Electronic Health Records, CPOE and CDS

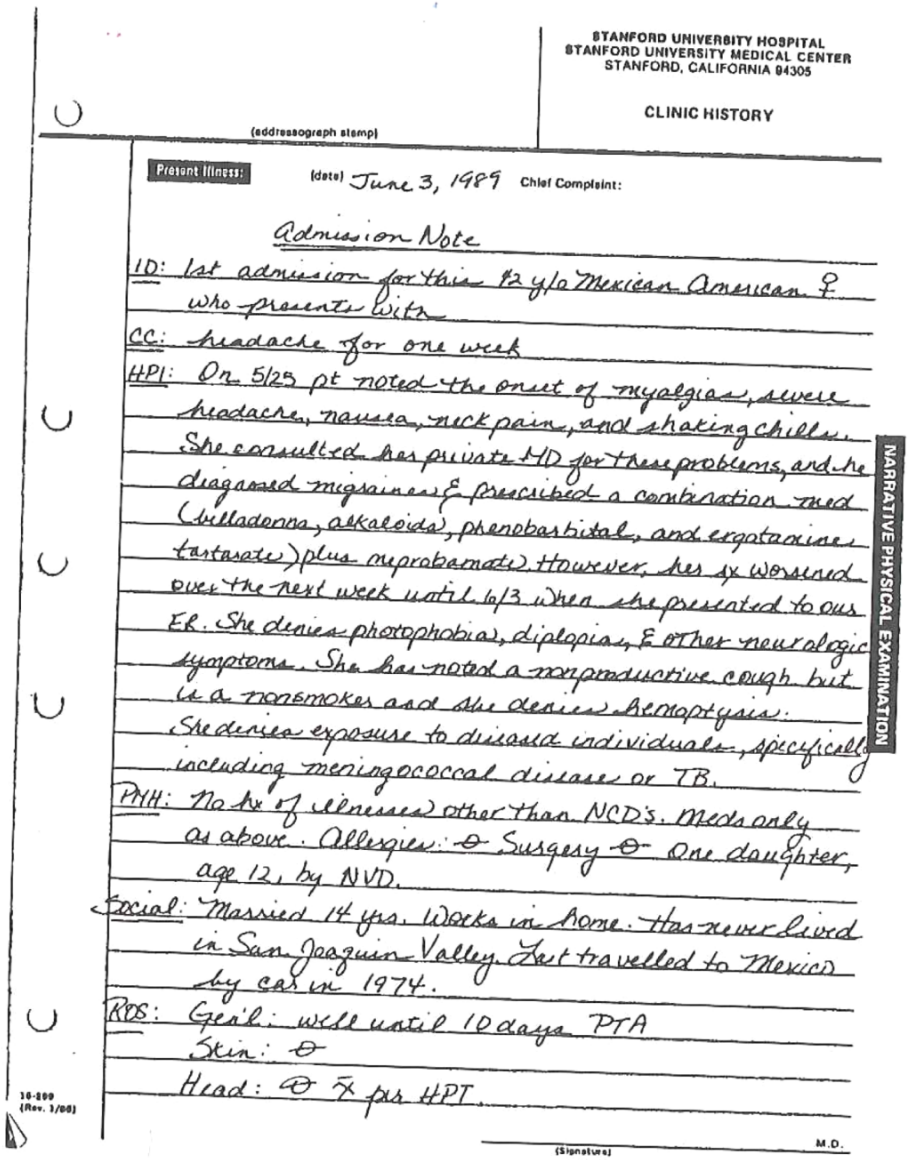
Andrew Post, MD, PhD

The Paper Chart's Natural Habitat

When a Paper Chart Leaves the Habitat

http://blog.scancare.com.au/blog/paper-based-medical-records-the-elephant-in-the-room

Admission Note



STANFORD UNIVERSITY HOSPITAL
STANFORD UNIVERSITY MEDICAL CENTER
STANFORD, CALIFORNIA 94305

CLINIC HISTORY

(addressograph stamp)

Present Illness: (date) June 3, 1989 Chief Complaint:

