BRIGHAM AND
WOMEN'S HOSPITAL

# Computerized Clinical Decision Support Tools in Clinical Pathology: The Brigham and Women's Experience


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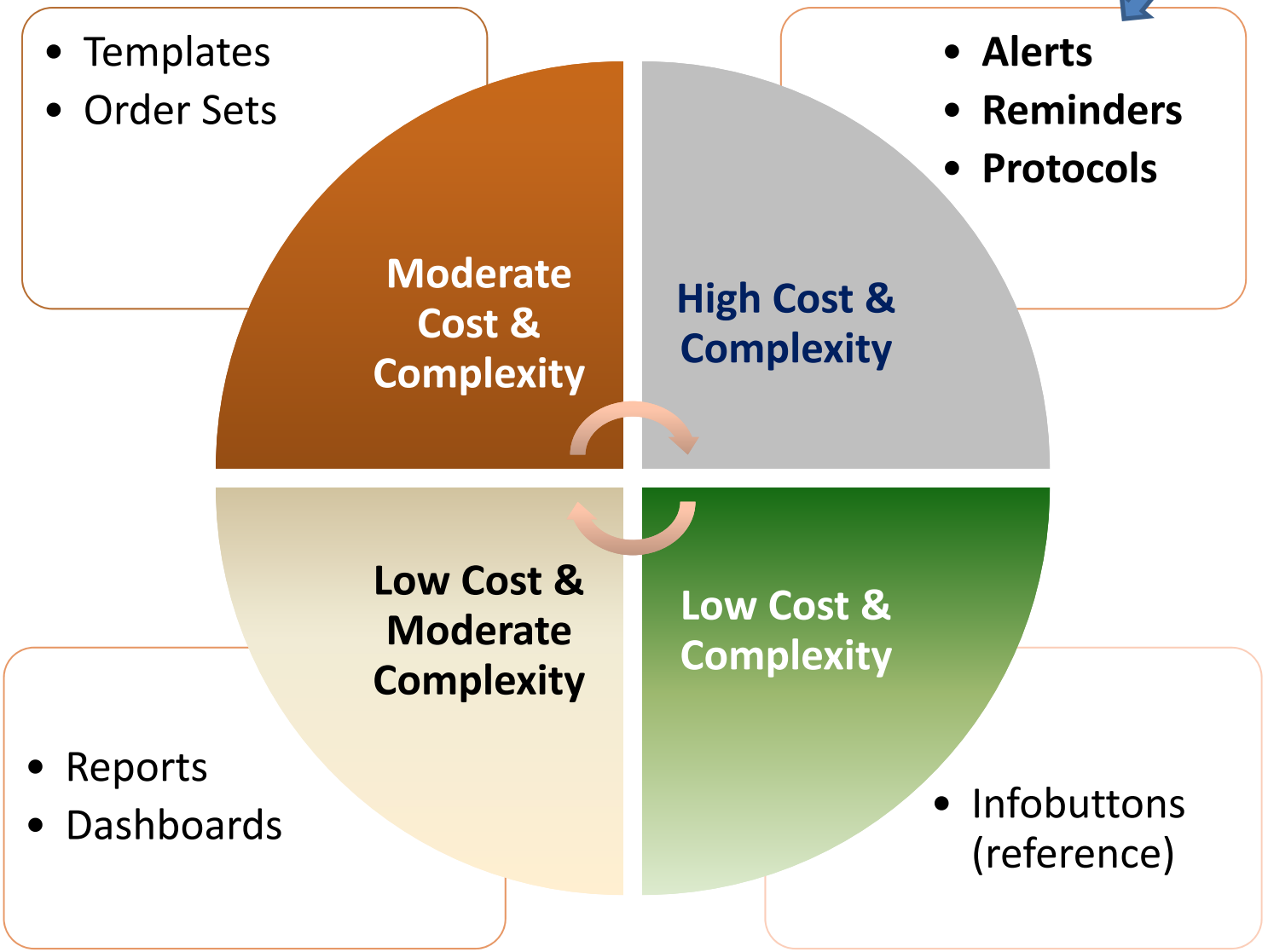
# Disclosures

- Cell Imaging Systems, Inc. (co-founder)
- Roche Hematology Systems, Inc. (royalty)
- Microtest Matrices Inc. (senior advisor)
- SynapDx (advisor)

# Clinical Decision Support (CDS) for Improved Lab Utilization

BWH Effort




Credits: Roberto A. Rocha, MD, PhD

# Non-Computerized Guidelines and Algorithms

*Can improve care BUT:*

- Hard to remember
- Hard to find when needed
- Sometimes providers forget/don't know about availability
- Dissemination slow

# Computerized Guidelines

- Immediate feed-back at time of entering orders
- Easily retrievable
- Clinical consensus – derived
- Allow measurement of impact
- Enable iterative refinement based on user's feed-back

# CDS for Laboratory Tests at BWH

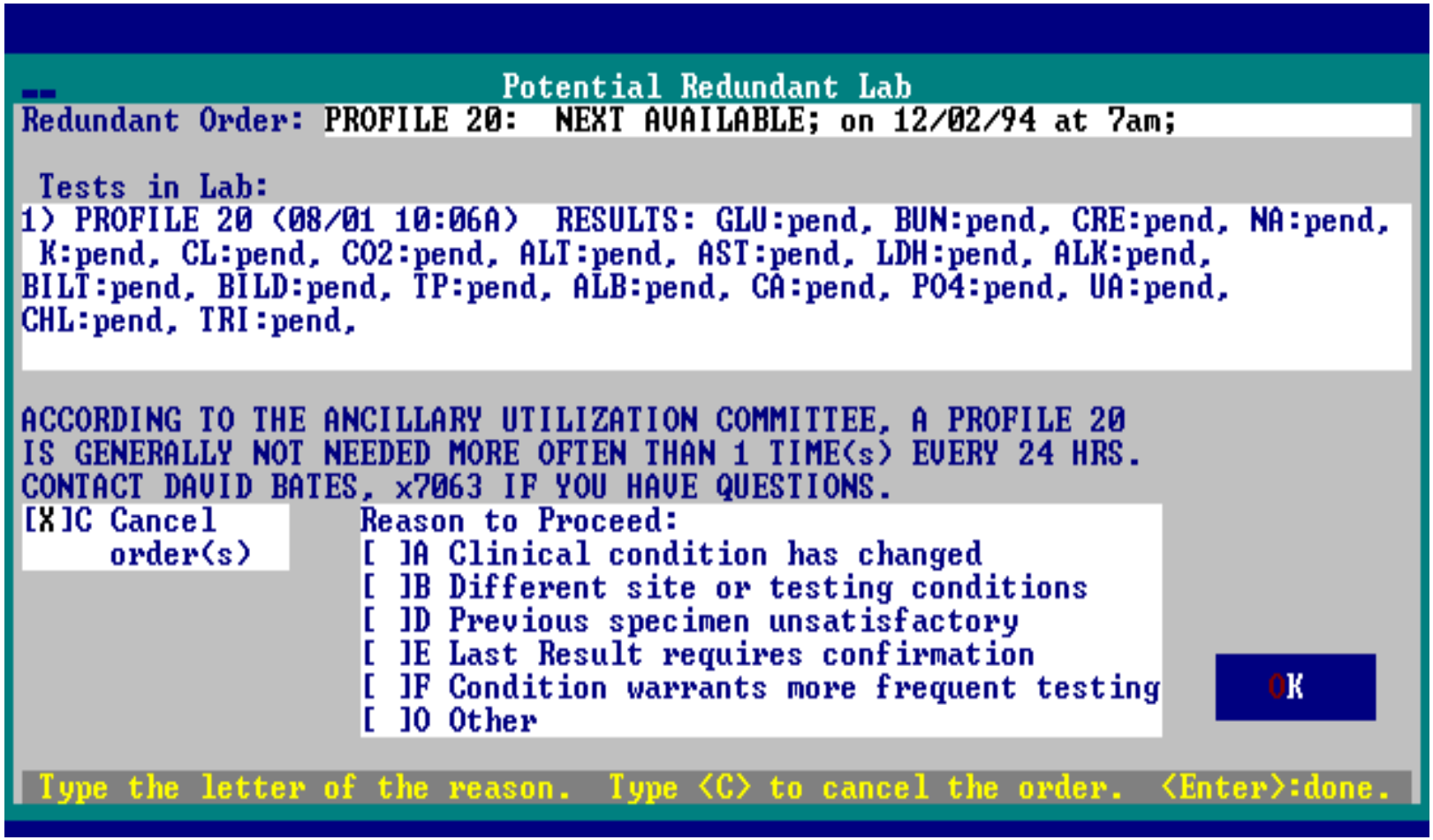
- Optimized Lab Utilization
  - Lab charges display
  - Reminders for redundant labs
  - Appropriateness guidelines for therapeutic drug levels and tumor markers
- Improved Patient Safety
  - Alert value identification and auto-paging
  - Appropriate timing of therapeutic drug levels
  - PPID and order communication

# CDS Guiding Principles

- **Speed** is everything
- Anticipate needs and deliver in **real time**
- Fit into the user's **workflow**
- Little things can make a big difference – proper **defaults**
- Physicians **resist stopping** - never say never
- Provide **alternatives**
- Simple activities work best – not complex guidelines
- Avoid manual data entry - be sure you really need it
- Monitor **impact**, get feedback, and respond
- **Manage** and update content on the ongoing basis

Bates et al, JAMIA 2003

# Redundant Test Reminders



# Level of Acceptance of Reminders

| | Intervention (n = 437) | Control (n = 502) |
|---|---|---|
| Accepted reminder | 300 (69%) | N/A |
| Test performed after reminder | 117 (27%) | 257 (51%) |

# Reasons for Overrides of Redundant Tests

| Reason | Frequency | Test Done | Justified |
|---|---|---|---|
| Condition warrants more frequent testing | 43 (31%) | 34 (79%) | 21 (49%) |
| Clinical condition has changed | 34 (25%) | 20 (59%) | 11 (32%) |
| Last result requires confirmation | 18 (13%) | 12 (67%) | 10 (56%) |
| Previous specimen unsatisfactory | 15 (11%) | 7 (47%) | 6 (40%) |
| Different site or testing conditions | 11 (8%) | 6 (55%) | 5 (45%) |
| Other | 16 (12%) | 9 (56%) | 3 (19%) |
| Total | 137 (100%) | 88 (64%) | 56 (41%) |

# Potential adverse consequences of canceled tests

- Evaluated canceled tests followed by abnormal result within 3 days
- Only 8 (4%) of these tests provided new information
    - 3 UA w/ few RBCs or WBCs, previously negative
    - 3 Sputum Cx w/ new pathogen, all patients had stable CXR
    - Digoxin level dropped from 1.0 to 0.5 ng/mL
- Change of medical management in 2/8 cases
    - One patient given new Abx
    - One patient given an extra dose of digoxin

# Redundant Order Reminders in EPIC

- **Phase I**
  - Planned 50 tests and appropriate durations for duplicate triggers on EPIC go-live
    - Display of previous results
    - At BWH, these rules will fire approximately 1-5% of the time
- Limitations of Epic functionality
  - Will not default to "cancel order", but will make the clinician choose "continue" or "discontinue"
  - Will not ask clinician for reason that reminders ignored

