undefined (6%) • Providers: house staff (77%), attending physicians (18%), others (5%) 822 events (incomplete order, followed by ordering medication on a different patient) reviewed by an experienced clinician. Of these, 32 intercepted wrong-chart errors identified. **Characteristics of intercepted wrong-chart errors (32)** • No errors due to same patient last name • 59% of interceptions when clinicians had both patient charts open while charting • Both patients cared for by ordering provider in all except 1 instance • Errors did not vary depending on venue or provider type • Certain medications involved significantly more often: most common medications involved in these errors were metformin and metoprolol

Author (Year)	Country, Context	Clinical Context	Methods	Findings
Levin et al. (2012)[6]	U.S., single institution (Children's Hospital of Pittsburgh)	Order entry	Survey and case-control study of retract-and-reorder events over roughly 5-year period Orders on misidentified patient events were defined as medication orders canceled within 120 minutes and reordered on different patient within 5 minutes of cancellation by the same provider.	Compared "cases" (644) versus controls (3,220): • Errors more likely on Friday, less likely on Monday (relative reduction 2.02, 95% confidence interval 1.37 to 2.98) • In multivariate analysis, factors significantly associated with increased error included patient age (higher for newborns, children), day of week (Friday), 2-letter overlap in last name, evening order (6 p.m. to midnight), patient location (close proximity) • When assessing what patient factors were associated with errors, only the spelling of the last name was significant (similar condition, similar service not significant). • "Overall…it is the context of the order entry process, more than the characteristics of the patient names themselves which are associated with increased risk of patient identification errors." Survey of 13 chief medical information officers: • Patient ID errors common initially after EHR launch, but declined thereafter • Errors caused by (1) having multiple charts open simultaneously and (2) poor screen design Survey of physicians: • "A majority" stated they have made an ID error before, and rates are higher in the ED • Distraction and fatigue are biggest contributing factors • Errors typically caught when reviewing order before signing • Suggested allowing only one open chart and creating verification alert 2,644 orders on misidentified patients (0.064% incidence) Median time from entry to cancellation was 1 minute Authors' conclusions: • Provider context (while entering orders), not the characteristics of patient's name, more likely to contribute to errors • Recommend deactivating ability to open multiple charts simultaneously

Author (Year)	Country, Context	Clinical Context	Methods	Findings
Härkänen et al. (2015)[66]	Finland, single institution	Medication administration	Direct observation of 32 nurses administering medications to patients on 4 adult wards over 2-month period in 2012 Observation of 32 nurses administering medication to 122 patients (1,058 medications total, 441 administrations) According to institutional protocol, patients should be identified by either (1) wristband (for impaired mental status) or (2) name and DOB before medication administration. No bar-code verification in the hospital.	Adherence to patient ID protocols was very low: Per administration occasion (441) only: • Name confirmed 21.5% (95) • DOB confirmed: 0.2% (1) • Wristband used: 0.7% (3) • Proposing patient's name 2.7% (12) • No identification 67.6% (298) • Unknown 7.3% (32) Distractions present: Too many people in medicine room (66.3%), noise (34%), busy atmosphere or time constraints (26.7%), other (e.g., guidance of student or discussion with relatives) (26.4%) Significantly higher adherence for: • Nurses with <4 years of working experience (70.1% performed identifications) • More distractions: 4 different distractions resulted in highest proportion of patients ID'ed (50.9%)
Steele and Bixby (2014)[67]	U.S., single children's hospital (Children's Hospital of Orange County, California)	Breast milk storage and administration	Failure mode and effects analysis (FMEA) multidisciplinary team identified 282 potential failure points, prioritized and identified root causes for top 85 causes	4 primary areas of concern identified: Process was unclear and cumbersome for bedside nurse Inadequate double-checks at key points (e.g., when mother provided with labels for milk, and when nurse preparing milk, often combining multiple bags) Risk of human error and confirmation bias due to frequency of feeding (e.g., as often as 12 times per shift) Contamination risk, because no place to handle breast milk in NICU aside from bedside
Jo et al. (2013)[105]	U.S.	Medication administration	Attached eye tracking devices to 28 nurses, asked to administer medication to 56 simulated patients	28 nurses administered 56 medications; only 44 videos were high enough quality for evaluation. Of medications administered using a bar-coding system, 56% of encounters involved confirmation of 1 identifier, and 12% used 2 identifiers. Of medications administered without using bar code technology, 41% involved confirmation of 1 identifier and 2% used 2 identifiers.

Author (Year)	Country, Context	Clinical Context	Methods	Findings
				Authors concluded: Perhaps options for verification of identity are confusing and should be simplified. More compliance with nursing verification of patient identifiers is needed; one solution is to train nurses to always use one trusted identity artifact and use it to verify other artifacts.
Cohen et al. (2012)[26]	U.S., modeling study of pharmacy errors	Outpatient pharmacy; preventable adverse drug events (PADEs)	Modeled risks for various errors and benefits of intervention on high-risk medications A group of model builders (6 pharmacists, 3 technicians) and model validators (11 pharmacists and observation of staff at 2 pharmacies) used data from 22 community pharmacies from 3 regions in the U.S. to model probability of errors Pharmacists drawn from varied contexts. Identified high-alert medications (warfarin, fentanyl, oral methotrexate, and insulin) from qualitative work, then built a model including an event tree. Modeling team led by experts in human factors, probability theory, and medication safety.	**Estimated probabilities**: • *Data entry error, prescription entered on wrong patient*: 5 in 1,000 prescriptions; 99% captured before reaching patients; PADEs reaching patients of 0.052 per 1,000 (or 1.15 in 100,000, or 197,849 annually in all U.S. community pharmacies). • *Point-of-sale error (drug given to wrong patient)*: overall, 3.4 in 1,000; only 64% captured before reaching patients; PADEs reaching patient of 1.22 in 1,000 or 4.6 million per year ○ Wrong patient bag chosen (3/1,000) ○ Drug placed in wrong patient's bag (0.4/1,000), ○ **Causes**: (1) working on more than 1 patient's medications during the verification and bagging process; bags are not typically opened at point of sale (so errors are not caught); (2) flawed or absent patient ID process; DOB hard to verify when caregivers or family pick up medications; address is not good identifier because patients sharing last name often live at same address; in stores with lower volume, staff might be able to visually identify customers, but also might skip formal identification. ○ **Interventions**: ▪ Opening bag at point of sale to look at medicine: decreased rate to 0.534 errors per 1,000 ▪ Patient identification at point of sale 80% of time (increase from estimated 50%) with last name and either DOB or address: 0.233 errors per 1,000 (81% improvement) ▪ Increasing counseling frequency from 30% to 50%: reduced rate to 0.899 per 1,000. Probability of dispensing warfarin to the wrong patient was 1.22 in 1,000 prescriptions.

Author (Year)	Country, Context	Clinical Context	Methods	Findings
Marquard et al. (2011)[68]	U.S.	Medication administration	Tracked eye movements of 28 nurses (data excluded for 8 due to poor quality) administering medications to 3 simulated patients Each nurse demonstrated the process of medication administration for 3 "patients," with the 3rd patient having a mismatch between medication label and ID band.	Post hoc analysis found that nurses who identified the error looked at fewer items on one ID artifact before shifting fixation to the other. The authors suggest that nurses may be checking individual components one at a time, instead of looking at 2 components at a time (e.g., name first, then DOB). Authors speculate that checking 1 identification item at a time may improve accuracy.
Snyder et al. (2012)[92]	U.S.	Bar-coding systems for laboratory specimen tracking and point-of-care test	Systematic review and meta-analysis	**Issues related to bar coding**: Curve of wrist can interfere with scanning Label printing can have artifacts Low batteries can affect scan Nonhospital bar codes potentially can be read as bar codes Multiple armbands/bar codes
Danaher et al. (2011)[16]	U.S., Australia (3 hospitals)	Radiology, imaging, and interventions	Followed wrong-patient/wrong-side errors over 45-month period before/after new safety protocols	**Completed errors**: 9 completed errors before implementation (6 wrong patient, 3 wrong procedure) versus 3 post-implementation errors (2 wrong patient, 1 wrong site/side). Most common cause of ID error is physicians requesting imaging for wrong patient because they used the wrong patient ID sticker. Staff acknowledged instances in which the "final check" is signed before patient arrives in department or hours after examination is completed. Also, audits were not an effective measure: an audit of 100 cases found 100% compliance with patient ID verification despite staff acknowledgment of workarounds and noncompliance.

Author (Year)	Country, Context	Clinical Context	Methods	Findings
Spain et al. (2015)[71]	Australia	Phlebotomy (specimen collection)	Assessed effect of education versus education + bar-code scanner in performance of key behaviors (e.g., protocols for preventing ID errors) Collection of specimens was directly observed for 284 collections in the ED.	Adherence to 8 "key behaviors" in collection of ED specimens (n = 284) for verifying patient ID during specimen collection significantly improved after education, and improved even more with addition of education + armband scanner. **Some of the key behaviors included**: • Armband checked before taking sample increased from 11.3% to 33.7% (education) and 58% (education + scanner), p <0.001. • Patient asked to state DOB: 21.9% (pre-intervention), 49.5% (education), and 92.8% (education + scanner), p <0.001.
Schmidt et al. (2013)[74]	U.S., single institution	Surgical pathology	Retrospective review of labeling errors reported over roughly 2-year period, with root cause analyses (RCAs)	2 types of errors: within-case errors versus between-case errors. Overall average error rate: 1.7 labeling errors per 1,000 cases 85 errors among 45,000 cases processed: • 46% between-case errors • Higher rate of errors for pathology residents compared with technologists (p <0.001); 27% of errors from residents even though they processed only 5.5% of cases. • Potentially due to rotating between 3 different hospitals and only working for short durations 42% transcriptions errors (24% off by 1 digit) 23% numbering and sequence errors 6% transposition errors 4% adjacent-number duplication errors Potential contributors: • Labeling machine had a dial that was difficult to turn and a readout that was hard to see, and often broke down, requiring personnel to label cassettes by hand • High turnover of residents (only worked here for 2 months/year) • Artificial deadlines: cases picked up for transfer to another laboratory at 6:30 p.m. every day; trend toward errors at end of day on Friday/Saturday

Author (Year)	Country, Context	Clinical Context	Methods	Findings
Rees et al. (2012)[73]	U.S., single institution (University of Wisconsin Hospital)	Specimen collection	Multidisciplinary team investigated patient ID errors and started quality improvement initiative.	One recurring problem: patient labels were printed in the department, and occasionally, a staff member would retrieve 1 or 2 labels from the batch printed for prior patient (even though they were separated by a blank label). Reprogrammed printer to print 3 large X's on label between different patients.
Dunn and Moga (2010)[19]	U.S., Veterans Health Administration (VA)	General laboratory	Qualitative analysis of root cause analysis (RCA) reports in VHA Analyzed 227 RCAs (253 adverse events) from 2000 to 2008 related to patient misidentification.	Of 227 RCAs analyzed, 72% associated with patient ID errors from mislabeled specimens due to a variety of problems **Preanalytic errors**: • Typically due to mislabeling during collection (contributors included batching of unlabeled specimens and presence of printed labels from multiple patients in common areas of the ED, OR, and nursing units) • Problems arose when patients with similar last 4 digits of SSN or birthdays or similar names • Manual entry of information for user-unfriendly request forms Example: (1) printed labels from prior patient in the OR from a fine-needle aspiration led to wrong-patient pulmonary resection; (2) batching specimens and printed labels in OR from prior patient led to unnecessary radical prostatectomy **Analytic phase**: • Manual entry of accession numbers once specimens reached laboratory • Slides were mislabeled when requiring only accession number for identification • Batching multiple slides together led to pathologists reporting results in wrong patient chart Examples: manual numbering of cassettes: unnecessary hysterectomy; 2nd patient with delay in diagnosis and treatment **Postanalytic phase**: • Reporting laboratory results in wrong record, delays in reporting critical results, reporting inaccurate results Examples: "View alert" for pathology results did not require provider to confirm receipt: 3-month delay in diagnosis and treatment of malignant melanoma