Admission Note

ID: 1st admission for this 12 y/o Mexican American ♀ who presents with

CC: headache for one week

HPI: On 5/25 pt noted the onset of myalgias, severe headache, nausea, neck pain, and shaking chills. She consulted her private MD for these problems, and he diagnosed migraines & prescribed a combination med (belladonna, alkaloids), phenobarbital, and ergotamine tartarate) plus meprobamate). However, her sx worsened over the next week until 6/3 when she presented to our ER. She denies photophobias, diplopias, & other neurologic symptoms. She has noted a nonproductive cough but is a nonsmoker and she denies hemoptysis. She denies exposure to diseased individuals, specifically including meningococcal disease or TB.

PMH: No hx of illnesses other than NCD's. Meds only as above. Allergies: Ø Surgery Ø One daughter, age 12, by NVD.

Social: Married 14 yrs. Works in home. Has never lived in San Joaquin Valley. Just travelled to Mexico by car in 1974.

ROS: Gen'l: well until 10 days PTA
Skin: Ø
Head: Ø ✗ yrs HPT.

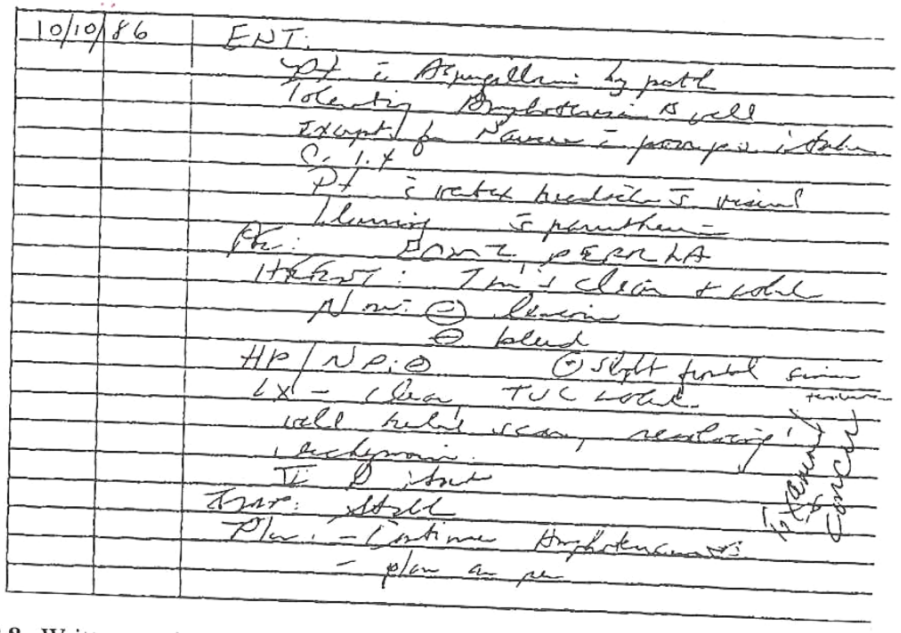
NARRATIVE PHYSICAL EXAMINATION

10-289 (Rev. 1/88)

(Signature) M.D.

Figure 2.1. Much of the information gathered during a physician–patient encounter is written in the medical record.