# Redundant Orders: Updated List

| Tests | Duration |
|---|---|
| CBC with autodiff | 24 hours |
| Hypercoag Panel | 30 days |
| Hemoglobin electrophoresis | 30 days |
| Hgb A1C | 30 days |
| Protein electrophoresis | 7 days |
| Immunology (ANA, RF, CCP) | 1 year |
| Vitamin D | 7 days |
| Anemia (Ferritin, Folate, B12) | 7 days |
| Thyroid (TSH, free T4, total T4) | 7 days |
| *Phenobarbital | 20 days |



* Previously at BWH

# Duplicate/Redundant Orders

| Tests | Duration |
|---|---|
| *Antiepileptics | 3 days |
| *C. Difficile | 5 days |
| *Stool Culture | 24 hours |
| O&P | 24 hours |
| *Urine culture | 24 hours |
| *Sputum culture | 24 hours |
| Viral loads | 24 hours |
| Viral and Micro serologies | 7 days |
| Beta glucan and GM | 4 days |
| | |



* Previously at BWH

# Duplicate Reminder in EPIC

# Duplicate/Redundant Orders

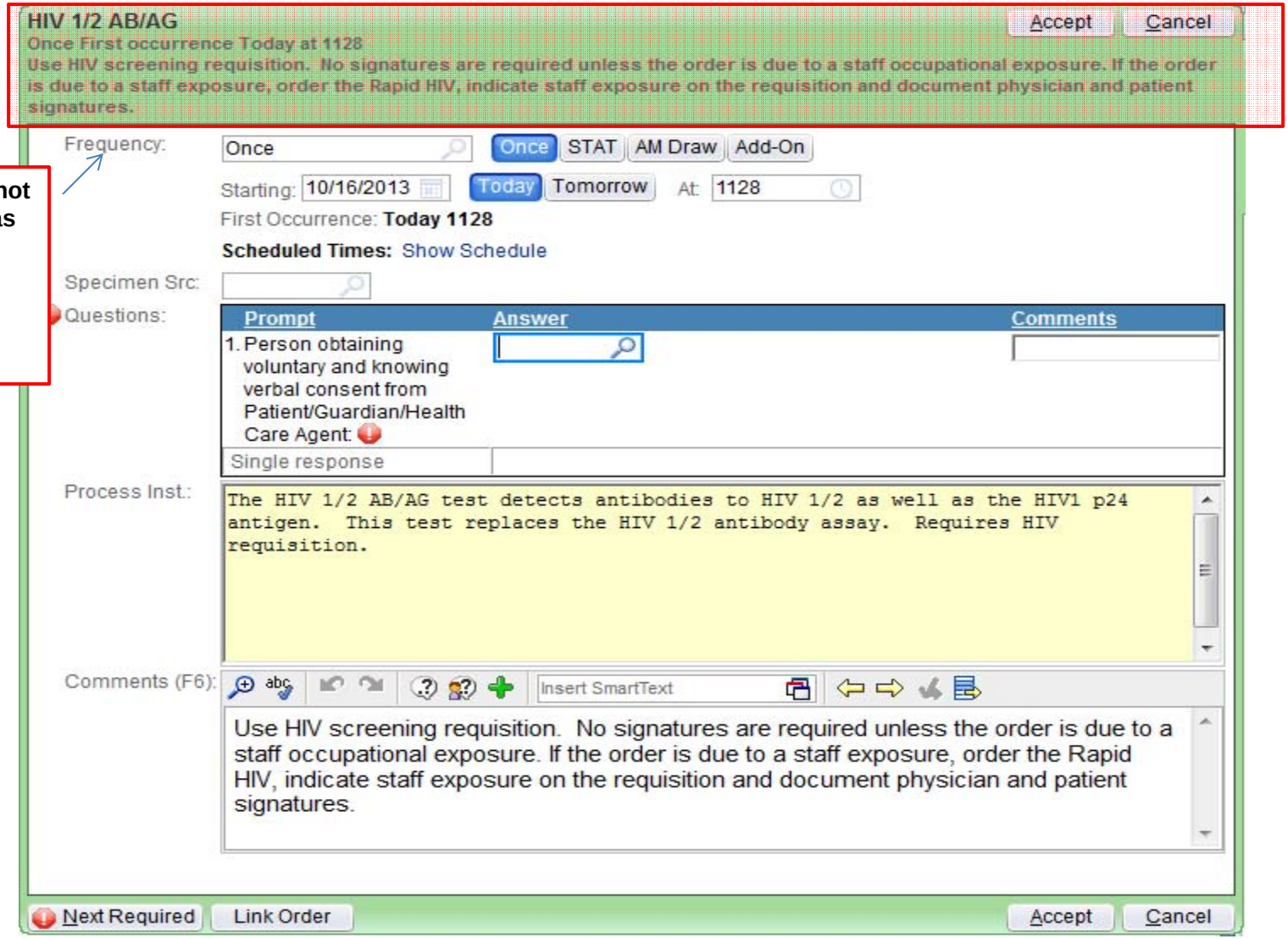
- **Phase II –** Work with Epic to understand how we can replicate functionality previously used at BWH (i.e. default to cancel, ask for override reason)
- Expand the list to more common tests (e.g. BMP, CMP) that will fire more frequently once we have the desired functionality

# Lab Order Duration Limits

- QD x 3 days or 3 instances (e.g. no daily labs during the hospital stay)
  - Approved by clinical content committee with few exceptions (e.g. oncology, POC glucose)
- 13% of labs at BWH are ordered with duration > 3 days

# Duration Limits

**"Daily" will not be allowed as frequency**



# CDS for Therapeutic Drug Monitoring

- Antiepileptic drugs
  - Phenytoin
  - Carbamezapine
  - Phenobarbital
  - Valproic acid
- Digoxin
- Vancomycin

# Guidelines for Monitoring Anti-Epileptic Drug Levels

Measuring a serum level is *always appropriate*

- Within 6 hours after a seizure recurrence
- In the event of suspected dose-related drug toxicity*
- In the event of suspected patient noncompliance

Measuring a serum level is *appropriate only* if the blood sample is drawn in steady state conditions, ie, after 4 half-lives on an unchanged dose regimen†

- As a baseline measurement after starting antiepileptic drug therapy
- As a control measurement after a change in the dose regimen
- After adding a second drug with a potential for interaction with the antiepileptic drug‡
- After a change in the patient's liver or gastrointestinal tract function

*For phenytoin, nystagmus, ataxia, and drowsiness; for carbamazepine, gastrointestinal symptoms, diplopia, and dizziness; for phenobarbital, sedation, depression, and cognitive decline; and for valproic acid, hepatic dysfunction and tremor.

†Steady state is assumed to be reached after 6 days for phenytoin, after 3 days for carbamazepine and valproic acid, and after 20 days for phenobarbital.

‡Another antiepileptic drug, warfarin, isoniazid, or rifampicin.

Schoenenberger, Tanasijevic, Bates JAMA. 1995; 274: 1622-1626

# Appropriateness of Antiepileptic Levels

| AED | No. of AEDL Measurements | Median (Range) AEDLs per Patient | Median (Range) Duration of Time Since Last AEDL, h | Median (Range) Daily Dose, mg | Median (Range) Dose Interval, h | Median (Range) AEDL, μmol/L [mg/L] | Indication Appropriate, % (95% CI) |
|---|---|---|---|---|---|---|---|
| Phenytoin | 204 | 7.5 (1-59) | 24 (5-189) | 300 (100-800) | 8 (6-24) | 45 (0-105) [11.5 (0-27.0)] | 29 (23-36) |
| Carbamazepine | 225 | 6.0 (1-69) | 24 (1-888) | 600 (200-2100) | 8 (4-24) | 28 (0-98) [6.7 (0-23.2)] | 25 (19-31) |
| Phenobarbital | 217 | 5.5 (1-43) | 24 (1-240) | 135 (90-500) | 12 (4-24) | 80 (0-175) [18.1 (0-40.4)] | 28 (22-34) |
| Valproic acid | 209 | 5.0 (1-38) | 24.5 (3-315) | 1500 (750-6000) | 8 (4-24) | 370 (0-810) [54 (0-117)] | 26 (20-32) |
| **Total** | **855** | 6.0 (1-69) | 24 (1-888) | NA | NA | NA | 27 (24-30) |

*AED indicates antiepileptic drug; AEDL, antiepileptic drug level; CI, confidence interval; and NA, not applicable.

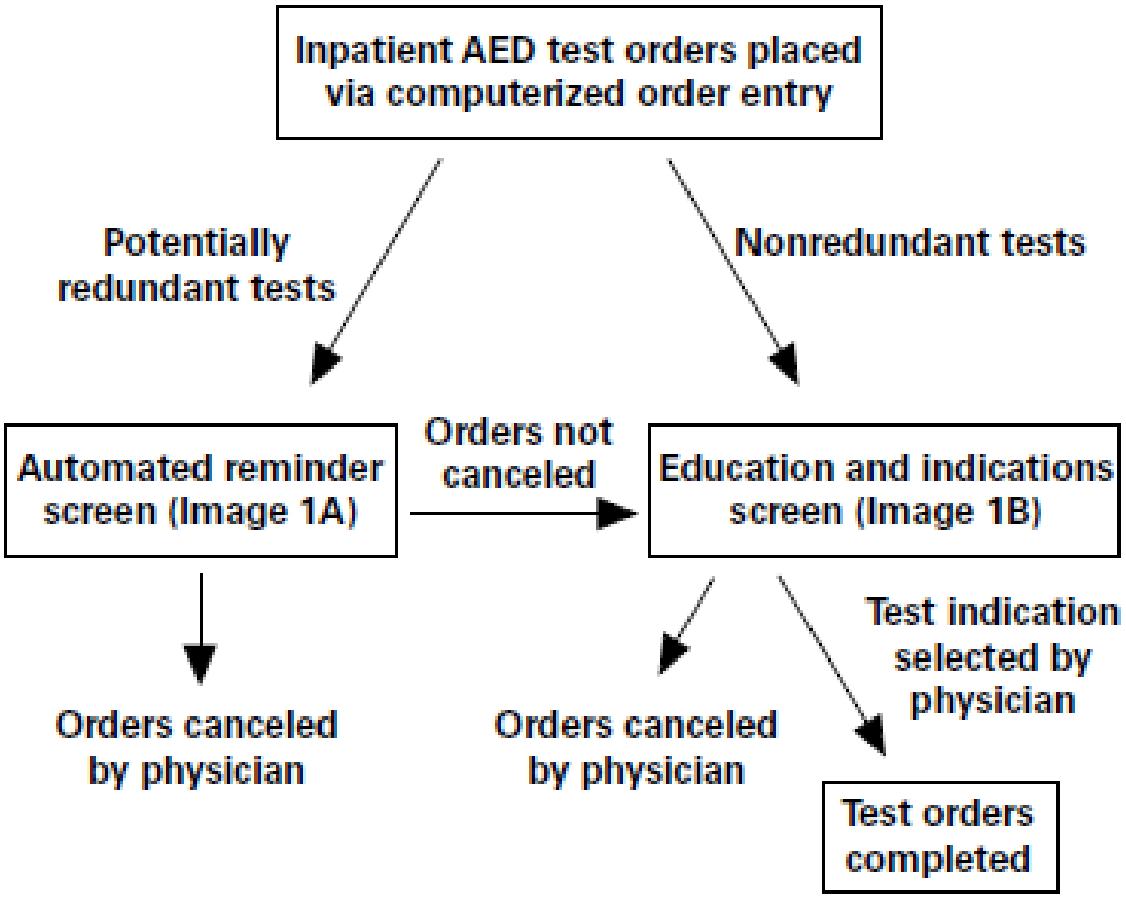



**Figure 1** Algorithm for computerized interventions designed to reduce inappropriate antiepileptic drug (AED) level testing.