Author (Year)	Country, Context	Clinical Context	Methods	Findings
				Authors' recommendations: • Apply wireless bar-code technology at the bedside to confirm patient ID and affix a bar-code label to a specimen immediately after collection • Apply bar-code technology in transfusion process • Use unique identifier for selecting a patient medical record and for labels on all specimens and blood products (full SSN is current unique patient identifier in the VHA) • Automate laboratory forms limited to electronic data entry, eliminate all manual entry for specimen labeling • Eliminate relabeling of clinical laboratory and anatomic pathology specimens after they reach lab; instead include accession number on original label placed on specimen after collection • Have continuously available centralized phlebotomy service for inpatients • Eliminate all paper labels in the OR with all room turnovers before bringing next patient into the room • Require 2-pathologist review as required documentation for final pathology report of all pathology slides with a cancer diagnosis

Ferrera-Tourenc et al. (2015)[48]	France, multiple hospitals	Transfusion	Description of patient ID errors over 18 months in blood issued to Marseille Public Hospital System by a centralized database from the Alps-Mediterranean French Blood Establishment (covering 149 area hospitals)	73 discrepancies (between new ABO typing and centralized database) were detected.
				Root cause analyses (RCA) of 12 errors was inconclusive; however, the remaining 61 errors were due to:
				• Specimen collection error (30, constituting 1 : 3,579)
				• Patient ID error: (31, constituting 1 : 3,3,29)
				  ○ 61.3% (19) identity theft (impersonation)
				  ○ 6.7% (2) registration errors by clerk for patients with similar names
				  ○ 3.3% (1) namesake (same first and last names, DOB, and sex)
				  ○ 29% (9) could not determine whether namesake or impersonation

Author (Year)	Country, Context	Clinical Context	Methods	Findings
				• In 61% of 31 identity errors, if a new sample each admission had not been required, ABO incompatible blood would have been released (as patients presumably had erroneous information on file) Authors' conclusions: Identity fraud and collection errors constitute significant causes for near misses in transfusion. Centralized database helps to detect these errors.
Karim et al. (2014)[106]	Pakistan, single institution	Transfusion errors	Retrospective observational study of adverse events and etiology	Between January 2006 and December 2012, total of 142,066 red cell units transfused 9 ABO mismatch transfusion (1 in 15,785 units) Causes: error in final bedside check (5), testing by blood bank on wrong tube (1), dispensing wrong blood (2), mislabeled cross-match tube (1). In 8 of 9 cases, failure at final bedside check was involved 6 of 9 mismatches were detected due to transfusion reactions; 2 cases recognized by blood bank personnel and 1 case stopped by patient son's recognition of his father's true blood type 2 deaths associated with mismatches
Seferian et al. (2014)[95]	U.S., single institution, tertiary care center	Specimen labeling	Part of larger intervention study Root cause analyses (RCAs) of 15 blood-bank specimen labeling errors	**Outcome measure**: Errors were defined as mislabeled specimens if (1) mismatch between specimen and requisition, (2) incorrect patient identifiers, or (3) unlabeled specimen 15 RCAs for blood bank specimen mislabeling events were conducted. Contributing factors were: • Local unit environment (32%) • Information technology (24.4%) • Team issues (12%) • Institutional environment (2.4%) • Provider (2.4%)

Author (Year)	Country, Context	Clinical Context	Methods	Findings
Cottrell and Davidson (2013)[70]	UK, multiple institutions	Wristband use in patients receiving transfusion	Prospective observation of 247 hospitals over roughly 3-month period in 2011 Data from 9,250 transfusions obtained from audits	In data from 9,250 transfusions, 49.5% of wristbands were printed and bar coded 21.1% were handwritten **Missing wristband**: Only 2.3% not wearing wristband (more missing wristbands for outpatient, 4.1% versus inpatient 1.8%) Reasons: 42.1% healthcare staff never applied it, 6% taken off by patient and not replaced, 12.5% taken off by healthcare staff and not replaced, 1.9% carried by the patient but not worn during transfusion, 25% other, 12.5% not known. Children more likely than adults to be missing wristbands: • 1.8% of adults, 9.5% of children, 12.5% of neonates Mismatch between patient ID (wristband and identifiers on unit of blood in 99 patients, 1.1%) National Health System (NHS) identifiers used on 58.8% of wristbands Authors conclude: All hospitals should have policy: "No wrist-band, no transfusion"
Delaney et al. (2013)[45]	U.S., Centralized Transfusion Service Database from Puget Sound Blood Center (19 hospitals and medical facilities)	Transfusion, wrong blood in tube (WBIT)	Retrospective observational study and description of errors	From July 2003 to November 2010, 77 WBIT specimens detected, corresponding to 0.9 per 1,000 samples Fewer errors occurred from patients seen at more than one hospital (25) compared with patients cared for at one hospital only (52), $p < 0.005$. Appear to have performed a subanalysis of WBIT errors from 2009 to 2012 and report that 5 of 19 errors were detected due to centralized transfusion service.
Miller et al. (2013)[107]	Australia, single institution hematology/ oncology day clinic	Transfusion	Pre/post study Before and after bar-code implementation 110 transfusions audited	Audits found that using personal digital assistants to scan bar codes on wristbands significantly improved the rate of adherence to bedside ID check before transfusion (rate improved from 76% to 100%).

Author (Year)	Country, Context	Clinical Context	Methods	Findings
Varey et al. (2013)[44]	UK	Wrong blood in tube (WBIT), transfusion	Survey of WBIT incidents from 15 hospitals	15 hospitals participated in the survey All sites required labels for transfusion samples to be handwritten (although 5 had electronic systems in place, none would accept transfusion labels printed using this). 44 WBIT cases were reported: • 14 cases: no reason determined • 15 incidents (sample was labeled away from patient bedside) • 11 cases: failure to confirm patient ID by verbal and/or wristband check (2 patients were not wearing wristbands) • 2 cases: mother and baby (cord blood) samples were transposed • 1 case: misidentified samples from newly born twins • 1 case: prelabeled sample • Distractions, lack of training, and asking another member of the staff to label a sample were all cited as well
Heddle et al. (2012)[60]	6 transfusion centers in 5 countries: Canada, UK, Norway, Italy, and U.S. Qualitative Evaluation for Safer Transfusion (QUEST Study)	Transfusion	Qualitative study of staff performing pretransfusion check process Overall 72 participants for 12 focus groups and 7 individual interviews conducted over 22 months (2008 to 2010).	Pretransfusion checking process: • 4 of 6 sites used manual checking, 1 used bar coding, and 1 used combination of manual check + mechanical locking system on bag Problems noted by participants included the following: • Distractions, busy clinical environment in which multiple units of blood may be delivered for several patients at the same time • Patients returning from surgery without wristbands; one solution could be for surgery patients to have 2 wristbands • Illegible wristband after print degraded when exposed to water • Language barriers between nurse and patient In general, staff felt one-on-one learning (as opposed to online/electronic) was the most effective way to become proficient at safety procedures around transfusion Authors recommend: Each surgery patient should have 2 wristbands placed (since they often return from surgery with 1 missing)
Grimm et al. (2010)[46]	123 institutions mostly from U.S. (95%), but also	Transfusion, wrong blood in tube (WBIT)	Prospective review of inpatient and outpatient samples for 30 days	122 institutions submitted complete data. Mislabeling was defined as all labels not meeting the institution's labeling policy.

Author (Year)	Country, Context	Clinical Context	Methods	Findings
	Australia, Canada, Saudi Arabia, and Spain			44% of participants were teaching hospitals **Survey of hospital policies**: • 97% require armband be present on patient before sample collection • Roughly 50% have a blood-bank-specific armband for inpatient and outpatient transfusions • Only 8% identify patients by using a bar-code reader • 60% require 2 ABO typings for patients without a historical type before issuing nonemergent nongroup red blood cells • 31% require ABO types to be performed on *different* samples • All institutions required confirmation of first and last name before collection; DOB was used by only 72% of institutions • 93.5% allow collection and labeling by nonlaboratory personnel • 26% of institutions with no policy for replacing missing armband • >90% of institutions accepted handwritten test requisitions • 2/3 of institutions do not have policies preventing production of multiple labels for *future* sample collections • Only 45.5% of institutions required photo ID for patient registration • 15.5% at least 1 case/year of identity theft **Errors**: Over a 30-day period, 122 institutions received 112,112 samples for ABO typing and identified 1,258 mislabeled specimens • Overall combined mislabel rate: 1.12% (1/89 samples); 81.2% of these were rejected • Median mislabel rate: 0.29% (highest mislabel rate = 13.7%) • 45 participants: no mislabel rate • Aggregate WBIT rate: 0.04% (95% confidence interval, 0.02% to 0.06%) with historical ABO type determined to be the correct type in 56.5% (16) of cases • Estimated annual WBIT rate for all institutions: 0.04%, with historical ABO type determined to be correct in 33.3% (52) of cases

Author (Year)	Country, Context	Clinical Context	Methods	Findings
				Causes of labeling errors: Higher mislabel rate significantly associated with: • Labeling/collection by nonlaboratory personnel (p = 0.001) • Institution allows clinicians to remove armbands during inpatient admission (p = 0.06) Lower mislabel rate associated with: • Requirement for ward location to be checked to verify patient ID before outpatient collection (p = 0.001) • DOB must be checked before outpatient collection (p = 0.05) • Ward/location required on patient sample labels (p = 0.05) • Sex is required on outpatient sample labels (p = 0.007) • Sex required on inpatient requisition forms (p = 0.02) • DOB required on outpatient requisition form (p = 0.003) Higher WBIT: • Labeling/collection by nonlaboratory personnel (p = 0.008) Lower WBIT: • Phlebotomist ID required on inpatient sample labels (p = 0.008) • DOB required on inpatient test requisition (p = 0.05) No significant association between sample mislabel rate and WBIT If analysis limited to 63 institutions reporting at least 1 WBIT, trend (p = 0.06) towards lower WBIT rate in labs requiring 2 ABO typings for patients without historical ABO type Higher rate of mislabeling in institutions that required submission of new ABO typing sample when patient's name is changed or updated during admission; this higher rate may be because these institutions are better at identifying mislabeled specimens, or have patient populations with high proportion of common names