Progress Note

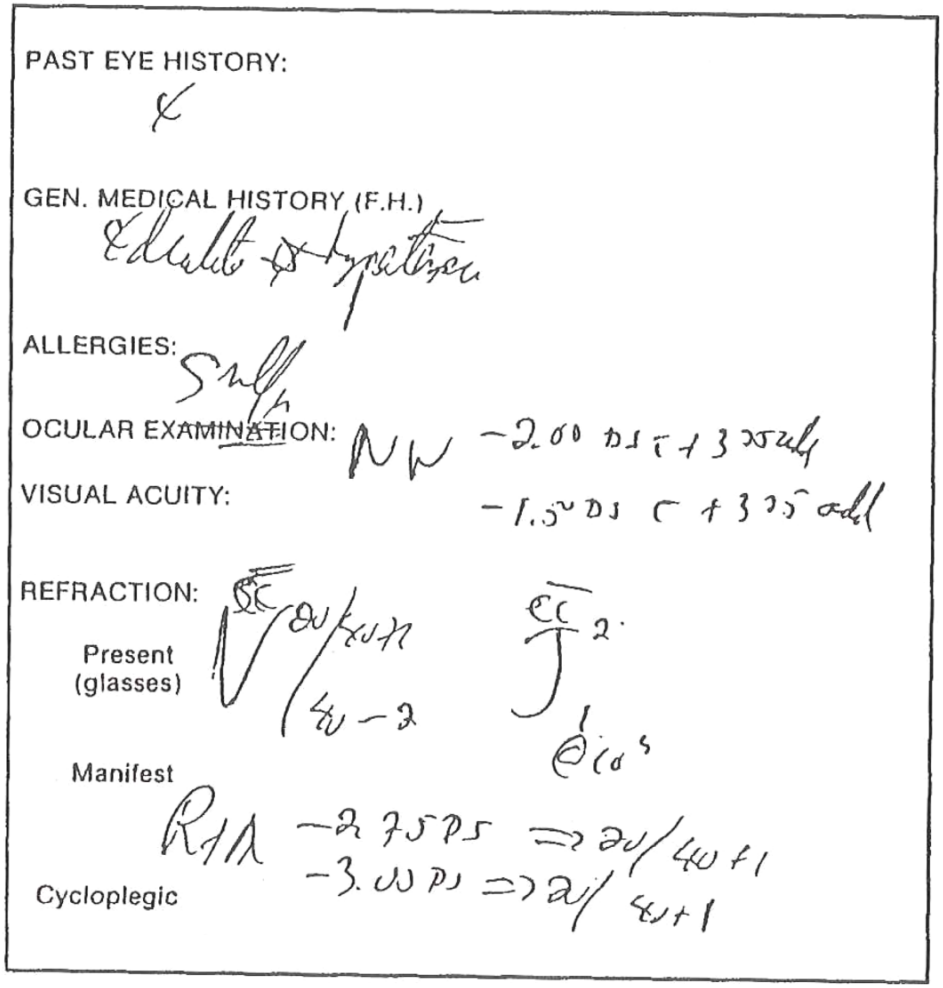


10/10/86

ENT.

Figure 2.8. Written entries are standard in paper records, yet handwritten notes may be illegible. Notes that cannot be interpreted by other people may cause delays in treatment or inappropriate care.

Sub-specialty Report


PAST EYE HISTORY:

GEN. MEDICAL HISTORY (F.H.)

ALLERGIES:

OCULAR EXAMINATION:

VISUAL ACUITY:

REFRACTION:

Present (glasses)

Manifest

Cycloplegic

Figure 2.3. An ophthalmologist's report of an eye examination. Most physicians trained in other specialties would have difficulty deciphering the symbols that the ophthalmologist has used.

Printouts

19-0505 Blood: Venous
ORDERED BY: INT MED CL - A160
ACCOUNT:

COLLECTED: 04/19/89 10:10 AM
RECEIVED: 04/19/89 10:51 AM
ACCESSIONED: 04/19/89 10:58 AM

HEMATOLOGY			NORMAL RANGE
HEMOGRAM			
WBC	5.5	K/UL	(4.0 - 11.0)
RBC	4.52	MIL/UL	(Female: 3.8 - 5.2)
			(Male: 4.4 - 5.9)
HBG	14.2	gm/dL	(Female: 11.7 - 15.7)
			(Male: 13.5 - 17.7)
HCT	42.8	%	(Female: 35 - 47)
			(Male: 40 - 52)
MCV	95.	fl	(80 - 100)
MCH	31.4	pg	(27 - 34)
MCHC	33.1	g/dL	(32 - 36)
RDW	13.1	%	(less than 14.5%)