Chen, Tanasijevic, Bates AJCP 2003; 119:432-8.

# Digoxin Level Monitoring

| Appropriate if |
|---|
| **For both inpatients and outpatients:** |
| 1. Subtherapeutic response (either *a*, *b*, *c*, or *d*) |
| a. No improvement or worsening of congestive heart failure or atrial fibrillation or flutter |
| b. Suspected noncompliance |
| c. Concomitant use of an interacting drug (antacids, a kaolin and pectin combination [Kaopectate], neomycin, quinidine, spironolactone, nifedipine, cholestyramine, verapamil) |
| d. Suspected malabsorption |
| 2. Suspected toxicity (either *a* or *b*) |
| a. Appearance of arrhythmias suspected to be caused by digoxin (supraventricular tachycardia, atrioventricular conduction defects, multifocal premature ventricular contractions) |
| b. Noncardiac signs or symptoms of digoxin toxicity (visual changes, anorexia, nausea, vomiting, diarrhea, abdominal pain, confusion, headache) |
| 3. High-risk patient (unstable or declining renal function, low serum potassium level, hypoxia, recent increase in diuretic dose) |
| 4. Initiation of digoxin therapy or dosage adjustment after steady state reached (5 half-lives, 10 days)* |
| **For inpatients:** |
| 5. Admission level for inpatients if no previous digoxin level within last 9 months† is available |
| **For outpatients:** |
| 6. Routine monitoring annually in outpatients on stable dose of digoxin (inappropriate if level drawn less than every 10 months)† |

** Ten days was chosen in this study as a conservative estimate of the interval required to reach steady state, although some patients may reach steady state in 8 days.*[16]

*† Time intervals chosen by consensus of expert opinions.*

Canas/Tanasijevic/Bates
Arch Int Med 1999; 159:363-368

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| Characteristics | Inpatient Levels (n = 224) | Outpatient Levels (n = 130) |
|---|---|---|
| Median (range) duration of time since last digoxin level, d* | 1 (1-1) | 56.5 (23-161) |
| Median (range) daily dose, mg* | 0.125 (0.125-0.25) | 0.0625 (0.0125-0.25) |
| Median (range) dose interval, h* | 24 (24-24) | 24 (24-96) |
| Median (range) digoxin level, nmol/L*† | 1.4 (1.0-1.9) | 1.4 (0.9-1.8) |
| Indication appropriate, % (95% CI)‡ | 16 (11-20) | 52 (44-61) |

**Ranges are 25th and 75th percentiles.*

*†To convert digoxin levels from nanograms per milliliter to nanomoles per liter, multiply nanograms per milliliter by 1.281.*

*‡CI indicates confidence interval.*

# Appropriateness of Timing of Vancomycin Levels

**Table 1: Criteria for Correctly Timed Vancomycin Trough Level**

| Basis for determining accuracy of trough timing | Rule | Percent of levels (n/total reviewed × sampling weight) | Percent of levels after removing exclusions |
|---|---|---|---|
| 1. Time of next administered dose | Specimen collected ≤ 2 h before next administered dose. | 25% (146/583 × 1.00) | 43.5% |
| 2. Time of next scheduled administration | Specimen collected ≤ 2 h before next scheduled dose, or ≤ 2 h after next scheduled dose if next dose not given. | 5%[a] (10/150 × 0.75) | 8.7% |
| 3. Time since last administration | Given a dosing interval of *x* h, specimen collected within 2 h of *x* h since last dose. | 9%[b] (18/150 × 0.75) | 15.7% |

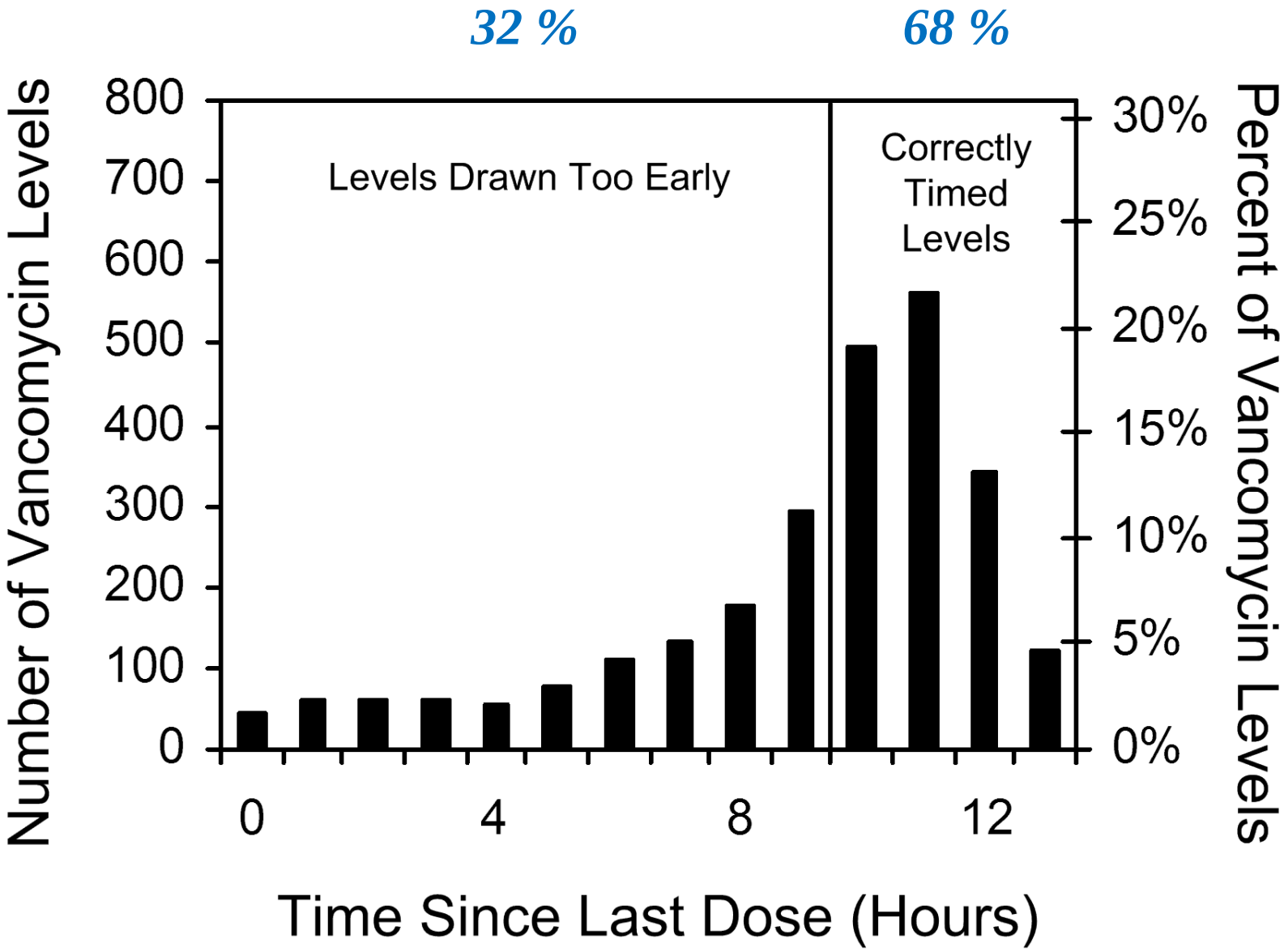
[a]This percentage represents an estimate of the proportion of analyzed levels (n=583) which do not meet the first criterion and do meet the second criterion. [b]This percentage represents an estimate of those which do not meet the first or second criteria but do meet the third.

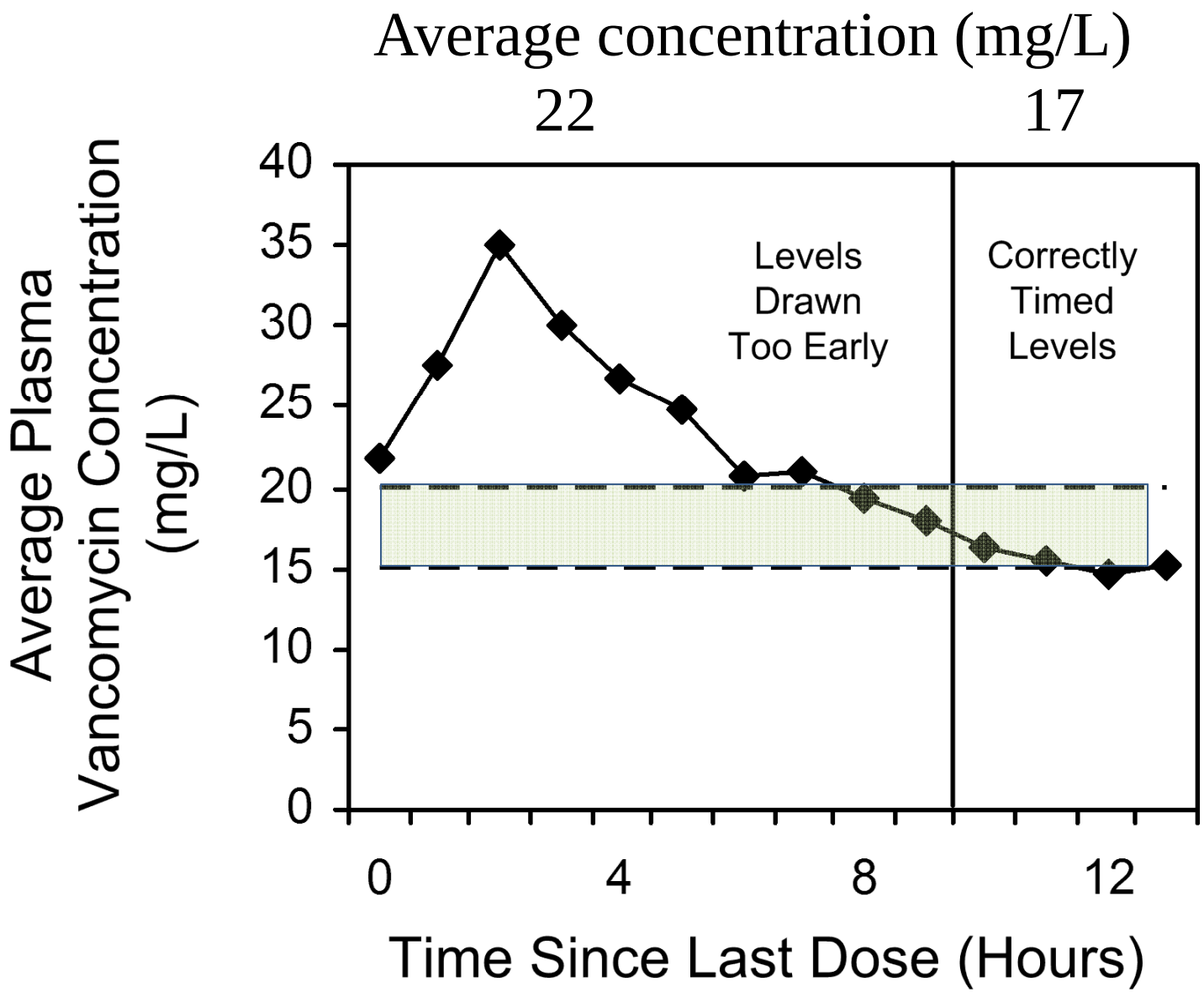
Morrison / Tanasijevic Am J Clin Path 2012