Author (Year)	Country, Context	Clinical Context	Methods	Findings
Hijii et al. (2010)[72]	United Arab Emirates, 2 hospitals	Transfusion	Observed random sample of 49 nurses administering transfusions	In observation of 49 nurses – 79% of nurses stated they had never received in-service training on blood transfusion Only 8% (3) asked patient to state name, and 0 asked for DOB 43% checked the patient's ID band and 29% compared ID band with blood bag
Tinegate et al. (2010)[108]	UK	Transfusion	Surveyed 34 hospitals and described 7 days of cross-matched samples in 34 laboratories	The 2008 Serious Hazards of Transfusion (SHOT) study of UK hospitals found that 74% of cases (29 of 39) in which patients actually received the wrong blood due to laboratory error occurred outside of normal working hours This study identified the proportion of requests processed outside of normal working hours in the UK 25% of all cross-matches performed outside of normal working hours, and 23.1% of these requests were for "less urgent" indications 65% of requests came from inpatient wards, only 24% from high-dependency areas or ORs During these hours, the majority of laboratories are staffed by only 1 biomedical scientist
Askeland et al. (2009)[47]	U.S., single healthcare system (University of Iowa Hospitals and Clinics)	Transfusion	Implemented bar-code system, reported reasons for near misses	Prevented identification errors (PIEs) reported anytime a mismatch detected between scanned bar-code labels: Over a 46-month period from 2005 to 2008: • Collection: 107 PIEs (0.15% of collections) • Dispensation: 247 PIEs (0.17% of all blood dispensed) • Administration: 33 PIEs (0.023%) OR (15 PIEs) Other (18 PIEs) These "near misses" (administration PIEs) occurred due to blood left in OR from prior surgery (4 events), blood taken to wrong OR (2 events), ordering error (1 event), inadvertent scanning of wrong bar code from prior patient's label (8 events) Rates of failure-to-scan bar code at administration studied in further detail from May 2007 to November 2008: 1% failure-to-scan rate

Author (Year)	Country, Context	Clinical Context	Methods	Findings

Stahel et al. (2010)[30]	U.S.	Wrong-site/wrong-patient surgeries	Retrospective analysis of Colorado Physician Insurance Company (COPIC) database, January 2002 to June 2008 (6.5 years)
			At time of analysis, covered nearly 6,000 practicing physicians in Colorado, including 31.7% surgical and 68% nonsurgical specialists
			Reporting is voluntary, but incentives offered for reporting
				27,370 occurrences with a total 107 wrong-site and 25 wrong-patient cases confirmed by chart review
				Most frequent specialists involved in wrong-patient cases:
				• Internal medicine (24%)
				• Family or general practice (8%)
				• Pathology (8%)
				• Urology (8%)
				• Obstetrics and gynecology (8%)
				• Pediatrics (8%)
				Root causes:
				• Errors in communication (100%)
				• Systems issue (84%)
				Outcomes:
				No patients died from a wrong-patient procedure; 1 patient died from wrong-side chest tube placement
				• 5 patients (20%) had significant harm or functional impairment:
				  ○ 3 patients received prostatectomies on the wrong side due to mislabeling of biopsy samples
				  ○ Vitrectomy was performed on 1 wrong patient due to 2 patients with identical names in the ophthalmologist's office
				  ○ 1 child received a myringotomy instead of scheduled adenoidectomy because the wrong patient was brought back to the OR
				• 8 (32%) minimal harm or functional impairment
				• 9 (36%) no-harm event
				• 3 (12%) outcome equivocal or not determined
				Errors occurred in diagnostic process for 56% of wrong-patient cases:
				Mix-up in medical records, radiographs, or laboratory or biopsy samples was the reason for wrong-patient procedures in 16 of 25 cases
				Significant proportion of wrong-patient errors could have been prevented with formal "readbacks" by the surgical team

Author (Year)	Country, Context	Clinical Context	Methods	Findings
Magrabi et al. (2012)[64]	Australia	Multiple contexts (reports on bar-code reader, but mainly picture archiving and communication system PACS issues)	All health information technology (IT) events reported in the Manufacturer and User Facility Device Experience (MAUDE) database of the U.S. Food and Drug Administration from January 2008 to July 2010 (MAUDE contains voluntary reporting for medical device–related errors)	Identified 678 health IT-associated reports, describing 436 events, which authors believe represented 712 problems Specifically, patient ID problems were related to: **Information input**: • PACS images were stored under the wrong patient's folder and exchanged with another patient's images en route (e.g., portable chest radiograph entered under wrong name, resulting in wrong diagnosis, subsequent intubation that may have contributed to patient's death) • Bar-code reader problems corrupted patient data and also caused wrong medication dose administration • Poor user display for computerized physician order entry (CPOE) interfaces led to wrong-patient and wrong-medication orders **Information output**: • PACS displayed wrong patient study; displayed wrong patient information in screen header • PACS concurrently displayed information from more than 1 patient or displayed information from the wrong patient when more than 1 viewing window was open • Switching from display to edit mode caused wrong patient image display • Caches in browser caused incorrect information to displayed (i.e., cached images from prior patient) **General technical**: • Because PACS does not support correction of reports, when updating imaging studies, PACS was noted to: Overwrite notes with those from another patient o Incorrectly merge new studies with existing studies Software issues accounted for >40% of reported events, and patient misidentification was the most common problem

Author (Year)	Country, Context	Clinical Context	Methods	Findings

				Author recommendations for safe design and implementation of software included the following:
				• Software functionality should ensure that patient information is accurate:
				  ○ Identification should not rely solely on first/last names, DOB
				  ○ System should not maintain multiple files for the same patient

Evidence Table 3. Key Question 3. What interventions are effective for decreasing patient identification errors in the clinical care setting (nonlaboratory medicine)?

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
Lee et al. (2015)[75]	U.S., single institution, 2 medical laboratory systems	Health information management, record linkage	Algorithm for matching patients within the electronic health record (EHR) using a hybrid of deterministic and probabilistic systems	Prospective validation study Comparator: naturalistic algorithm (NA) versus standard registration patient identification (ID) checking Used health level 7 (HL7) data from 2 medical laboratories: Olympic Medical Center (OMC), Washington, U.S., and Diagnostic Laboratory Services (DLS), Hawaii, U.S. Removed patient ID field from the source data and used algorithm to detect patients in the data set Flagged for review if the match was similar but would require manual review to confirm Tested false positives with DLS data set (different geography and therefore would expect few matches)	OMC 2013-2014	The naturalistic algorithm can be used for duplicate record checking within a data set and for identifying same patients between data sets. **OMC test**: 137,470 HL7 messages, 84,458 unique accessions Agreement on 19,788 patient assignments (99.65%) 42 likely duplicated by NA (0.21%) not flagged for review 14 likely duplicates (0.07%) flagged for review 4 patient records potentially missed by NA (0.02%) flagged for review 9 patient records potentially missed by NA (0.05%) not flagged for review **DLS test**: 1,134,406 HL7 messages, 217,379 unique accessions 2 matches between OMC and DLS datasets Deterministic matching—uses exact matching for Social Security number (SSN), date of birth (DOB), name, other demographic data Probabilistic matching—assigns similarity scores and determines a match when 2 sets of data are "close" to exact Patient matching is affected strongly by data quality

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
Judson et al. (2014)[14]	U.S., single institution (Massachu-setts General Hospital [MGH])	Prevention of identity theft	Creation of notification tree to standardize reporting of "red flag" incidents (warning signs of identity theft, e.g., suspicious personal identifiers, account activity) Education targeted towards administrators at patient intake sites and expanded to specific providers, specifically about: First 3 digits of SSNs (increase geographically from east to west on basis of state of birth) Sample scripts to communicate with patients Asked to comment on when core demographic information (name, gender, DOB) were changed in patient's account Multidisciplinary data integrity committee formed by health information management department VERI (Verify Everyone's Identity) Safe Patient	Pre/post study Red flag incidents tracked beginning in late 2006 VERI Safe Patient Care implemented in August 2011	Red flags tracked from 2006 to 2013	**Prevalence**: In 2010, 81 suspected cases of medical identity theft at MGH, resulting in $2.92 million in charges at risk for not being reimbursed Estimates that about 120 duplicate records created per month 25 patient encounters tied to identity theft/fraud each quarter 14 patients treated under wrong medical record number (MRN) each year **Over 9-month period (October 2008 to June 2009), 56 red flags identified**: Clinician has seen patient under another name (4) Patient received payment request for services not received (23) Suspicious/evasive behavior by patient and or family/friends (8) Identity documents appear altered/forged (1) Information given doesn't match reference system information (8) Clinical information provided by patient inconsistent with history and physical (3) Patient contacted regarding a visit he or she did not schedule (2) Family/friends refer to patient by another name (2) Triggered by law enforcement or investigator (5)

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
			Care (implemented in 2011) Staff required to document asking for photo identification at all appointments and document reason it was not provided Patients missing photo identification were reminded to bring identification at next visit and asked additional verification question, "When was the last time you were seen, and by which doctor?"			During these months, there were the following outcomes for prior red flags: Confirmed ID theft (3) Confirmed ID fraud (2) Suspected ID fraud (entry error excluded) (11) Data entry error (46) Record correct (no error) (19) Undocumented/demographic change (17) Still under investigation (8) **Effect of intervention**: Red flag triggers rose steadily after tracking began in 2006 to >80 in 2010. After implementation of VERI Safe Patient Care (in August 2011), red flag incidents decreased to 40 in 2013 (no measures of significance provided). Under the Health Insurance Portability and Accountability Act (HIPAA), patient can request changes to record, but in general, physicians may alter only those records he or she authored or created. This poses significant barrier for correcting records once inaccuracies are introduced (and requires victims to track down individual providers). Authors suggest vascular pattern recognition "in which infrared light identified the unique pattern of blood vessels in each patient" as a promising biometric system. No contact is required (no infection risk). Difficult to forge because it is subcutaneous. Authors call for implementation of national policies to (1) improve

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
						efficiency of correcting errors in medical records, (2) alter financial disincentive hospitals have to detect and report cases, and (3) create a single point of entry to decrease burden on providers/ individuals to reconcile cases. Creation of a single government agency would ensure that providers are not in the position of enforcement.
Phillips et al. (2012)[57]	U.S. 6-site study (freestanding children's hospitals, children's hospitals with academic centers, community hospitals with pediatric/ neonatal inpatient care areas (neonatal intensive care units [NICUs])	Improve use and accuracy of patient identification bands	Collaborative quality improvement initiative with monthly conference calls to implement interventions from Monroe Carell Jr Children's Hospital at Vanderbilt (MCJCHV) initiative: Run charts transparently reported failure data for each hospital ID bands verified at nursing bedside handoff Patient and family engagement in patient ID and purpose of ID band Education for hospitals/units regarding importance of accurate patient ID bands Sense of urgency created by using storytelling	Pre/post study ID band audits conducted on 11,377 patients over a 1-year period Compared baseline prevalence (September 2009 to April 2010) to monthly audits through September 2010 Not all hospitals contributed data monthly (range 6 to 13 months of data); but all hospitals reported the final 5 months of the study (May to September 2010).	13 months Baseline prevalence assessed from September 2009 to April 2010 Evaluation continued through September 2010	Authors found a 77% relative reduction rate in ID band failures over 13 months ($p < 0.001$) At baseline, the mean failure rate was 22%, with combined rate of 17% (140 failures in 795 audits). Failure rates by hospital ranged from 4.9% to 52%. In the final month, the mean failure rate was 4%, with a combined rate of 4.1% (50 failures in 1,129 audits). Failure rates by institution ranged from 0% to 11%. 957 ID band failures identified **Reasons for ID band failure**: ID band off patient 90.4% (865) **Inaccurate ID information (4.7%, 45)** Illegible, 3.6% (34) Other, 1% (10) **Wrong patient, 0.3% (3)** Most common reason for failure: band not included on patient Common reasons the band was not on patient were band falling off patient (18.4%), placement on another object (16.7%), removal by parent or patient (12.7%), removal by staff (3.2%), never