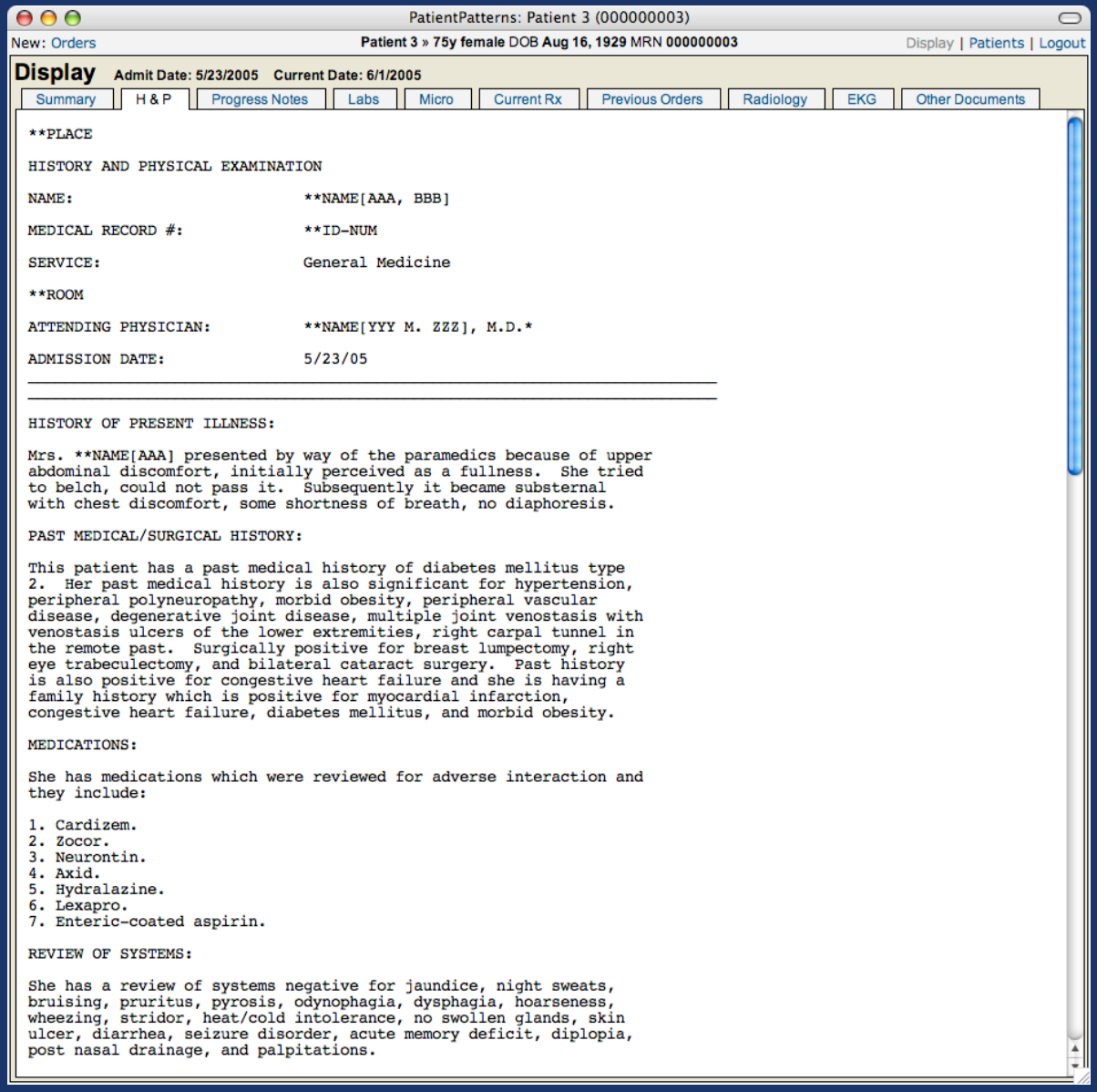
DIFF

POLY	BAND	META	LYMPH	MONO	EOS	BASO	REAC-LYM
56			27	13	2	2	

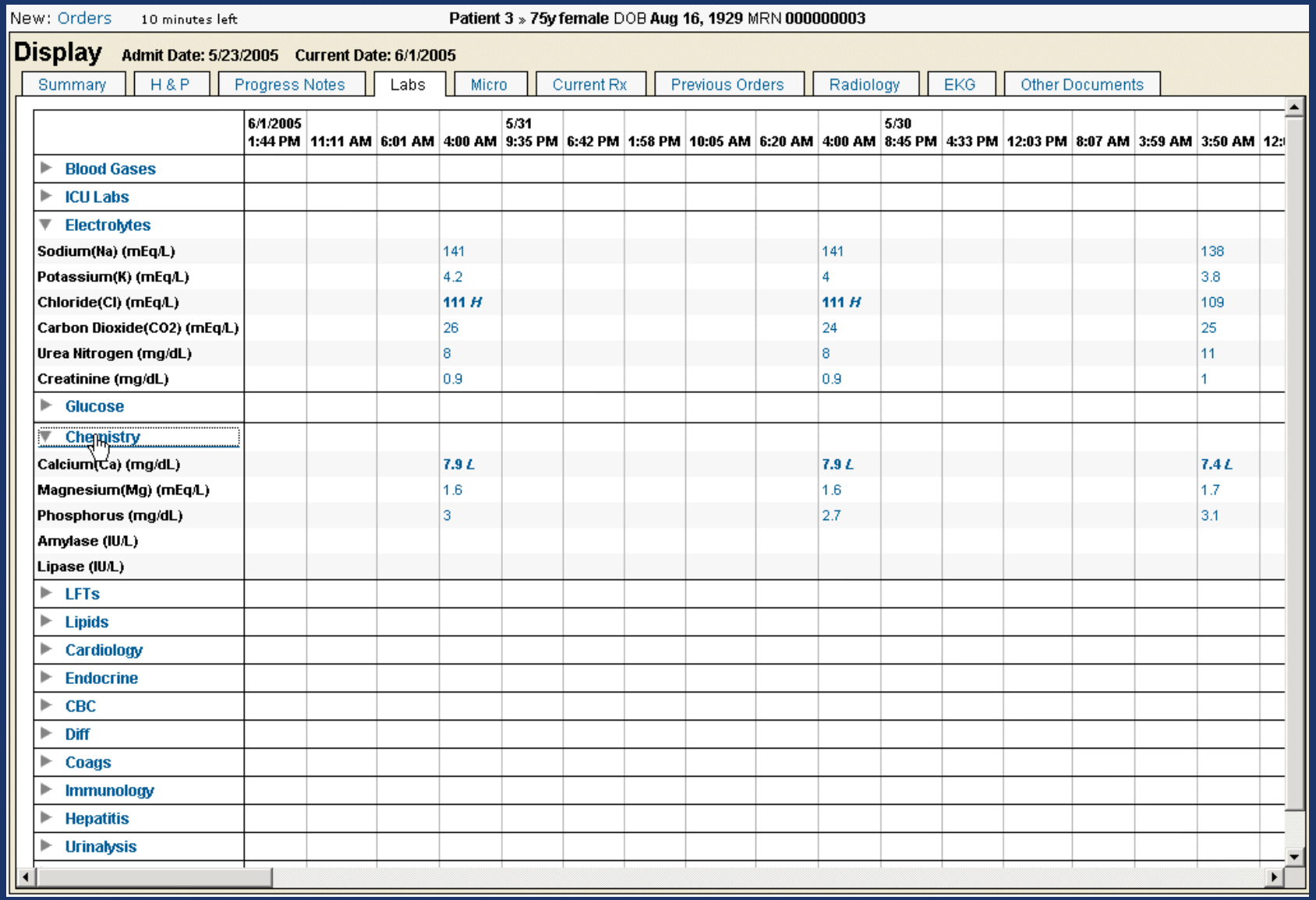
MYEL	PROM	BLAS	LYMPHOMA	OTHER	NRBC/100W	CELLS_COUNTED
						100

Figure 2.9. Laboratory reporting forms record medical data in a consistent, familiar format.