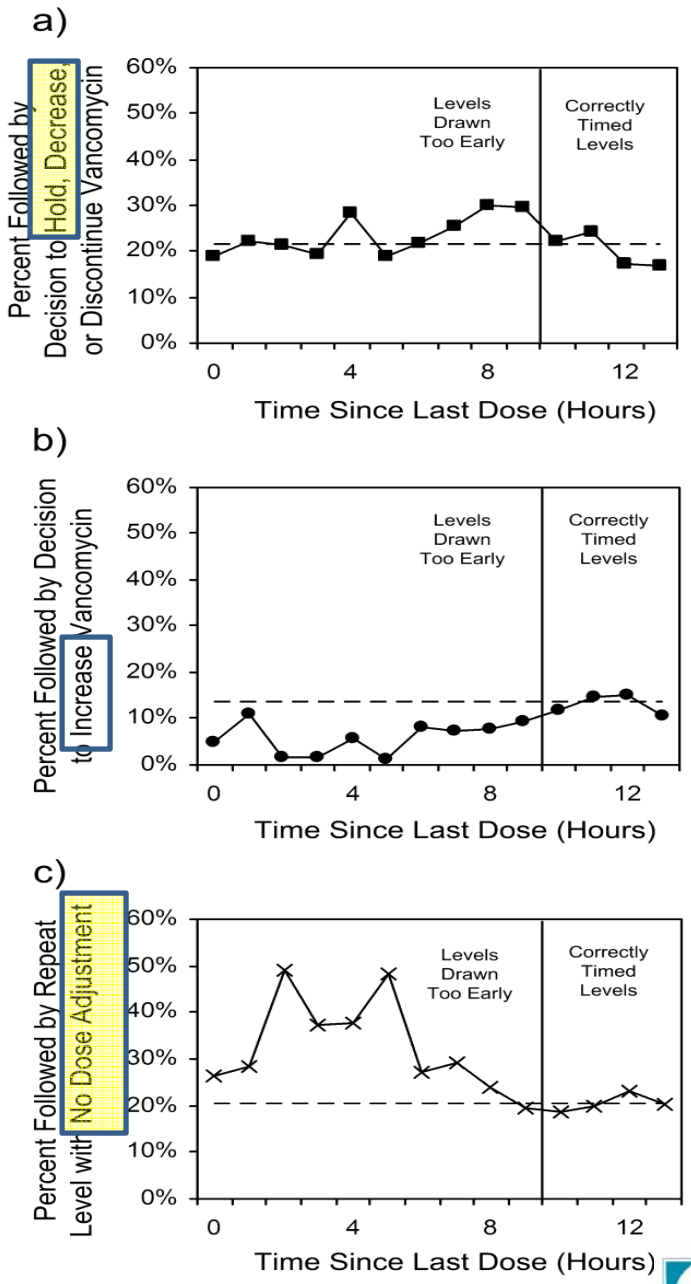
**Table 2: Criteria for Exclusion from Evaluation[a]**

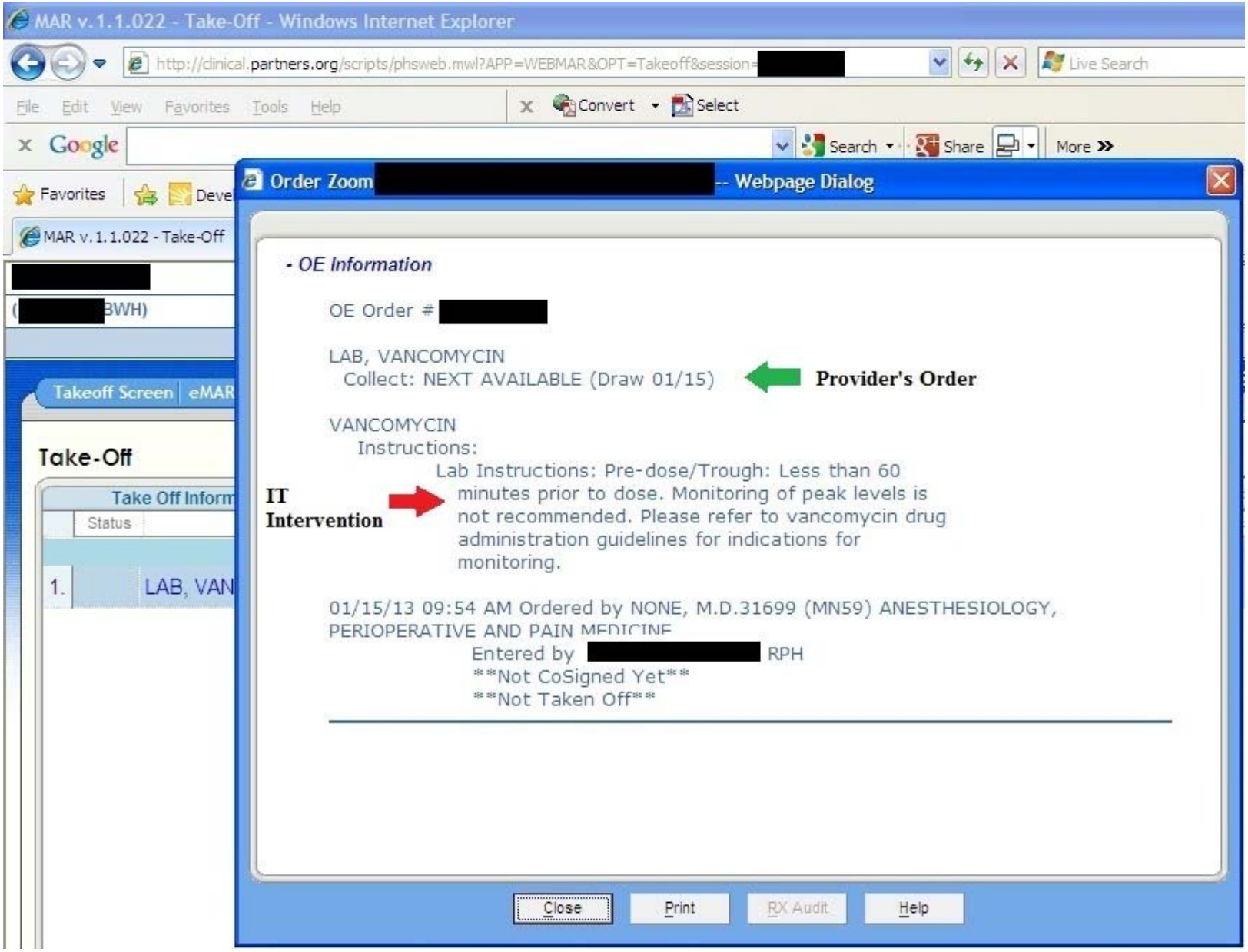
| Category | Rule |
|---|---|
| **Random / Spot-Levels Permitted :** | |
| 1. Rapidly changing renal function | Patient receiving dialysis, or change of ≥ 0.5 mg/dL or 50% reduction in SCr or 50% increase in SCr in 48 h, within 14 days prior to specimen collection. |
| 2. Checking after a high level | Last vancomycin level ≥ 20 mg/L and next dose not given. |
| 3. Patient not actively on vancomycin (admit/discharge) | Level checked on day of admission or transfer and no existing medication order for vancomycin or level checked on day of discharge and vancomycin previously discontinued. |
| 4. Test ordered accidentally | Patient not currently on vancomycin; test ordered in error. |

[a]Only levels which did not meet the first timing criterion were screened for exclusions.


32 %
68 %
Levels Drawn Too Early
Correctly Timed Levels
Number of Vancomycin Levels
Percent of Vancomycin Levels
800
700
600
500
400
300
200
100
0
30%
25%
20%
15%
10%
5%
0%
0
4
8
12
Time Since Last Dose (Hours)


Average concentration (mg/L)
22
17
Average Plasma Vancomycin Concentration (mg/L)
40
35
30
25
20
15
10
5
0
Levels Drawn Too Early
Correctly Timed Levels
0
4
8
12
Time Since Last Dose (Hours)


a)
Percent Followed by Decision to Hold, Decrease, or Discontinue Vancomycin
60%
50%
40%
30%
20%
10%
0%
Levels Drawn Too Early
Correctly Timed Levels
0
4
8
12
Time Since Last Dose (Hours)
b)
Percent Followed by Decision to Increase Vancomycin
60%
50%
40%
30%
20%
10%
0%
Levels Drawn Too Early
Correctly Timed Levels
0
4
8
12
Time Since Last Dose (Hours)
c)
Percent Followed by Repeat Level with No Dose Adjustment
60%
50%
40%
30%
20%
10%
0%
Levels Drawn Too Early
Correctly Timed Levels
0
4
8
12
Time Since Last Dose (Hours)