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
			Voluntary event reporting systems to catch errors/patient lacking bands Bedside nurse asked about failures and fix occurred immediately Discussion of topic on safety walkrounds and leadership engagement			placed (3.2%), gets in the way of care (2.7%) Failure rates highest in NICUs, due to accepted practice of placing band on intravenous tubing attached to patient or taped to isolette Implementation and self-auditing differed from site to site
Hain et al. (2010)[76]	U.S., single academic pediatric hospital (Vanderbilt)	Improve use and accuracy of pediatric ID bands	Development of unit-specific (including emergency department [ED]) corrective action plans by nursing manager Input was provided by results of survey, and representatives from nursing, respiratory therapy, intravenous therapy, and medical directors. Educational programs for ancillary providers including transport, child-life specialists, and dietary and radiology technicians.	Pre/post study The institutional performance management and improvement group performed initial audit of "all available patients in the hospital" in November 2007. Hospital staff were surveyed about barriers to ID band use. Implementation of unit-specific action plans was followed by at least 4 audits per month. Identification errors defined as missing bands, inappropriately placed bands, illegible bands, or inaccurate data.	November 2007 to May 2008	**Baseline ID band failure rate: 20.4%** Staff awareness of audits resulted in a decreased defect rate to 6.5% (from 20.4%). **Post-intervention**: About 4 months after implementation of action plans (January 2008), defect rate dropped from 6.5% to 2.6% (a 60% drop from original mean). **Staff survey regarding barriers to compliance (501 responders, 30.6% response rate)**: Improper fit (22%) Band placement impedes care (16%) No barriers (12%) Patient/family removal (12%) Removed and not replaced (7%) Skin irritation (6%) Swelling (5%) Memory (not further defined by authors; 4%)

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
Adelman et al. (2015)[5]	U.S., single institution (Montefiore medical system, within 2 NICUs)	Order entry	Assigning unique name to newborns at birth Incorporation of mother's name into newborn's temporary name (e.g., Wendysgirl) For multiple births, number added to front of first name (e.g., 1 Judysgirl, 2Judysgirl)	Prospective pre/post study DISTINCT study **Pre-intervention**: July 1, 2012, to June 30, 2013 **Post-intervention**: July 1, 2013, to June 30, 2014 **Outcomes**: Retract-and-reorder tool: retraction of orders within 10 minutes that are subsequently reordered by same clinician for another patient within 10 minutes The rate of wrong-patient orders was then estimated based on prior work suggesting that 76.2% of retract-and-reorder events represent wrong-patient errors.	2 years	**Total orders placed**: Pre-intervention: 157,857 orders placed with 94 retract-and-reorder events (60 events per 100,000 orders) and estimated 45 wrong-patient orders (per 100,000). Post-intervention: 142,437 orders placed with 54 retract-and-reorder events (38 per 100,000 orders) and estimated 29 wrong-patient orders (per 100,000). **Provider type**: 677 providers: 14.8% (100) attending physicians, 53% (359) house staff, 3.1% (21) nurse practitioners, physician assistants (4.7%), respiratory therapists (7.7%), other (16.7%) **Retract-and-reorder events**: Compared with pre-intervention, the odds of a retract-and-reorder event significantly decreased after the intervention: odds ratio 0.64; 95% confidence interval, 0.42 to 0.97. There was a 36.3% reduction in retract-and-reorder events; the rate decreased from 59.5 per 100,000 orders to 37.9 per 100,000 after the intervention. Benefits were more pronounced for: House staff: odds ratio 0.48; 95% confidence interval, 0.24 to 0.93 Orders on male patients: odds ratio 0.39; 95% confidence interval, 0.19 to 0.83. Although improvement of retract-and-reorder events was most significant for orders on male patients, an

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
						improvement was seen for female infants and infants of all ages captured in the study. **Estimated wrong-patient orders** (per 100,000 orders): For house staff, the estimated rate of wrong-patient orders decreased from 52 to 21. For attending physicians, there was no change (28 before versus 28 after) Authors note: 81.7% of NICUs reported using a nondistinct naming convention. *This intervention's potential to distinctively benefit NICU*: Patient photos are less helpful in this context because neonates may lack distinguishing physical features. Alerts may eventually result in alert fatigue. A new naming convention is simple and inexpensive and addresses each of these concerns. Limitations: No accounting for secular trends (only pre/post study) Hawthorne effect (staff not blinded, may have known they were being observed) Estimation of wrong-patient order rate was validated in *general* hospital setting, while this study focuses on NICUs
Green et al. (2014)[77]	U.S., 5 academic EDs in New York (2 adult,	Order entry	Dialog box (with full patient name, DOB, and MRN) displayed with forced delay of	Prospective pre/post study	**Pre-intervention** January to April 2011	A total of 5,637 retract-and-reorder events identified. Using positive predictive value from Adelman et al. 2013 (see next row in this table), the

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
	2 pediatric, 1 combined)		2.5 seconds at beginning of each ordering session, requiring providers to verify the patient for whom the order was being placed. Additional information was also displayed (length of stay, chief complaint, bed location, recent medication orders, male/female icon, and warning message if another patient in ED had the same name).	Secondary analysis: inpatient orders were used as a control group (to control for institution-wide quality control initiatives) If providers hit cancel, prompted to select why. **Primary outcome**: retract-and-reorder rate	**Short-term assessment**: June to September 2011 **Long-term assessment**: January to April 2013	average rate of wrong-patient orders was 1.63 per 1,000 orders (95% confidence interval, 1.59 to 1.67). 40.6% diagnostic procedures (15% imaging, 85% laboratory tests) 21.1% medications 38.2% nursing and miscellaneous Providers committing wrong-patient orders: 50.7% resident physicians 34.1% attending physicians 12.1% physician assistants 3.1% others **Short-term effects**: Compared with 4 months prior, 30% reduction in rate of wrong-patient orders (2.02 versus 1.41 per 1,000 orders, relative reduction 0.70; 95% confidence interval, 0.63 to 0.77). Patient variables (sex, age, race), provider roles (attending, resident, etc.), and day/night shift were not associated with wrong orders. After adjusting for these potential confounders, there was still a significant reduction: odds ratio 0.72; 95% confidence interval, 0.64 to 0.80. Also, the difference was significant when inpatient orders were used as control: relative reduction 0.69; 95% confidence interval, 0.62 to 0.76). **Long-term effects**: 24.8% decline (1.53 per 1,000 orders, relative reduction 0.76; 95% confidence interval, 0.69 to 0.83).

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
						All 5 EDs had reductions, but reduction was significant in only 2 sites. **Reasons for canceling order** (observed in first 4 months after implementation, 5.3% of the time, order was canceled): 0.4%: wrong patient selected 0.3%: accidental clicks of order entry button 0.3%: interruptions 4.3%: other **Time required for intervention**: Additional 2.1 minutes per 12-hour shift, with maximum of 6.3 minutes **Unclear whether the positive predictive value is applicable here (i.e., the rationale given in the other paper—rounds, etc.—unlikely to apply to ED).
Adelman et al. (2013)[8]	U.S., 4 hospitals	Order entry	ID verify alert (single-click confirmation of patient's name, sex, and age) ID reentry function (reentry of patient initials, sex, and age)	Prospective randomized controlled trial (RCT): ID verify alert versus ID-reentry function versus control Retract-and-reorder measurement tool: identified orders (medications, blood tests, imaging, and general care) retracted within 10 minutes and reordered by same provider on different patients within 10 minutes (not counted as an error if reordered on the initial patient within 24 hours). For 3 months, conducted semistructured interviews with providers (n = 236) within 12 hours to confirm orders were wrong-patient orders. Each error was independently classified by 2 physicians for severity of potential harm. **Primary endpoint**: Proportion of *ordering sessions* containing retract-and-reorder	Intervention: December 2010 to June 2011 (6 months)	**Phase I** (validation of retract and reorder as a wrong-patient order): 236 providers used retract and reorder 13 did not recall placing orders; 223 did recall (170 confirmed erroneous order: positive predictive value 76.2%) 95% confidence interval, 70.6% to 81.9%) Description of errors: 10.6% (18) juxtaposition 80.5% (137) interruption 8.8% (15) other Frequency of wrong-patient errors (all orders placed at Montefiore in 2009)

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
				events (surrogate for wrong-patient electronic orders) **Secondary endpoint**: Additional time required Blinding: study personnel analyzing data were blinded		6,147 providers, 9 million orders: 6,885 retract-and-reorder events (from 1,388 providers) Mean time to retraction: 1 minute, 18 seconds Applying positive predictive value, estimation that 5,426 wrong-patient orders placed in 2009 **Phase II**: 901,776 order sessions from 4,028 providers Control (1,419 providers), ID-verify alert (1,352 providers), ID-reentry function (1,257 providers) *Rates of retract and reorder (per 1,000 orders)*: Control: 1.5 ID-verify: 1.2 ID-reentry: 0.9 Both interventions significantly reduced the odds of a retract-and-reorder event: ID-verify: odds ratio 0.84; 95% confidence interval, 0.72 to 0.98 ID-reentry: odds ratio 0.60; 95% confidence interval, 0.50 to 0.71 *Additional time*: ID-verify alert: 0.5 seconds ID-reentry: 6.6 seconds Common reasons for retract and reorder that do *not* represent erroneous errors: physician canceled order (for reasons other than wrong-patient error), then moved to next patient on rounds and ordered total parenteral therapy, warfarin, etc. for the next patient)

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
Hyman et al. (2012)[3]	U.S., single institution, pediatrics	Order entry (pediatrics)	ID verify, and integration of patient photo into verification screen	Pre/post study Comparator 1: verification screen versus standard of care (retrospective data) Comparator 2: verification screen with photo versus standard of care (retrospective data) Additional verification screen begun in 2010; throughout 2011, photo IDs added. By end of 2011, 95% of charts had photo IDs.	2010-2012	Improved error rate after initiation of photos during order entry The number of wrong-patient errors decreased from 12 (in 2010) to 3 (in 2011), a 75% reduction. 51 identification errors in 2010 12/51 during order entry (2nd highest type) 37 identification errors in 2011 3/37 during order entry (3rd highest type) Time between errors in patients with photo was 15 months In the 15 months after implementation of the intervention, no patient whose picture was in the EHR was reported to receive unintended care because of an erroneous order placement. Data rely on voluntary reporting system (known bias toward underreporting).
Wilcox et al. (2011)[78]	U.S., single institution (Columbia University Medical Center)	Order entry	Pop-up window (with patient name and MRN) before completion of each note	Prospective pre/post study Patient-note mismatch defined as a patient's note found in a different patient's chart. Assessed change in rate of clinician-discovered mismatches or change in estimated rates of sex mismatches from January to October 2007 versus January to October 2008 in admission notes. Used rates of sex mismatch to extrapolate the total number of mismatches from "discovered" mismatches by clinicians.	January 2007 to October 2008	Rate of clinician-reported patient-note mismatches per admission note written was 0.0005 (95% confidence interval, 0.00037 to 0.00060) in 2007. This declined to 0.0003 (95% confidence interval, 0.00021 to 0.00038) in 2008, $p < 0.004$. Although these confidence intervals overlap, the difference is significant because the numbers are correlated. Sex mismatch did not significantly differ between the 2 periods. "A pop up window reduced the patient-note mismatch rate by about 40%."