EHRs in General Duplicate the Paper Chart



EHRs in General Duplicate the Paper Chart



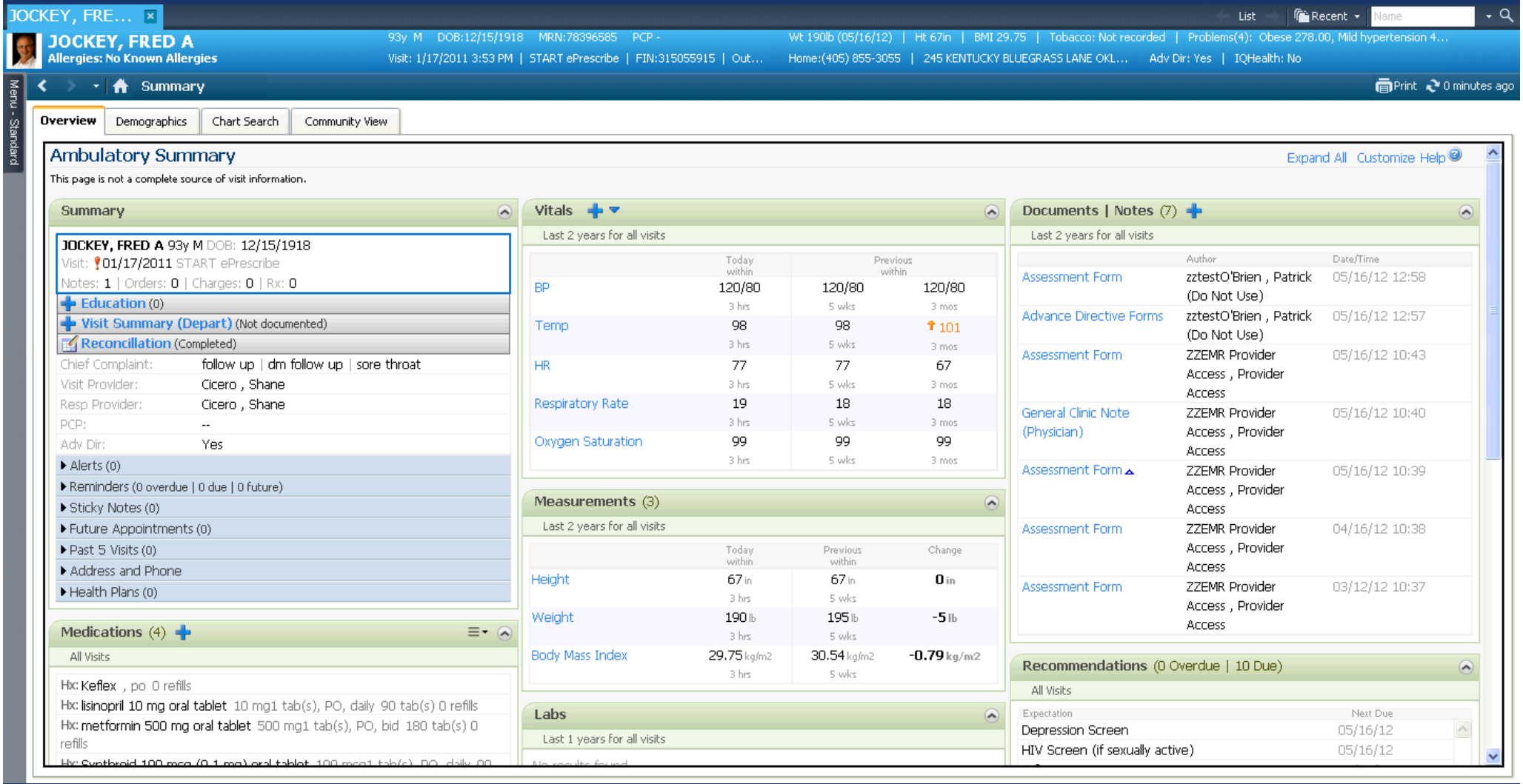
New: Orders 10 minutes left — Patient 3 » 75y female DOB Aug 16, 1929 MRN 000000003

Display Admit Date: 5/23/2005 Current Date: 6/1/2005

Summary | H & P | Progress Notes | Labs | Micro | Current Rx | Previous Orders | Radiology | EKG | Other Documents