Melanson / Tanasijevic: Am J Clin Path. 2013

# Computerized Communication of Alert Laboratory Values

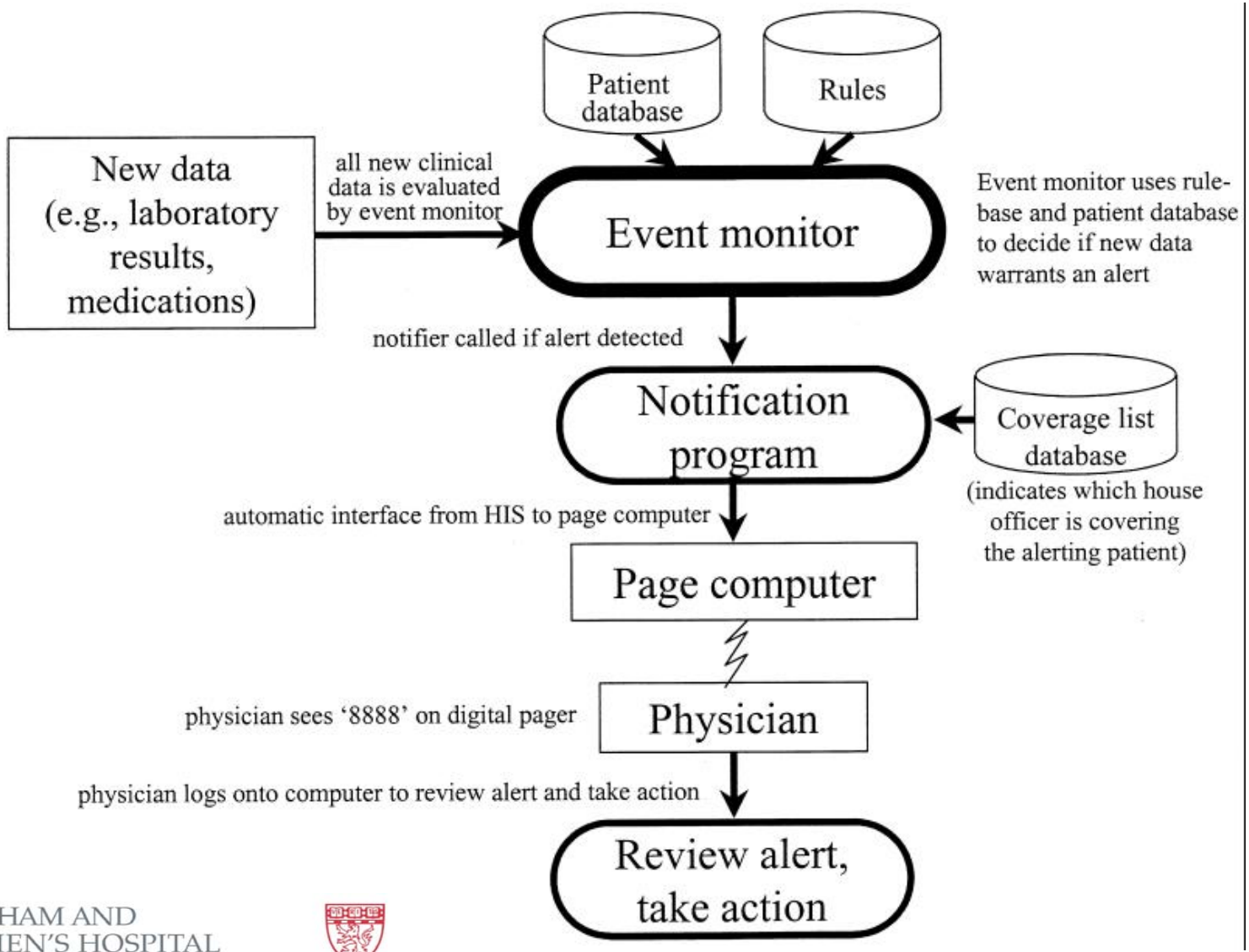
**Table 1**

Frequency Distribution of Alerts

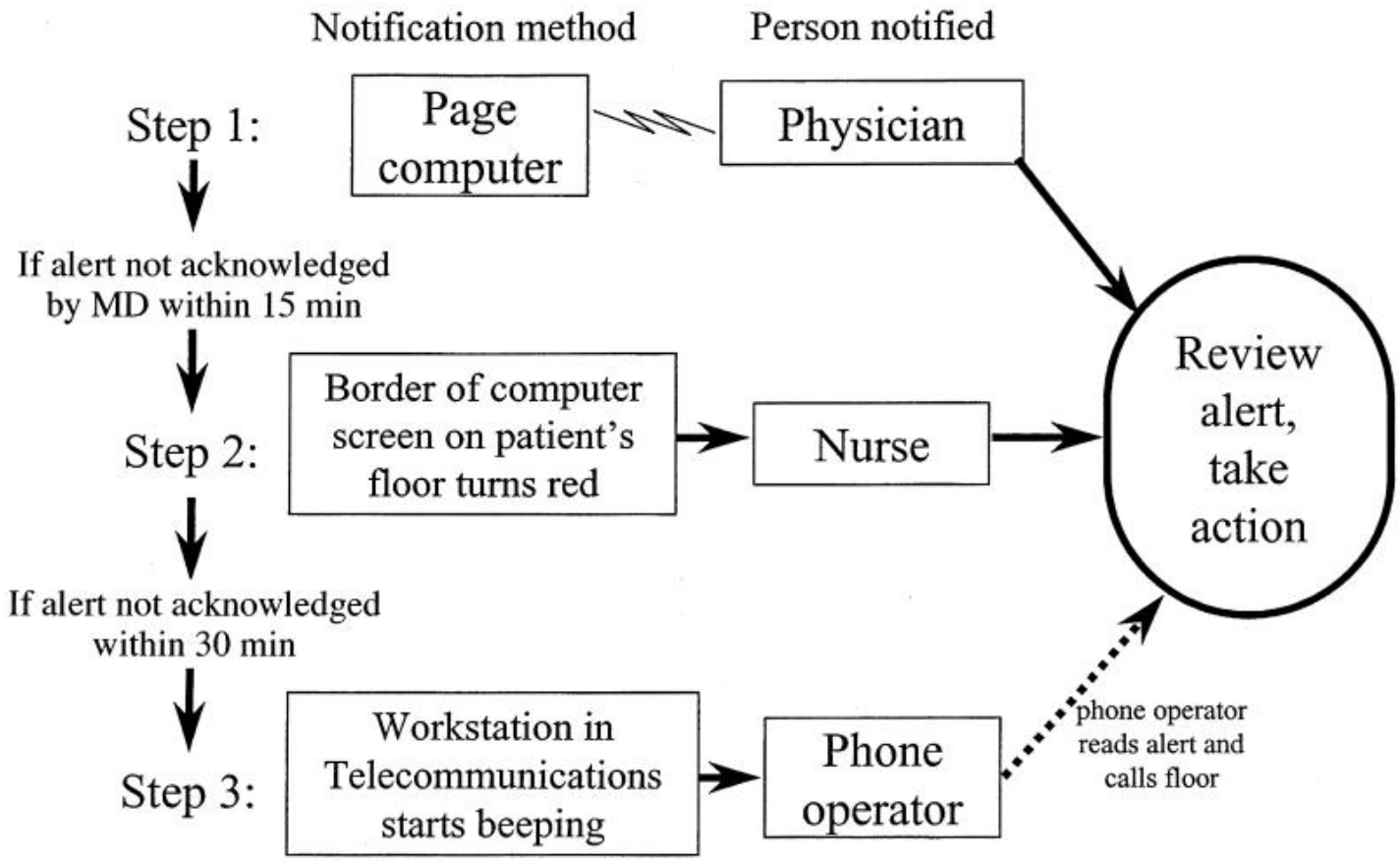
| Rule | Alerting Criterion | No.* (%) |
|---|---|---|
| 1 | Hematocrit has fallen 10% or more since last result and is now less than 26%‡ | 38 (19.8) |
| 2 | Serum glucose is greater than or equal to 400 mg/dL | 34 (17.7) |
| 3 | Hematocrit has fallen 6% or more since previous result, and has fallen faster than 0.4% per hour since last result, and is now less than 26% and the patient is not on the cardiac surgery service‡ | 32 (16.7) |
| 4 | Serum potassium is greater than or equal to 6.0 mEq/L | 32 (16.7) |
| 5 | Serum potassium has fallen 1.0 mEq/L or more over the last 24 hours and is now less than 3.2 mEq/L‡ | 29 (15.1) |
| 6 | Serum potassium less than 3.3 mEq/L and patient has an active order for digoxin‡ | 15 (7.8) |