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
						The authors note: Because the overall prevalence of these errors (compared with other inaccuracies in the patient note) is relatively low (i.e., a rare event), although a 40% reduction is impressive, the absolute prevalence remains low.
Sakushima et al. (2015)[80]	Japan, single academic hospital	Medication administration	Bar code	Retrospective pre/post study Voluntary reporting of medication errors by staff through electronic system.	April 2003 to March 2012, implemented in April 2008	2,867 error reports total. Implementation of bar-code verification resulted in a decrease in wrong-patient/drug errors from 41.6/year to 24.8/year, a decline of 40%. Wrong-patient errors decreased significantly after implementation (17.4/year to 4.5/year, p <0.05). However, no significant change in wrong-drug errors (24.2/year to 20.3/year). Wrong-drug errors caused by: Similar drug names (Veen D/Veen F) Nurse carries multiple drugs to room with more than 1 patient, but scans bar codes for both patients at once; then administers wrong drug to patient
Steele and Bixby (2014)[67]	U.S., single children's hospital (Children's Hospital of Orange County, California)	Breast milk storage and administration	Creation of breast milk handling **Phase 1**: centralized preparation + manual double-check Intervention designed by performance improvement team: *Preparation of feedings*: 12 hours of feedings prepared by dietetic technicians twice daily	Pre/post study Error rate initially measured; after intervention designed and implemented No description of how errors were captured.	3.5-year period	Failure mode and effects analysis (FMEA) multidisciplinary team identified 282 potential failure points, prioritized and identified root causes for top 85 causes. Causes of problem—4 primary areas of concern identified: Process was unclear and cumbersome for bedside nurse Inadequate double-checks at key points (e.g., when mother provided with labels for milk, and when nurse preparing milk, often combining multiple bags)

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
			and placed into syringes for tube feedings or bottles. Order reviews in EHR before each batch prepared 2 technicians required to confirm matching of first/last name/MRN for each bottle—compared to EHR-generated labels for placement on new feedings Double confirmation was recorded on each patient's individual breast milk preparation sheet *Before feeding/ discharge*: After providing double-check of each bottle for a patient, 2 technicians would place bottles into sealed bag, labeled with patient's name, and initial to confirm check complete. At administration, registered nurse (RN) would confirm identity with patient or another staff member (instead of having to check each individual bottle again).			Risk of human error and confirmation bias due to frequency of feeding (e.g., as often as 12 times per shift) Contamination risk, because no place to handle breast milk in NICU aside from bedside From May 2010 to May 2012 (2 years): 45 total breast milk handling errors identified (unclear how these were identified). 3 cases of wrong milk given to patient 16 labeling errors 26 storage errors (milk in wrong bin) 0 administered expired breast milk **After introduction of new protocol** (over 10-month period): Total of 7 errors captured, with no administration of milk to wrong patient. Of these 7 errors, 4 were labeling errors, 3 were storage errors. * Of note, 45 errors captured over 2 years while 7 errors measured over 10 months. After introduction of bar-code system, detected 5 errors (1 labeling, 4 storage errors) in the next 6 months. Detected 55 near misses in which breast milk was scanned to the wrong patient.

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
			Phase 2: Bar-code system introduced—replaced the double-check protocol			
Higgins et al. (2010)[81]	U.S., single large teaching hospital (Baystate Medical Center)	Medication administration	Bar-code scanning and positive patient identification Quality improvement initiative	Pre/post study Unclear if prospective or retrospective Wrong-medication dispensing errors were measured by self-report (via online reporting system).	2007 to first quarter 2010	Implementation in 2nd to 4th quarters of 2008; in the 5 quarters following intervention, medication errors reaching the patient significantly decreased to 0.69 per million doses (73% decrease, p <0.05). However, total errors (near misses + errors reaching the patient) significantly rose from 20.1 to 38.4 events per million from pre- to post-intervention (p <0.05). In 2007, 15 events reached the patient; in 2009, only 5 events, including delay in administration (1) and labeling errors scanning could not detect (2).
Poon et al. (2010)[9]	U.S., single large academic institution (Brigham and Women's Hospital)	Medication administration	Bar-code electronic medication administration record (eMAR) **Outcomes**: Timing errors (administrations early or late by >1 hour) Non-timing-related errors (including transcription errors, and doses)	Observational, controlled study Trained research nurses directly observed order transcription and medication administration in each unit: 2 to 4 weeks before implementation 4 to 9 weeks after implementation Research nurses shadowed staff for 4 hours—these observers were blinded to physician's medication orders—and recorded details about medications administer-ed. Observations were compared to either the paper or the electronic record. Types of errors were classified by study staff; presence of error was confirmed by multidisciplinary panel of physicians, nurses, and pharmacists to confirm	9 weeks	**Nontiming errors**: Significant decrease in nontiming errors after introduction of eMAR: 776 errors, 11.5% error rate, decreased to 495 errors, 6.8% error rate, 41.4% relative reduction, p <0.001. Rate of potential adverse drug events resulting from nontiming errors decreased from 3.1% to 1.6% (50.8% relative reduction, p <0.001). Wrong-medication errors decreased by 57.4% Wrong-dose errors decreased by 41.9% Administration documentation errors decreased by 80.3% Significant reductions in nontiming administration errors were seen across

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
				presence of error and assessment for patient harm (if the observer believed an error was being made). Study observed total of 14,041 medication administrations for 1,726 patients. Most observations occurred during weekday nursing shift.		surgical units, intensive care units (ICUs), and medical units. Significant decreases in potential adverse drug events were seen for surgical units and ICUs, but not for medical units (likely due to low baseline rates). **Timing errors**: Timing errors decreased from 16.7% to 12.2%, p = 0.001. Most of these errors occurred due to late administration. **Transcription errors**: 1,799 orders on units without bar-code eMAR were assessed. After implementation, the number of transcription errors decreased from 110 errors to 0, p <0.001. Of these 110 errors, 53 were potential adverse events. Authors speculate errors persist because of noncompliance: 20% of medications given without scanning, even when bar-code eMAR was supposed to be used.
White et al. (2010)[82]	Canada, single institution	Medication administration (chemo-therapy)	Old checklist versus new checklist for intravenous chemotherapy error detection Order of new checklist was designed to eliminate confirmation bias; also, offered specific step-by-step instructions.	Simulation study Simulated environment for error checking: actors played the role of 1st nurse and cancer patients and simulated interruptions. Study assessed the ability of 2nd nurse to detect errors Half of participants used old checklist first. Each participant checked 14 pumps. 2 observers collected data on number and type of errors detected and time to complete check.	Not applicable (N/A)	Compared with the old checklist, the new checklist was associated with higher error detection (errors of any type): 55% (71/130) versus 38% (49/130), p <0.01. No difference between checklists for: Detection of pump programming errors (90% versus 80%, p >0.05). New checklist (with addition of check MRN and name from armband) resulted in significantly higher detection of

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
			Observed 13 nurses for 30 hours to categorize errors. 10 nurses participated in study.			identification errors (80%, 16 of 20) versus 15%, 3 of 20), p <0.01. Low detection of mismatch errors, and no difference between checklists (45% old, 60% new). Neither checklist allowed detection of clinical errors (0 of 30 detected). Efficiency: No significant difference between old checklist (2 minutes, 16 seconds) and new checklist (1 minute, 55 seconds). Nurses commented new checklist was easier to use.
Young et al. (2010)[79]	U.S.	Medication administration errors (MAEs)	Bar-code technology	Systematic review Purpose: To determine whether implementation of bar-code medication administration is associated with reductions in MAEs Search/dates: PubMed, Cumulative Index to Nursing and Allied Health Literature (CINAHL) from 1999 to 2009. **Included**: English language, clinical trials, direct observational trials of medication administration in an acute-care setting; studies were required to report pre- and post-intervention rates **Excluded**: bar-code technology before point of care (e.g., in the pharmacy area itself); studies using incident reporting as a pre-intervention incidence; studies on nonmedication use of bar-code technology 6 quasiexperimental design studies met criteria for inclusion. Setting: acute tertiary care 5 of 6 studies assessed adults Study interval: 6 months to 1 year after implementation	N/A	Only 5 studies reported pre/post intervention data. 3 studies found decrease in medication administration error (MAE) rate after implementation; 1 study found no change and 1 study reported a significant *increase* in MAEs after implementation (although medication errors with potential to harm decreased). **Positive studies** (3): *Medical intensive care unit*: 1 study found MAEs decreased from 19.7% to 8.7% after implementation (56% decrease, p <0.0001) *Surgical ward*: 1 study found MAEs decreased from 8.6% to 4.4% (39% decrease, p = 0.005). *3 inpatient units*: 1 study found control unit had no change in MAE rate; of 2 units receiving the intervention, 1 unit had a nonsignificant decrease, and 1 unit had a significant decrease from 15.6% to 10% (54% reduction, p = 0.05).

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
				Outcomes: (measured monthly) Preimplementation: direct observation of medication errors Postimplementation: electronic logs from bar-code technology		**Studies with no change or increase in MAEs**: 2 medical-surgical units, 2 ICU units: Helmons et al.*: No change in MAE rates for medical-surgical units; increased MAEs in the ICUs Neonatal ICU: MAE rates significantly increased (69.5 to 79.9 per 1,000 doses [15%] after implementation, p <0.001). Errors with potential to harm decreased from 15.1 to 4.4 per 1,000 doses. Right-patient errors: 2 of 5 studies reported right-patient MAE errors: both studies found a decrease in right-patient errors after implementation. This decrease was significant for 1 study (Skibinksi et al.*, p = 0.003), but not the other (Franklin et al.*).
Spruill et al. (2009)[83]	U.S., single institution (University of North Carolina, Chapel Hill) marrow transplant program	Medication administration (chemo-therapy)	Protocol (bedside check of patient identification by 2 chemotherapy-competent nurses before administering chemotherapy)	Pre/post study Implemented protocol on the bone marrow transplant unit **Briefing**: At beginning of shift, charge nurse and patient's nurse discussed all patients receiving chemotherapy on that shift. **Debriefing**: Before end of shift, nurses asked by charge nurse, "Did you have two RNs check chemotherapy in the patient's room?" **Outcomes**: Incidence of wrong-patient-related chemotherapy medication errors	6 months August 1 to November 1, 2008, compared with November 1 to February 1, 2009	No misidentification-of-patient chemotherapy errors before or after introduction of new protocol. 90 of 90 instances of chemotherapy administration were double-checked by 2 chemotherapy-competent nurses at the bedside. 100% of staff cited implementation of bedside check as an improvement in practice. Barriers: Resistance to change Lack of readily accessible nurse to perform bedside check