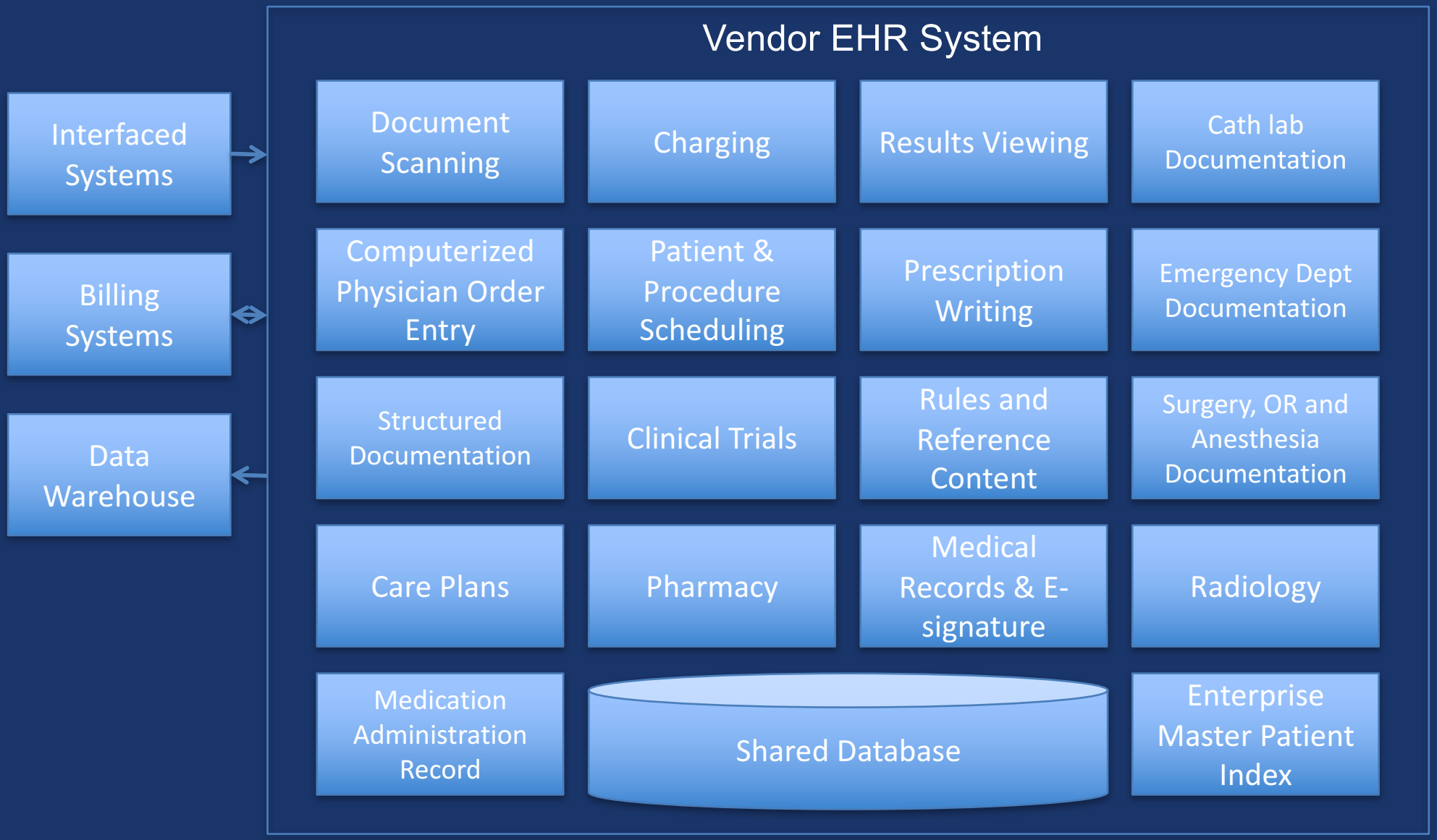
	6/1/2005 1:44 PM	11:11 AM	6:01 AM	4:00 AM	5/31 9:35 PM	6:42 PM	1:58 PM	10:05 AM	6:20 AM	4:00 AM	5/30 8:45 PM	4:33 PM	12:03 PM	8:07 AM	3:59 AM	3:50 AM	12:
▶ Blood Gases																	
▶ ICU Labs																	
▼ Electrolytes																	
Sodium(Na) (mEq/L)				141						141						138	
Potassium(K) (mEq/L)				4.2						4						3.8	
Chloride(Cl) (mEq/L)				**111 *H***						**111 *H***						109	
Carbon Dioxide(CO2) (mEq/L)				26						24						25	
Urea Nitrogen (mg/dL)				8						8						11	
Creatinine (mg/dL)				0.9						0.9						1	
▶ Glucose																	
▼ Chemistry																	
Calcium(Ca) (mg/dL)				**7.9 *L***						**7.9 *L***						**7.4 *L***	
Magnesium(Mg) (mEq/L)				1.6						1.6						1.7	
Phosphorus (mg/dL)				3						2.7						3.1	
Amylase (IU/L)																	
Lipase (IU/L)																	
▶ LFTs																	
▶ Lipids																	
▶ Cardiology																	
▶ Endocrine																	
▶ CBC																	
▶ Diff																	
▶ Coags																	
▶ Immunology																	
▶ Hepatitis																	
▶ Urinalysis																	