Kuperman G et al., J Am Med Inform Assoc. 1999

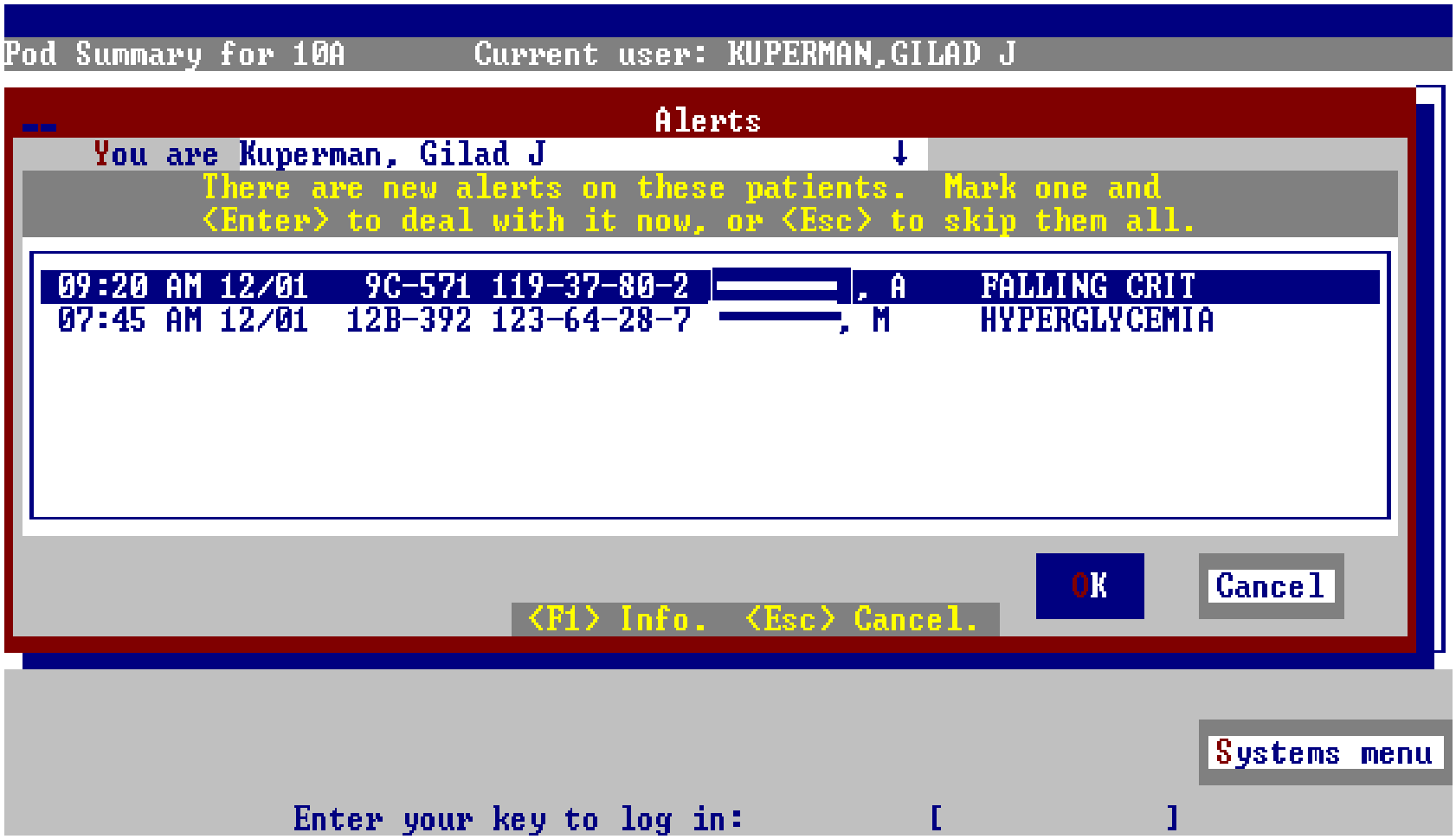
# Design of the Alerting System

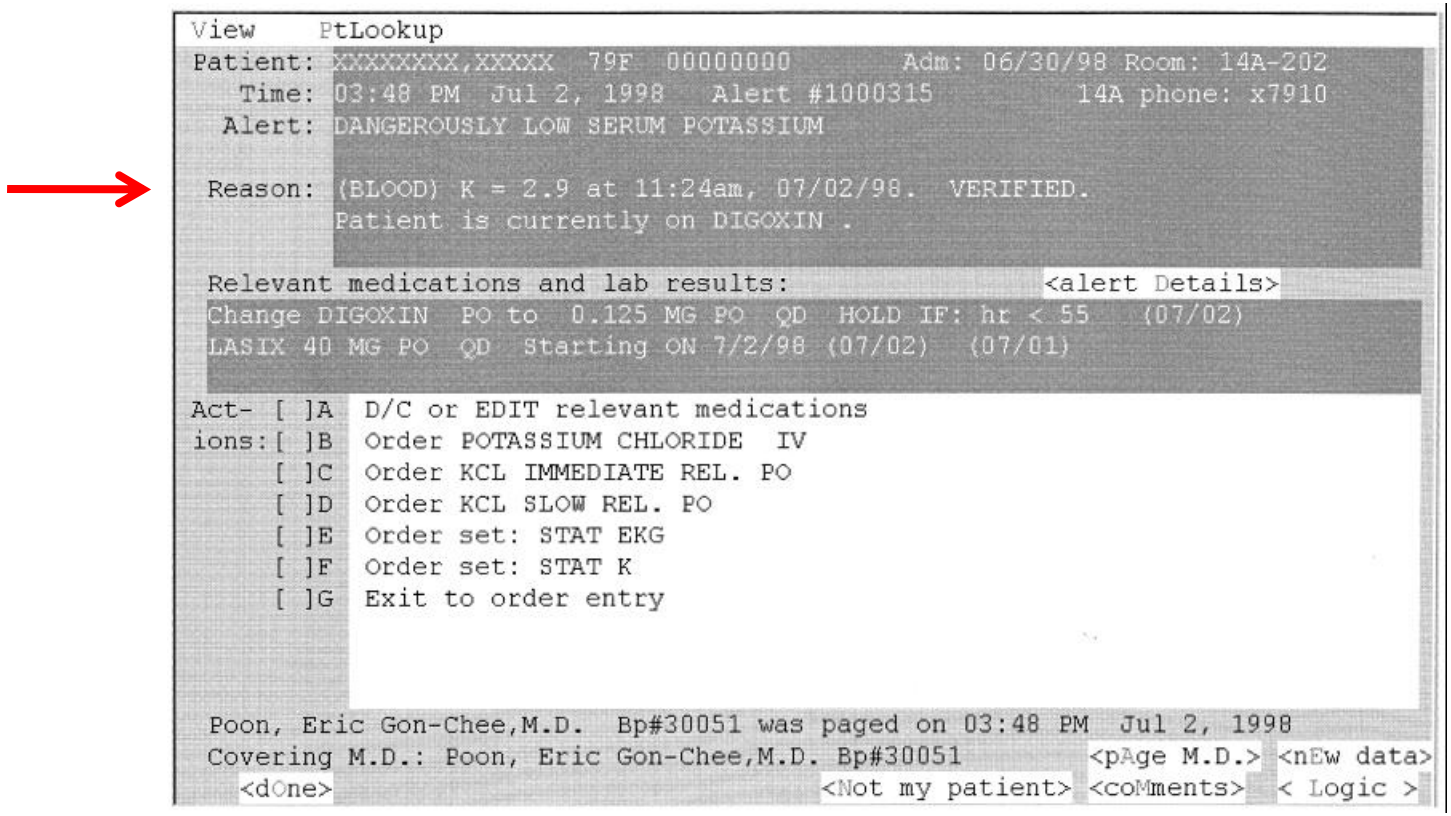


# Fail-Safe Notification Sequence



# “Alerts” Screen: Emphasizing an Abnormality




View PtLookup
Patient: XXXXXXXX,XXXXX 79F 00000000 Adm: 06/30/98 Room: 14A-202
Time: 03:48 PM Jul 2, 1998 Alert #1000315 14A phone: x7910
Alert: DANGEROUSLY LOW SERUM POTASSIUM
Reason: (BLOOD) K = 2.9 at 11:24am, 07/02/98. VERIFIED.
Patient is currently on DIGOXIN .
Relevant medications and lab results: <alert Details>
Change DIGOXIN PO to 0.125 MG PO QD HOLD IF: hr < 55 (07/02)
LASIX 40 MG PO QD Starting ON 7/2/98 (07/02) (07/01)
Act- [ ]A D/C or EDIT relevant medications
ions:[ ]B Order POTASSIUM CHLORIDE IV
[ ]C Order KCL IMMEDIATE REL. PO
[ ]D Order KCL SLOW REL. PO
[ ]E Order set: STAT EKG
[ ]F Order set: STAT K
[ ]G Exit to order entry
Poon, Eric Gon-Chee,M.D. Bp#30051 was paged on 03:48 PM Jul 2, 1998
Covering M.D.: Poon, Eric Gon-Chee,M.D. Bp#30051 <pAge M.D.> <nEw data>
<dOne> <Not my patient> <coMments> < Logic >

# Alert Evaluation

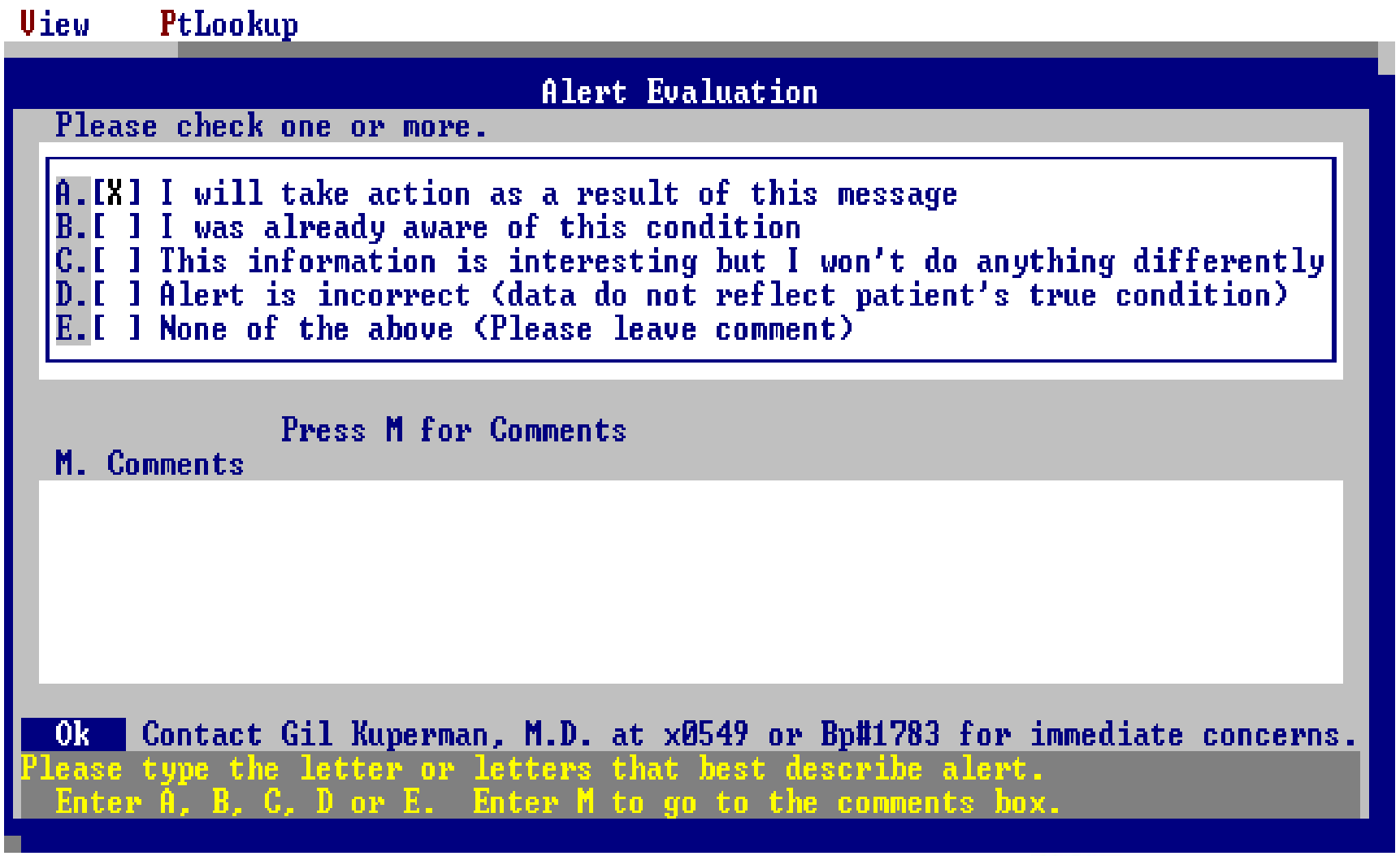


**Table 2**

Criteria Used by Reviewers to Determine the Time Appropriate Treatment Was Ordered

| Alert Type | Examples of Appropriate Treatment |
|---|---|
| Low or falling sodium | Isotonic or hypertonic solution intravenously, fluid restriction, demeclocycline |
| High sodium | Isotonic or hypotonic solution intravenously |
| Low or falling potassium, or low potassium with patient on digoxin | Potassium replacement (intravenous or oral) |
| High potassium | Discontinue potassium 50% dextrose with insulin |
| | Furosemide |
| | Bumetanide |
| | Discontinue spironolactone or triamterene |
| | Kayexalate (sodium polystyrene sulfonate) |
| | Sodium bicarbonate |

# Impact of the Intervention

| | Intervention (N = 94) | Control (N = 97) | P-value |
|---|---|---|---|
| Time Until Rx Ordered (hrs) | | | |
| Median | 1 .0 | 1.6 | 0.003 |
| Mean | 4 .1 | 4.6 | 0.003 |
| Time Until Condition resolved | | | |
| Median | 8.4 | 8.9 | 0.11 |
| Mean | 14.4 | 20.2 | 0.11 |

# Partners Health Systems: 20 Types of CDS

- Drug-Drug Interactions
- Drug-Pregnancy
- ***Drug-Laboratory***
- Drug-Disease
- Drug-Utilization
- Duplicate Therapy
- Food-Drug Interactions
  - Nephros (Renal Dosing)
  - Gerios (Geriatric Dosing)
  - Insulin Ordering