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
Jani et al. (2015)[89]	U.S., single institution	Radiation therapy (treatment)	Automated system to detect patient identification and positioning errors before initiating treatment The study team developed algorithm to detect wrong patient and wrong position using anatomic data comparing image pairs (the planning computed tomography [CT] image and the setup CT)	Prospective validation study Comparator: algorithm versus control (gold standard of database with known errors) Study team created a set of same-patient image pairs and different-patient image pairs to test their algorithm Images from 496 patients were used (2 CT types analyzed separately). The study evaluated images from 2 CT systems (TomoTherapy and TrueBeam). TomoTherapy (256): 100 head and neck 100 pelvis 56 spine TrueBeam (240): 83 head and neck 100 pelvis 57 spine A planning CT image was compared with a setup image using the study algorithm. The algorithm indicated same patient or wrong patient. 2 different-patient pairs were created for each planning image (912 total; inferred because number is not stated).	Used images from 2011-2014	When analyzed using a database of known errors (gold standard), the algorithm had few misclassification errors (MCEs). **TomoTherapy**: MCE rates (0% is best): Head and neck 0.66% (± 0.02) Pelvis 1.67% (± 0) Spine 0% (± 0) *Sensitivity*: Head and neck 99.2% (± 0.087) Pelvis 98.1% (± 0.12) Spine 100% (± 0) *Specificity*: Head and neck 99.0% (± 0.12) Pelvis 97.5% (± 0.21) Spine 100% (± 0) **TrueBeam**: MCE rates (0% is best): Head and neck 3.5% (± 0.04) Pelvis 2.3% (± 0.05) Spine 2.1% (± 0.06) *Sensitivity*: Head and neck 96.2% (± 0.22) Pelvis 97.3% (± 0.16) Spine 97.7% (± 0.2) *Specificity*: Head and neck 95.4% (± 0.35) Pelvis 96.5% (± 0.29) Spine 96.7% (± 0.35)

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
						Different-patient pairs were simulated rather than natural. There is no discussion of the mechanism for creating different-patient pairs. No discussion of patient characteristics. TomoTherapy has superior image quality than TrueBeam, which is a potential cause of difference between the 2 systems tested. The results were affected by image quality (high-quality CT gives better data for algorithm to work). The algorithm could run in the background as a safety check (with the potential for automatic prevention of ID errors).
Pandit and Boland (2015)[86]	U.S., Johns Hopkins	Ophthalmo-logic test data	DICOM (digital imaging and communications in medicine) workflow Developed in 1985, as a universal, nonproprietary standard DICOM image files have: Header section (including data about the imaging-acquisition parameters, filters, image dimensions) >2,000 demographic and medical attributes including patient name, DOB, provider, and diagnosis)	Pre/post study Assessed work performed by 6 technicians (0-3 months immediately before and after implementation) and long term (15 to 18 months after). At implementation, all existing visual field data uploaded from Humphrey field analyzers to DICOM archive. DICOM archive linked to central patient registration system. Technicians would select from patients already entered instead of manually reentering patient demographic data before acquisition.	3 months immediately before imple-mented (June to September 2011) and 3 months immediately after (September to December 2011) and longer term (3 months after: December 2012 to March 2013)	Prior to implementation, 48% of encounters required intervention to add/edit demographic information. Compared with 3-month evaluation, at 18 months more encounters had the correct demographics available to the technician (80% versus 73%, p = 0.08). Compared with pre-implementation, the DICOM system decreased the misfiled image rate by 76% (9.2% to 2.2%, p <0.01).

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
			Acquired images sent and stored in central server (archive)—this combination known as picture archiving and communication system (PACS): DICOM archive and review stations			
Rubio and Hogan (2015)[85]	U.S., pediatric hospital, tertiary care single institution	Wrong-patient/ wrong-study errors	New protocol 2-person verification protocol ("Rad Check") 2 healthcare employees read back a name and MRN with additional verbal confirmation of study to be performed. Readback required patient armband and paper/electronic order.	Retrospective pre/post study Review of electronically submitted incident reports Excluded following errors: Clinician ordered wrong study on intended patient Ordering any study on the wrong patient Correct studies field under wrong PACS patient jacket Studies performed on correct side of patient, but labeled incorrectly **Outcome**: Incidence of wrong-patient or wrong-study errors Only interested in whether radiology staff performed their part adequately, not whether the clinician ordered the study on the wrong patient	January 2009 to December 2014	Over 72 months, overall incident rate was 15 per month (180 over the year). 45 wrong-patient or wrong-study errors were identified. After use of Rad Check, the incidence of errors dropped from 9.4 to 2.9 (per 100,000 examinations) (p = 0.001). The time between errors also increased from a baseline rate of 1 per 35 days to 1 per 101 days. On average, the verification step required 12.5 seconds (range 5 to 95 seconds) to complete. **Composition of errors**: Wrong patient: 36% Wrong study: 64% Radiography: 71.1% CT: 11.1% MRI: 6.7% Nuclear medicine: 4.4% Fluoroscopy: 4.4% Ultrasound: 2.2% In 20% of cases, patients received unnecessary radiation.

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
Tridandapani et al. (2015)[4]	U.S., single institution, radiology	Radiology image interpretation (reading room)	Test the effect of inclusion of patient photograph with radiographic image on reading time and patient identification errors	Pre/post study Chest radiograph-photograph combinations obtained during routine clinical care Tested 5 radiologists blinded to study on ability to detect patient identification errors in 28 patients 13 male, 15 female Mean age 61 (22-89) Clinical conditions: variable Site: cardiothoracic ICU Studies: 166 studies, used to create 83 matched pairs and 12 error sets Studies: single view chest or abdomen First tested on set of 20 randomly selected image pairs without photographs, then on set of 20 images with photo-graphs. Selection was done with no replacement (no repeat images). Radiologists not informed that study was to assess patient identification errors. Clinical information and patient ID not provided to test subjects	August to November 2011	**Use of photographs improved detection of image mismatches** Without photographs 0/20 patient errors detected. With photographs 17/18 mismatched pairs identified. Also 1 false positive. 2 of 5 radiologists believed photographs were a distraction. Time to complete review of films decreased in phase with photographs; however, this was the 2nd set of images, so it may be related to task familiarity. No comparison for time to 2nd stack without photographs. Limitations: Radiology images typically include some form of patient ID and in this study they were excluded, which would bias results towards the intervention. Generalizability consideration: Only cardio-thoracic ICU patients were included, so results may not reflect typical worklist Error detection rate in this study may be falsely elevated due to high error prevalence intrinsic given the study design.
Tridandapani et al. (2014)[87]	U.S., data from single institution, participants from many institutions	Radiology image interpretation (reading room)	Tested the effect of inclusion of patient photograph with imaging studies on reading time and patient identification errors. Used simultaneous photographing system (automated)	RCT Comparator: photograph versus no photograph on image pairs Study conducted at American Board of Radiology oral examinations—90 radiology participants recruited for study Images from 34 patients in cardiothoracic ICU obtained with patient identifiers removed 30 patients included in study	August to November 2011	**Radiologists were better at identifying errors when presented with photographs.** Odds ratio, 7.3; 95% confidence interval, 2.29 to 23.18), p = 0.006 Without photographs 9/29 (31%) errors identified With photographs 23/30 (77%) of errors identified No false positives

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
				Clinical conditions: variable 166 radiographs obtained, 83 unique pairs, created 10 mismatched pairs (randomly created) Each participant reviewed 10 pairs of films with at most 1 error in the set. Participants asked to review the films and not informed about the potential mismatch. A free-text box for "Other comments" allowed radiologists to note the mismatch (or make other comments). After the 10 studies, participants asked if any patient mismatches were noticed.		Time to read was 60 seconds without and 61 seconds with (standard deviations of 22 and 25, respectively) Observers who felt photographs delayed them took longer to review images than those who did not feel that the photographs delayed them Authors note: Color photographs may falsely elevate identification rate because black-and-white monitors are still normal in reading rooms
Kao et al. (2013)[91]	Taiwan, single institution, radiology	Radiology image storage retrieval system: PACS Chest radio-graphy only	Identify patient using 6 biologic markers: length of lung field, size of heart, area of body, widths of upper/middle/lower thoracic cage	Prospective validation study Created 999,000 data sets for different identities from 1,000 image pairs (each image "matched" to the other 999) Calculated similarity score for 1,000 randomly selected mismatched pairs and compared this to the 1,000 matched pairs to determine the difference in scores between the sets. Repeated this 10 times with different mismatched pair sets.	Not reported	Using the 6 features, can predict whether there is a matched set or mismatched set based on a calculated similarity score. Using the 6 features: Mean similarity score for same patient was 4.53 (± 0.84) and 1.90 (± 1.18) for different patients 1.1% of different patients had similarity score >4.5 (false positives)
Lamb et al. (2013)[12]	U.S., single institution, radiology	Radiation therapy (treat-ment)	Automated system to identify patient identification errors and gross positioning errors in patient setup	Prospective validation study Comparator: algorithm versus control (gold standard of database with known errors) System acquires 2 planar radiographs that are matched to the planning CT using 2-dimensional and 3-dimensional registration algorithm Images from 283 patients used (100 cranial, 100 prostate, 83 thoracic/lumbar) Measured similarity using a correlation coefficient (lower is better)	NR	**The software was able to detect patient identification mismatches at the time of radiation therapy treatment**. No false negatives or false negatives for cranial studies, with a similarity coefficient of 0.5 2% false-positive rate, 0% false-negative rate for prostate studies, with similarity coefficient of 0.5 Similarity coefficient of 0.4 for spinal alignment; identified 162/166 incorrect

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
				ExacTrac software and algorithm used; unaltered from off-the-shelf version		localizations and 81/83 correct localizations. Misclassification probability of 0.000, 0.0045, and 0.014 reported for cranial, prostate, and thoraco/lumbar images, respectively, after a 10-fold cross-validation linear discriminant analysis
Toge et al. (2013)[90]	Japan, single institution, radiology	Radiology image storage retrieval system: PACS Chest radiograph only	Identify misfiled patient images in the PACS using automated image-comparing algorithm	Prospective validation study Comparator: algorithm for reindexing versus already indexed Used database with 36,212 patients, anatomized 200 chest radiographs randomly selected (100 male, 100 female) and intentionally "misfiled." Used 5 biologic markers on chest radiograph (cardiac shadow, lung apex, superior mediastinum, right lower lung, and whole lung field) to make "fingerprint" Compared biologic fingerprint of misfiled image to those in the database	NR	**System effectively identifies patients for misfiled images, if a "seed" image exists.** Unweighted algorithm: 78% (200) of misfiled images were correctly reindexed in the database (found correct patient) Weighted algorithm: 87.5% of images able to be automatically reindexed to correct patient; another 5% were sufficiently similar that radiologist review could identify correct patient from potential patients. Cardiac shadow was strongest marker of similarity. Whole lung field was least useful comparator. Previous study by authors (Morishita* 2005) gave prevalence of misfiled images at 0.117% (327/279,222) Confirmation system in use in Japan (kenzo system) checks patient identification before storing images—prevents misfiling (cited as #3). Not automated.
Tridandapani et al. (2013)[88]	U.S., single institution, radiology	Radiology image interpretation (reading room)	Test the effect of including patient photograph with imaging studies on reading time and	Pre/post study Comparator: inclusion of photograph with radiograph versus solely radiograph Convenience sampling of patients	August to October 2011	Error detection without photograph 3/24 (12.5%) With photograph 16/25 (64%)

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
			patient identification errors. Use simultaneous photographing system (automated)	Images from 34 patients in cardiothoracic ICU obtained, patient identifiers removed 28 patients included in study 13 male, 15 female Mean age 61 (22-89) Clinical conditions: variable 176 radiographs obtained, 88 unique pairs, created 10 mismatched pairs (randomly created) 10 radiologists (recently trained) read 20 film pairs without photographs and with photographs (different film pairs in each set). Up to a 20% mismatch rate was used in each of the phases. Radiologists not informed regarding the purpose of the photographs.		Interpretation time without photograph 35.73 minutes, with photograph 26.52 minutes. One reader actively ignored the photographs because he thought the intent was to distract the radiologists (noticed only the last mismatch) 40% (4/10) of participants felt the photographs helped identify mislabeled patients.
Alreja et al. (2011)[84]	U.S., Baystate Health System	Point-of-care testing (POCT)	New glucose meter and workflow. With new workflow, after scanning patient wristband, operator confirms ID by entering year of birth, which then unlocks meter and allows testing to proceed. Prior meter required scanning wristband and entering 9-digit MRN. Results from all patients downloaded and *only then* checked against system's ID.	Pre/post study (although not specified) Prospective versus retrospective not stated. All glucose POCT using both meters was monitored over 2-month period. No description of where new or old meters were used (e.g., which patients got control versus intervention).	2 months	Decrease from 61.5 to 3 errors per month with use of new meter. Old meters: 19,269 POCT tests performed per month. Average of 61.5 patient ID errors/month with error rate of 0.319%. Most errors occurred outside of the ED. New meters: 18.858 tests per month performed. Statistically significant decline to 3 errors per month (0.015%, p = 0.002) noted after implementation. Most errors with new meter due to transient use of ID numbers/emergency codes for unregistered ED patients. (These occur when patients are being tested for triage—and before wristbands are issued.)