- ***Comparable feature in Epic***
  - *Partially supported in Epic*

- Chemotherapy (includes oral and investigational)
- ***Order sets***
- ***Clinician Reminders***
- Patient Reminders
- Health Monitoring
- ***Critical Lab Results***
- ***Relevant Lab Results***
- Immunization Schedules
  - Family History
  - Problem list refinement

| Knowledge Asset | Type | Epic Capability | Content Gap |
|---|---|---|---|
| KnowledgeLink - Infobutton manager: ~650 rules | Reference: local | P | TBD |
| Partners Handbook - POC web portal | Reference: local | × | TBD |
| Knowledge Management Portal | Reference: local | × | TBD |
| Clinical Reminders - disease management and preventive care: ~340 rules; outpatient | Rule: local | ✓ | TBD |
| Drug-Pregnancy Alerts: ~687 rules; outpatient | Rule: custom | ✓ | TBD |
| → Drug-Laboratory Alerts: ~440 rules; outpatient | Rule: custom | ✓ | TBD |
| Drug-Disease Alerts: ~509 rules; outpatient | Rule: custom | ✓ | TBD |
| Drug-Utilization Alerts: ~12 rules; outpatient | Rule: local | ✓ | TBD |
| Health Monitoring: ~70 rules; outpatient | Rule: local | ✓ | TBD |
| → Critical Laboratory Alerts: ~70 rules + 175 (new); results review | Rule: local | ✓ | TBD |
| Problem List Dictionary: ~4,000 concepts from SNOMED CT with ICD mappings; in/outpatient | Dictionary: custom | ✓ | TBD |
| Problem List Classification Subsets: ~501 problem classes using SNOMED/ICD/CPT; in/outpatient | Dictionary: local | ✓ | TBD |
| Immunization Schedule Reminders: ~370 rules; outpatient | Rule: local | ✓ | TBD |
| Maple - Problem-list reminders: ~70 rules; outpatient | Rule: local | P | TBD |
| Documentation Flowsheets: ~5 templates + 400 concepts; outpatient | Template: local | ✓ | TBD |
| Master Drug Dictionary (MDD): ~8,600 customized medication concepts; 3,500+ non-commercially available medications; in/outpatient | Dictionary: local | ✓ | TBD |
| MMIDL - Medication Concept Mappings: 15,700 mappings to First Databank and RxNorm | Dictionary: local | **P** | TBD |
| Outpatient neonatal dosing dictionary: 60 orderable medication concepts; outpatient | Dictionary: local | ✓ | TBD |
| Drug-Drug Interaction Knowledge Base (DDI): ~10,000 rules; in/outpatient | Rule: local | ✓ | TBD |
| Duplicate Therapy Alerts: 23 duplicate therapy categories; in/outpatient | Rule: custom | ✓ | TBD |
| Nephros - Drug Dosing in Renal Insufficiency: 400 dosing rules; in/outpatient | Rule: local | **P** | TBD |

# Inpatient Phlebotomy

- Centralized phlebotomy services
  - 375,000 venipunctures per year
  - 50% of inpatient draws (non-central line draws)
- Until recently, order entry and eMAR existed, but there was no electronic order communication with LIS
  - Paper requisitions were utilized
  - Specimens relabeled in the lab

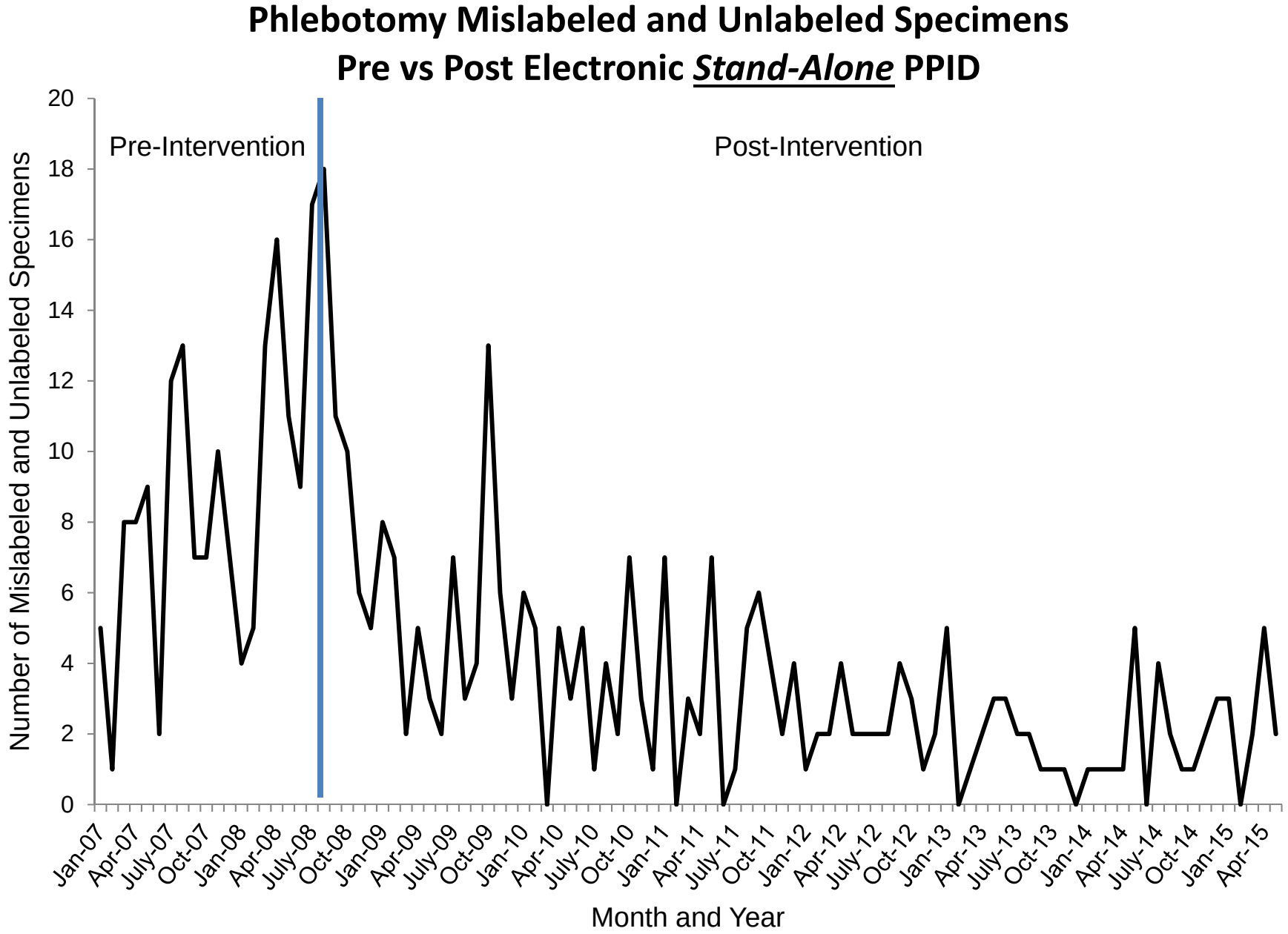
# Positive Patient Identification (PPID) System

- Decreased the number of mislabeled/unlabeled specimens
- Enhanced compliance with the Joint Commission standards
  - All patients identified using 2 patient identifiers
  - Specimens labeled at the bedside
- Implemented stand-alone Lattice system in inpatient phlebotomy in August 2008

Morrison et al. Am J Clin Pathol 2

# Positive Patient Identification (PPID)


1. Scan Patient for PPID, 2. Collect Tubes, 3. Scan Phlebotomist, 4. Print and Label Tubes at Bedside


Phlebotomy Mislabeled and Unlabeled Specimens
Pre vs Post Electronic Stand-Alone PPID
Pre-Intervention
Post-Intervention
Number of Mislabeled and Unlabeled Specimens
0
2
4
6
8
10
12
14
16
18
20
Jan-07
Apr-07
July-07
Oct-07
Jan-08
Apr-08
July-08
Oct-08
Jan-09
Apr-09
July-09
Oct-09
Jan-10
Apr-10
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July-12
Oct-12
Jan-13
Apr-13
July-13
Oct-13
Jan-14
Apr-14
July-14
Oct-14
Jan-15
Apr-15
Month and Year

# Introduction of Order Communication System

- Sunquest LIS in Nov 2014
- Epic HIS in May 2015
- Order communication between Epic and Sunquest
  - Limit the number of paper requisitions
  - Reduce specimen re-labeling
- Fully integrated PPID system (Sunquest Collection Manager)
  - Sunquest labels at the bedside
  - Collection and processing instructions shown
  - Use of Collection Manager by nursing, ED, outpatient phlebotomy and procedural areas

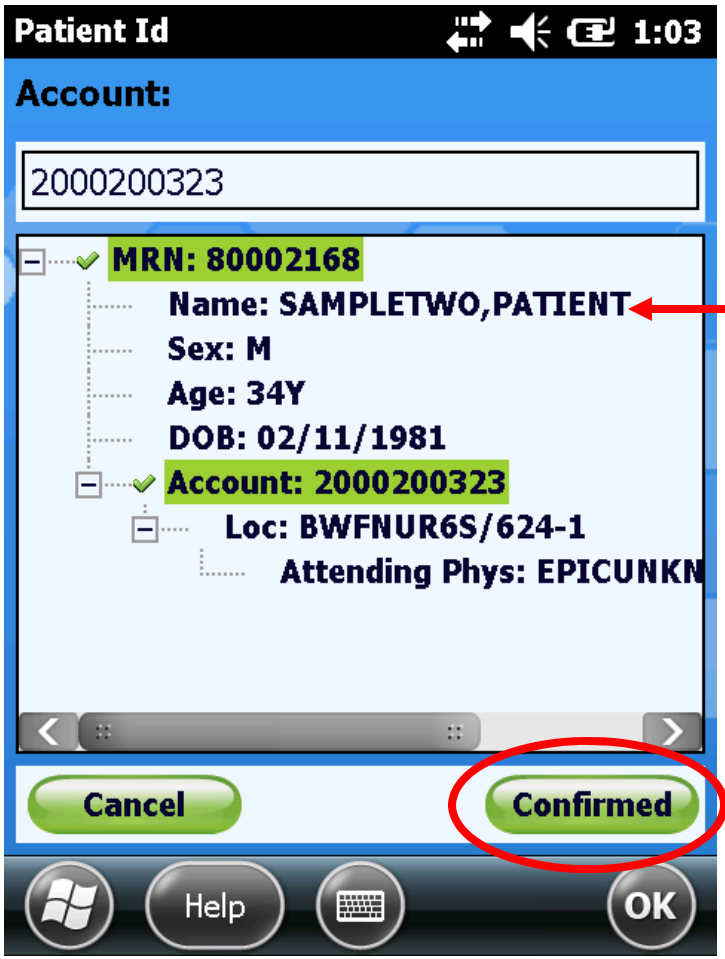
# Phlebotomy Hardware



All inpatients and
larger outpatient sites

# Sunquest Collection Manager

Use scroll bar and +/- icons to navigate screen



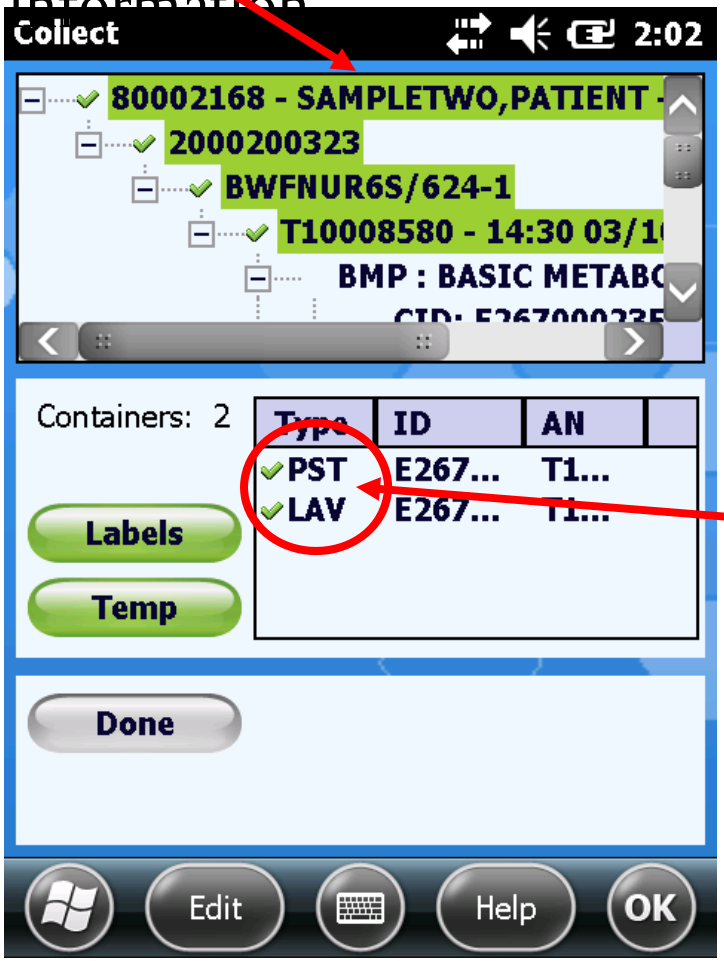

Verify that correct patient is displayed

Tap Confirmed

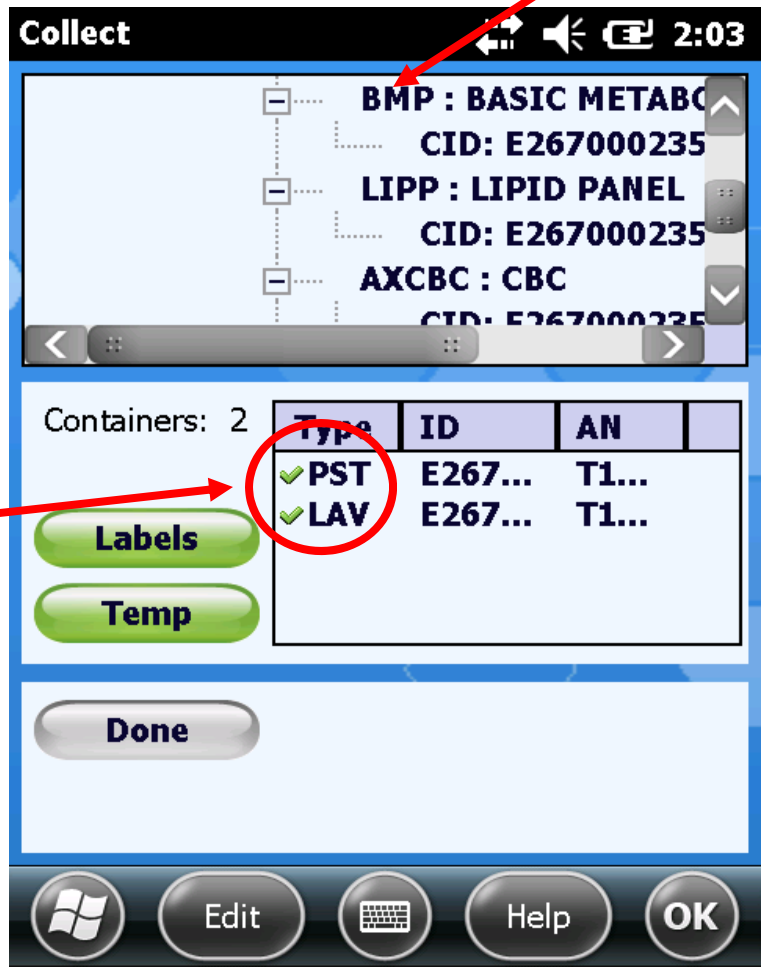
# Collection Screen

Patient information

Ordered tests



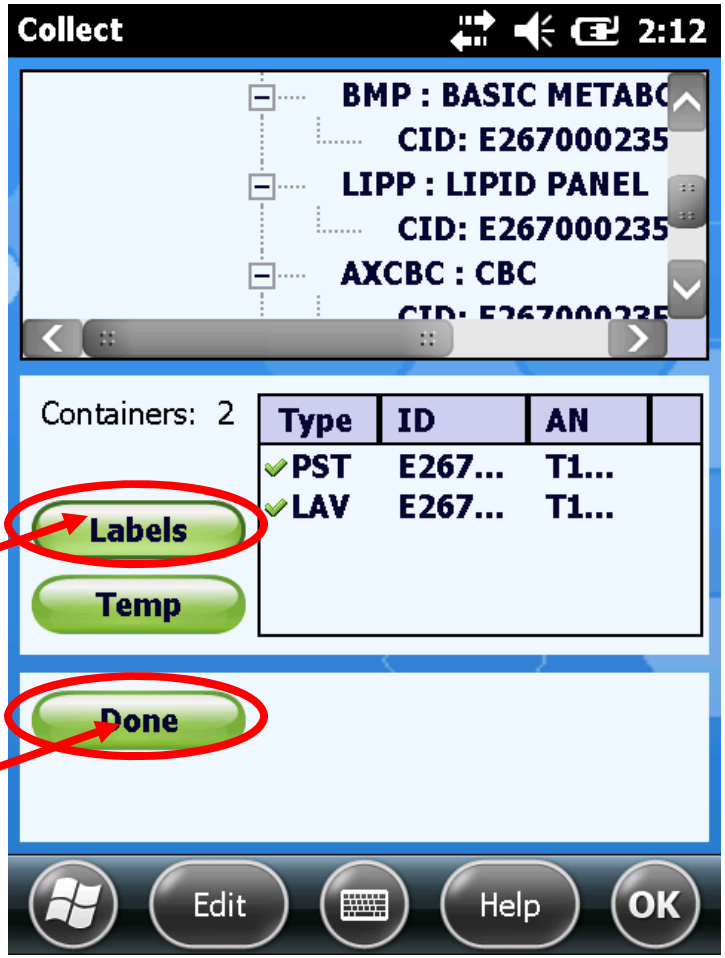

Tube types Listed in correct Order of draw



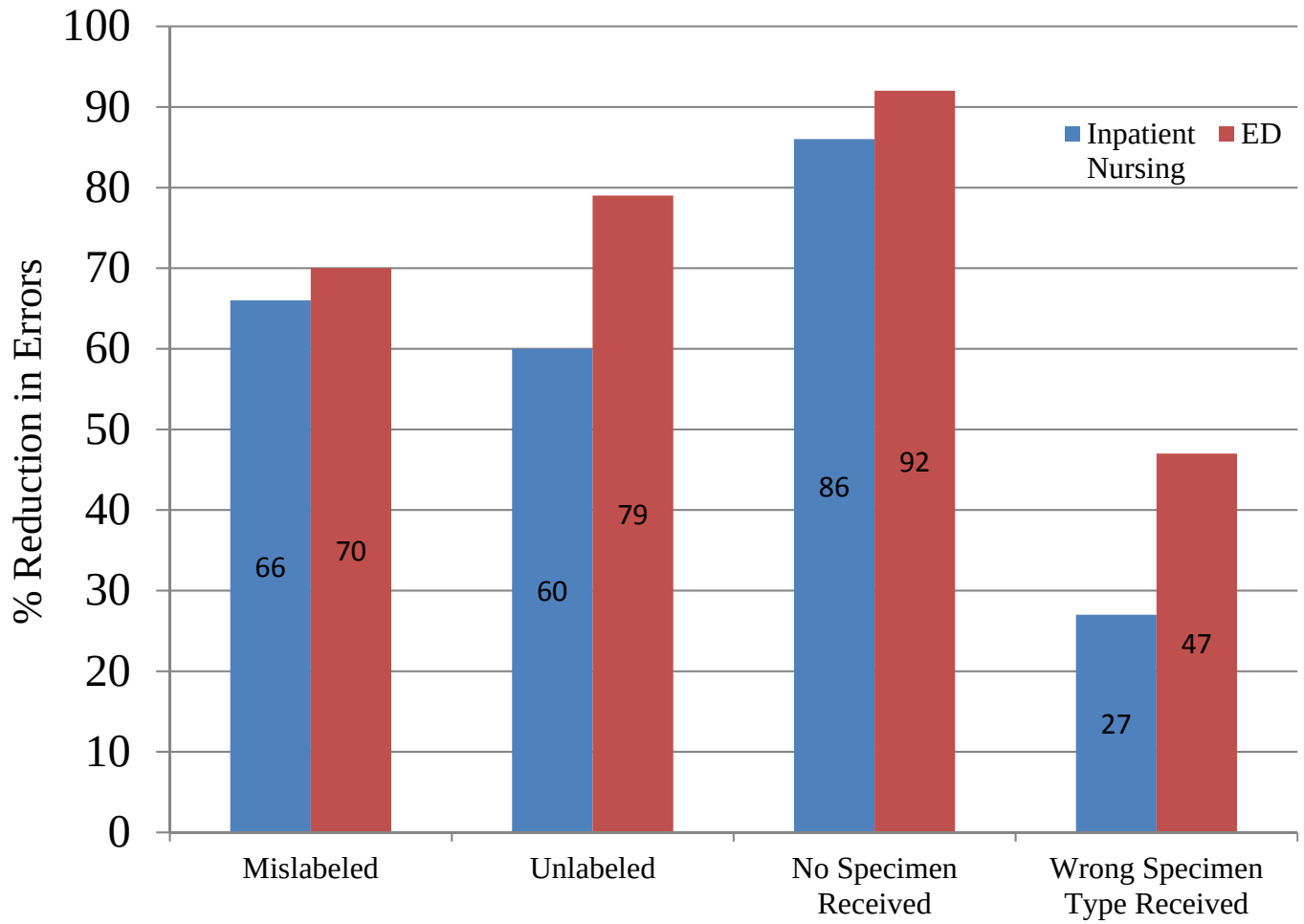
# Print Labels – Label Specimens

You must click on **Labels** first and Label all specimens

When specimens Are labeled – click **Done**



# Reduction of Pre-analytical Errors Pre- vs. Post-Epic in Inpatient Nursing and ED (Aug-Oct 2014 and Aug- Oct 2015)



# Conclusions

Computerized, physician order entry-driven CDS *integrated with the LIS* can decrease costs and improve quality of care by providing either *physician or patient-specific* :

- Redundant reminders
- Clinical context -derived guidelines for appropriate testing
- Guidelines for appropriate timing of blood collections
- Computerized communication of important abnormal findings in the context of changing clinical status and/or treatment
- Ensuring PPID and providing accurate specimen collection instructions

# BWH CDS Team

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  - Alex Mijailovic
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  - Ida Bixho
  - Ellen Goonan MT, ASCP
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- Paul Tzumita PhD (Pharmacy)
- Roberto A. Rocha MD (Partners' CDS)