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
Danaher et al. (2011)[16]	U.S., Australia (3 hospitals)	Wrong-side/ wrong-site errors Radiology, imaging, and interventions	New protocol Adoption of 3 C's (correct patient, correct site and side, and correct procedure)	Pre/post study 4-step protocol: Patient identification check Obtain and check informed consent Correct side and site verification Team final check For unconscious, uncooperative, or noncommunicative patients, a nurse or physician confirms the information	18 months before versus 19 months after versus 8 months after new reporting system. (January 2007 to July 2010) Incident reporting system under-went major upgrade in December 2009 to improve ease of reporting and convert to online.	The radiology error rate decreased after implementation of 3 C's (0.63 errors per month to 0.11 errors per month), but subsequently increased after new error-reporting system introduced (1.13 errors per month). **Near misses**: Only 1 near miss (wrong patient) before implementation versus 8 afterwards: 6 wrong patient, 1 wrong site/side, 1 wrong procedure **Completed errors**: 9 completed errors before implementation (6 wrong patient, 3 wrong procedure) versus 3 after implementation (2 wrong patient, 1 wrong site/side). Most common cause of ID error is physicians requesting imaging for wrong patient because they used the wrong patient ID sticker. Staff acknowledged instances in which the "final check" is signed before patient arrives in department or hours after examination is completed. Audit of 100 cases found 100% compliance with patient identification verified. Convenience survey of 90 staff: 55% agreed process is easy 48% agreed process is quick 52% process is relevant 61% process is useful Study subject to significant reporting bias

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
Miller (2015)[93]	U.S., Rush Medical Center	Blood specimen labeling	Automated algorithm Composite complete blood cell count/delta (CCD) algorithm, incorporating mean cell hemoglobin (MCH)	Validation study Validation of CCD algorithm to identify mislabeled blood specimens: Complete blood count (CBC) CCD Mean red blood cell volume (MCV) MCH: not affected by hydration/dialysis CCD algorithm was used to assess 11,193 CBC samples over 2 weeks. Algorithm was validated using samples from 49 patients with multiple sequential blood tests (>2,000 tests, 98% acquired <2 days apart).	2 weeks	On a base of 11,193 CBC samples taken over 2 weeks – 52% (5,792) had prior CBC values to allow assessment. 110 failed the delta check, with the following causes: 49% (54) due to interim transfusion 36% (39) valid (false positive) after medical chart review 8% (9) presumed or confirmed mislabeled 7% (8) failure due to another problem Algorithm specificity: 97.6%; sensitivity: 92.5%
Hawker et al. (2014)[98]	U.S., single institution	Laboratory specimen handling	Optical character recognition (OCR) technology to detect mislabeled specimens	Prospective validation study Comparator: OCR versus routine quality assurance (QA) procedure Simultaneously used OCR and routine QA to assess >1 million laboratory samples. OCR captured an image of each tube as it was being processed. Samples that met prespecified criteria were passed through as correct; others were flagged for review. Each image was manually reviewed. Failed images were classified as patient identification events, spelling events, or false negatives (missed patient identification errors). 1,009,830 images obtained; manual confirmation by human observer of accuracy of OCR rendering was performed to determine accuracy of OCR algorithm All samples went through standard QA, without prior knowledge of OCR results. All assessors were blinded.	2006-2013	OCR recognized significantly more mislabeled specimens than routine quality checking; however, the high rate of false positives remains barrier to implementation. With 1,009,830 images obtained to determine accuracy of OCR algorithm, 73.6% passed OCR screening; 0 mislabeled samples were passed: • 26% (266,852) flagged as mislabeled by OCR: of these, 121 were true patient identification errors (of which only 71 were detected by QA) and 148 were discrepancies between spelling of a patient name in laboratory system versus label • 266,583 falsely flagged by OCR as potential misidentifications (high false-positive rate)

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
						21 (rate of 5/1,000,000) of the patient identification errors resulted in clinically meaningful changes. Without OCR, undetected error rate is reported as 2.1/100,000 samples
Rizk et al. (2014)[97]	Egypt, single institution	Specimen handling for chemistry tests	Education initiative for nurses, secretaries, and technicians	Pre/post study (prospective versus retrospective, NR) Comparators: education versus control (baseline, preeducation) Assessed all inpatient chemistry specimens over a 3-month baseline, then at months 1 to 4 after intervention. **Outcome measure**: Incomplete patient identification on requisition form	3 months before intervention; months 4 to 6 after intervention	At baseline, 1.02% (326) requisition forms had incomplete patient information; this significantly decreased to 0.24% (68) after the intervention, p = 0.001. No description of how errors were detected; measurements reflect "rejected" requisitions, but the criteria for this are not reported.
Seferian et al. (2014)[95]	U.S., single institution, tertiary care center	Specimen labeling	Series of interventions: Staff engagement Data transparency (monthly reporting) Process changes Bolded name and MRN, increased font size 2-person verification Patient engagement in verification Sweep the operating room (OR) after cases (remove extra labels) Bar-code scanning POCT Highlight patient ID and MRN in ICU and ED	Pre/post with repeat measurement Comparator: baseline measurement (6 months pre-intervention) versus series of interventions **Outcome measure**: Errors were defined as mislabeled specimens if (1) mismatch between specimen and requisition, (2) incorrect patient identifiers, or (3) unlabeled specimen Measured inpatient blood and body fluid specimens. Excluded: anatomic pathology and cytology specimens and outpatient specimens All errors were confirmed by a multidisciplinary team. Interventions rolled out over a 24-month period as a quality improvement initiative. Run charts with intervention points used to identify impactful interventions Root cause analysis (RCA) performed on blood bank specimen events	April 2011 to April 2013	>1.8 million specimens were included; 618 labeling errors identified. Rate of label error decreased from 4.39/10,000 to 1.97/10,000 over the intervention period (p value not given) Rate of label error was lower in central phlebotomy 3.4/10,000 versus 4.8/10,000 for unit-based specimen draws (p value not given). Decreases in error rates across all settings except for labor and delivery and OR postanesthesia care unit (PACU). Drop in mean mislabeling rate after initial label redesign (3.06/10,000) and after patient engagement in ID verification (1.97/10,000) Other interventions had less of an independent impact 15 RCAs for blood-bank specimen mislabeling events were conducted. Contributing factors were:

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
			Event review and accountability system			• Local unit environment (32%) • Information technology (24.4%) • Team issues (12%) • Institutional environment (2.4%) • Provider (not defined by authors; 2.4%)
Thomas et al. (2014)[94]	UK, single center	Wrong blood in tube (WBIT)	2-sample policy (protocol)	Pre/post study No details provided regarding how the information was collected	Introduced in August 2011	From 2010 to 2013, there was no change in WBIT rates: (0.22, 0.26, 0.25: WBIT per 1,000 samples). 160 staff were observed and surveyed regarding adherence to procedures: 15% reported not labeling sample at bedside 26% had not completed safety training 28% reported not identifying patient according to correct procedure
Snyder et al. (2012)[92]	U.S.	Specimen labeling	Bar-coding systems for laboratory specimen tracking and POCT	Systematic review and meta-analysis Search: PubMed, Excerpta Medica database (EMBASE), CINAHL for English-language articles from 1996 to 2012 (although the date of the search is listed as August 2011). Inclusion criteria: Report at least 1 ID error outcome measure. 17 studies were identified (of which 8 were unpublished). **Bar-coding systems (10 studies, 7 published)**: All were large U.S. studies with comparison groups of significantly ≥1,000 specimens; diverse geography Inpatient specimens/bedside label printing: 4 studies ED-only specimens: 2 studies	Bar coding: Studies published 2005-2010 Data from 1999-2011 POCT data from 2002-2011	Meta-analysis of 9 studies revealed bar coding associated with significant increase in identification of patient ID errors, (odds ratio, 4.39; 95% confidence interval, 3.05 to 6.32; I^2, 0.24) Overall summary effect (meta-analysis of 7 studies): odds ratio 5.93; 95% confidence interval, 5.28 to 6.67) in favor of bar coding Meta-analysis of patient identification errors for 5 "good" quality studies was in favor of bar coding: odds ratio 5.83; 95% confidence interval, 3.86 to 8.82) Issues related to bar coding: Curve of wrist can interfere with scanning

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
				7 studies assessed POCT bar coding (5 unpublished, 2 published); they focused on POCT glucose measurements Each study assigned quality rating (good, fair, poor) and 1 of 3 effect size ratings (substantial, moderate, or minimal/none).		Label printing can have artifacts Low batteries can affect scan Nonhospital bar codes potentially can be read as barcodes Multiple armbands/bar codes
Doctor and Strylewicz (2010)[96]	U.S. **Study 1**: National Health and Nutrition Examination Survey (NHANES) and Diabetes Prevention Program (DPP) **Study 2**: Diabetes Control and Complications Trial (DCCT)—26 study sites across the U.S.	Wrong blood in tube (WBIT; to detect mismatched $HgbA_{1c}$ and glucose results)	Algorithm **Study 1:** A Bayesian network that encoded probabilistic relationships among analytes was used to detect mismatches between patient data in the NHANES/DPP data set. This data set contained randomly and intentionally mismatched $HgbA_{1c}$ and glucose results. **Study 2:** The same Bayesian network was used to detect errors in the DCCT data.	Prospective validation study Comparator: Bayesian network versus standard error detection software (aka LabRespond) (study 1) versus human (study 2) **Study 1:** Selected glucose and $HgbA_{1c}$ results from the NHANES/DPP dataset were intentionally mismatched. The Bayesian network algorithm was used to detect errors in the data set. Error detection rate for the Bayesian Network was compared with that of standard error detector software. Data set included 6,486 patients with a glucose value, $HgbA_{1c}$, sex, age, and self-reported diabetes status. 2,000 records used for the training set. 3 mismatch scenarios evaluated (50% mismatch, 10% mismatch, 3% mismatch) **Study 2:** Bayesian network detection of errors compared with human study participants. Participants were 11 chemists who self-reported that they could detect glucose/$HgbA_{1c}$ errors. 120 glucose values were selected from the data source and paired with a computed $HgbA_{1c}$, or $HgbA_{1c}$'s were switched to generate errors.	NR Data from 2003-2004 NHANES survey	**Study 1:** *Baseline data* Patient demographics: average age 24.3 years, 51.2% female Not reporting diabetes (92.22%): Average (standard deviation) glucose: 5.017 mmol/L (± 0.694) Average (standard deviation) $HgbA_{1c}$ 5.32% (± 0.21) Reporting diabetes: Average (standard deviation) glucose 7.931 mmol/L (± 4.179) Average (standard deviation) $HgbA_{1c}$ 7.2% (± 2.94) Performances of Bayesian network and LabRespond were not affected by 50% error rate. Bayesian network is better for low and moderate false-positive rate allowances. LabRespond was better at picking up errors when allowing for high false-positive rates. Neither system did well at detecting clinically insignificant switches. Switches between patients with different reported clinical states were easier to identify (both systems). Error detection rates reported using area under receiver-operator curve (AUC) for 95% specificity—higher is better, indicates higher sensitivity at

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
				Respondents reviewed 60 pairs and reported likelihood of error on Likert scale.		95% specificity. In general, Bayesian network was more sensitive. In full sample: Bayesian network mean (standard deviation) AUC 0.65 (± 0.003) LabRespond mean (standard deviation) 0.55 (± 0.01) z-test 29.77 (p <0.0001) In diabetics: Bayesian network mean (standard deviation) AUC 0.79 (± 0.020) LabRespond mean (standard deviation) AUC 0.50 (± 0.04) z-test 13.66 In nondiabetics: Bayesian network mean (standard deviation) AUC 0.63 (± 0.001) LabRespond mean (standard deviation) AUC 0.56 (± 0.01) z-test 25.33 **Study 2:** Bayesian network performed with higher accuracy than 7/11 human chemists and at least as well as the remaining 4 chemists. Expert detection of error ranged 0.67 to 0.85 AUC, which suggests humans were sufficiently skilled to determine errors.
Coustasse et al. (2015)[10]	U.S.	Patient ID errors in transfusion	Radiofrequency identification (RFID)	Systematic review Search: EBSCOhost, PubMed, Academic Search Premier, ProQuest Nursing, *RFID Journal*, Google Scholar, Google from 2000 to 2014.		2 studies reported clinical pre/post information: 1 study reported use in Iowa hospital system for transfusion medicine; in the pilot study (5 units), detection of misidentified patients/blood products increased from 3% to 10%; in system-

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
				Inclusion: Presented benefits/barriers to RFID use; technological, organizational, and financial impact 56 articles identified. A qualitative analysis was performed.		wide implementation, this rate increased to 30%. (Other measures of significance NR). 1 study reported RFID implemented in blood center; detection of misidentified products improved 19%. A 3rd study described RFID implementation in a 700-bed academic ED and blood and bone marrow units; system payback period was 2 to 5 years, with increase in employee performance of 10%. **Benefits of RFID in blood blank supply chain:** Ability to scan item without being in proximity Can scan multiple items at once Tags can be reused Can ensure proper storage and handling through supply chain Can automate reconciliation and inventory check-in Positive ID of recipient, decreasing transfusion to wrong patient Monitors time and temperature Memory capacity 96 or 128 bits at present; larger than single chip on bar code (up to 2,000 characters) Decrease in % of products lost in transit between facilities Ability to track tainted blood **Barriers to implementing RFID**: Cost: (1) tags can be 300% more than current tracking methods, 10 to 15 times more expensive than traditional

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
						bar-code systems; (2) RFID system can cost from $20,000 to >$1 million; readers cost $50 to $3,000 each; software costs $25,000 to $100,000 per facility Medical devices may fail in presence of high-power RFID reader Interoperability problems due to lack of standardization for hardware/software RFID readability can be affected by read range and existence of multiple tagged objects Privacy: chips read by unauthorized readers could allow sensitive personal information to be exposed; health information could be inadvertently transmitted/compromised. Safety: tags can have biochemical and morphological effects on blood products (American Association of Blood Banks)
Cottrell et al. (2013)[99]	U.K.	Wrong blood in tube (WBIT) in transfusion	Interventions that have been implemented to reduce WBIT	Systematic review Search/dates: MEDLINE, EMBASE, Central and Database of Abstracts of Reviews of Effects (DARE), CINAHL, PubMed, British Nursing Index, International Prospective Register of Systematic Reviews (PROSPERO) and United Kingdom Blood Transfusion Services/Systematic Review Initiative (UKBTS/SRI) Transfusion Evidence Library from inception to April 2013 Inclusion criteria: Include pre/post implementation incidence of WBIT Focus on blood samples taken for cross-match or group and save	Studies included ranged from 1.9 to 12 years.	**Single interventions (5 studies)**: Changes to blood sample labeling (3) 1 study reported addressograph labels no longer permitted 1 study reported reinstatement of handwritten patient information on transfusion request form 1 study reported on an electronic transfusion system 1 study noted weekly WBIT incidence reporting 1 study reported use of confirmatory blood grouping samples Each of these studies reported a reduction in WBIT after implementation

Author (Year)	Country, Context	Clinical Context	Intervention	Study Design	Study Duration	Findings
				Identified 11 articles, 3 of which contained the same study data. 9 articles included.		**Multiple interventions (4 studies):** 1 study reported educational campaign, structured educational campaign: WBIT incidence decreased by 75% 1 study reported consent form for transfusion, transfusion newsletter: after 2 years, initial decrease followed by return to baseline, suggesting no significant change 1 study reported policy change, labeling and patient ID corroboration by 2 bedside witnesses, followed by introduction of confirmatory grouping. This resulted in overall decrease in WBIT events from 11 to 3 (over a 10-month period in 2009). 1 study reported education and redesign of group and cross-match tubes; nurses trained to take samples; nurse training was the most effective for reducing the error rate. Authors conclude: All identified interventions reduced WBIT and suggested that multiple interventions introduced at different time points may increase duration of effect.
Nuttall et al. (2013)[100]	U.S., Mayo Clinic	Near-miss and transfusion errors	Bar-code-based blood identification systems Verification process: user must scan patient ID band and the 3 bar codes on blood bag before administration. Then, after administration, the bar-coded blood component identification number	Retrospective pre/post study Prior to implementation, manual verification of patient's identity via identification number with voluntary reporting by staff administering blood.	January 1, 2002, to December 31, 2005 compared with January 2007 to December 31, 2010	Transfusions to the wrong patient were rare: however, implementation was *not* associated with a significant decrease in number of transfusions to the wrong patient (6 events to 1 event, p = 0.14). Before implementation, there were 6 misidentification episodes resulting in transfusion to the wrong patient (1 in 64,806 units or 1.5/100,000 transfusions; 95% confidence interval, 0.6 to 3.3 per 100,00 transfusions).

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			is scanned a second time to document the unit number in the fluids documentation in the chart.			One acute hemolytic reaction in 2004 that was stopped after 20 mL had been infused. After implementation, 1 misidentification episode (1 in 304,136 units, or 0.3/100,000 transfusions; 95% confidence interval, <0.1 to 1.8, p = 0.14). In this case, the unit was not scanned until *after* administered. 43 near misses identified (in which bar code detected mismatch, and blood was not given) 9 events: merged clinic numbers, in which registration updated a number after order for blood was placed The remainder were true near-miss events
Marberger et al. (2011)[101]	Global, 800 sites in 42 countries	Pathology specimen labeling	DNA profiling used to detect patient identification errors Initiated after 3 biopsy mismatches identified in study population Study personnel received education on specimen handling between: • Visual inspection of slides • Bar coding	Pre/post study Comparator: education + patient and sample verification process versus no intervention Gold standard: DNA testing Mandatory biopsy testing program initiated after 3 mismatches noted in year 2 of study Testing involved comparing biopsy to blood sample using DNA identity testing. In cases of potential mismatch, repeat testing of other samples (biopsy and blood) occurred until the source of the mismatch was confirmed as the reference blood or the biopsy. DNA markers used to identify source of switched biopsy sample within the study population	Recruitment into study between March 2003 and December 2004, 4-year study	In year 4 of the study (after intervention and education), biopsy mismatch rate decreased from 26 to 1 (0.4% to 0.02%), 6,458 specimens (year 2) and 4,777 specimens (year 4). Only 4 samples could not be tested (no source DNA to compare) Reference blood tests were also mismatched for 0.5% of samples (31/6,733) DNA testing required additional steps for 13% of samples (DNA contamination) It is not clear whether multiple mismatches occurred on the same patient or if specific sites were responsible for disproportionate mismatch errors.

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Francis et al. (2009)[11]	United States, Mayo Clinic, 41 surgical suites	Endoscopy specimen labeling	RFID (off-the shelf commercial system modified for use) + 2-provider confirmation + paperless requisitions	Pre/post study Comparator: RFID tagged specimens (and paperless requisition and dual-provider confirmation) versus no RFID 3 months before implementation compared with 3-month period (6 months after implementation) RFID stickers placed on bottoms of specimen bottles Concurrent implementation of paperless requisitions and 2-provider confirmation (endoscopist and nurse) of site/procedure	January to March 2007 versus January to March 2008	Marked decrease in class 1-2 errors (typographical and limited significance). Class 3 errors (unlabeled, wrong site and/or wrong patient) decreased in frequency from 7 (0.09%) to 2 (0.02%). Total numbers of samples pre/post were 8,231 and 8,539, respectively. Both type 3 errors were caught before processing. The study does not distinguish between wrong patient and wrong site. Cell phones and other electronic devices can potentially interfere with RFID.
Meyer et al. (2009)[102]	U.S., single institution (Dartmouth Hitchcock Medical Center)	Specimen labeling	Label placement	Pre/post study Comparator: placing label on opposite side of slide (post) versus label overlying handwritten patient identifier (pre) Cytotechnologists are trained to look at the underside of the slide to see the handwritten identifier through the back of the slide to match the patient identifier on the label. A workflow change was implemented at the study site to have labels printed on the other side of the slide rather than overlying the handwritten patient identifiers. Instead of flipping the slide to check the patient identifier, a technologist could look at the same side of the slide (top and bottom) to compare the name. **Outcome measure**: Mislabeled identifiers: patient name, cytology accession number on the printed label did not match corresponding identifiers on the handwritten, frosted portion of the glass slide.	Baseline: October 31, 2006, to November 21, 2006 Follow-up: December 1, 2006, to December 1, 2007	Over the approximate 1-month initial period, 17/2,844 Papanicolaou smears mislabeled. After the intervention, 0 errors (34,335 slides) reported over 1-year period. Concluded that opposite-side labeling is a more active process and less prone to errors. Process facilitates checking label at multiple stages and by personnel not trained to flip the slide.

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				Cytotechnologists asked to record number of mislabeled slides sent to them, or identified during 10% quality improvement review.		

*Study cited in Young et al. systematic review (2010)[79]