Moving Toward Integrated Information Displays



http://www.ehrscreenshots.com/files/2012/06/Cerner1.png

EHR System Architecture



HL7 Version 2 Data Interchange Messages

http://hl7.org

```
MSH|^~\&|||.|||199908180016||ADT^A04|ADT.1.1698593|P|2.7
PID|1||000395122||LEVERKUHN^ADRIAN^C||19880517180606|M|||6 66TH AVE NE^^WEIMAR^DL^98052||(157)983-3296|||S||12354768|87654321
NK1|1|TALLIS^THOMAS^C|GRANDFATHER|12914 SPEM ST^^ALIUM^IN^98052|(157)883-6176
NK1|2|WEBERN^ANTON|SON|12 STRASSE MUSIK^^VIENNA^AUS^11212|(123)456-7890
IN1|1|PRE2||LIFE PRUDENT BUYER|PO BOX 23523^WELLINGTON^ON^98111|||19601|||||||THOMAS^JAMES^M|F|||||||||||||||||ZKA535529776
```

Data in an HL7 message is organized hierarchically as follows:

- message
  - segment
    - field
      - component
        - Subcomponent

Each line of an HL7 message is a segment. A *segment* is a logical grouping of fields. The first three characters in a segment identify the segment type. In the above message, there are five segments `MSH` (message header), `PID` (patient identification), two `NK1` (next of kin) segments, and `IN1` (insurance).

Each segment consists of fields. A *field* contains information related to the purpose of the segment, such as the name of the insurance company in the `IN1` (insurance) segment. Fields are typically (but not always) delimited by a `|` character.

Fields can be divided into *components*. Components are typically indicated by a `^` character. In the above example, the `PID` (patient identification) segment contains a patient name field containing `LEVERKUHN^ADRIAN^C` which has three parts, last name (LEVERKUHN), first name (ADRIAN), and middle initial (C). Components can be divided into *subcomponents.* Subcomponents are typically indicated by a `&` character.

http://support.pb.com/help/spectrum/9.1/webhelp/en/EnterpriseDataIntegrationGuide/ClientTools/ReadFromHL7/ReadFromHL7.htmlData Interchange

Health Information Exchange (HIE)

Physicians

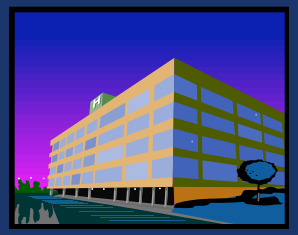
Referral Process
Eligibility
Claim/Status

Claims/Prescriptions

Pharmacies

Eligibility
Claim Status
Referral Process

Payors



Hospitals

Medical Records
Patient Data
Lab results

Public Health
Medical Society
Family Planning
Mental Health

County/Community Entities

Testing Organizations
Lab/Images

Orders
Results
Images

Government
Medicare/Medicaid

Insurance Updates
Health Information

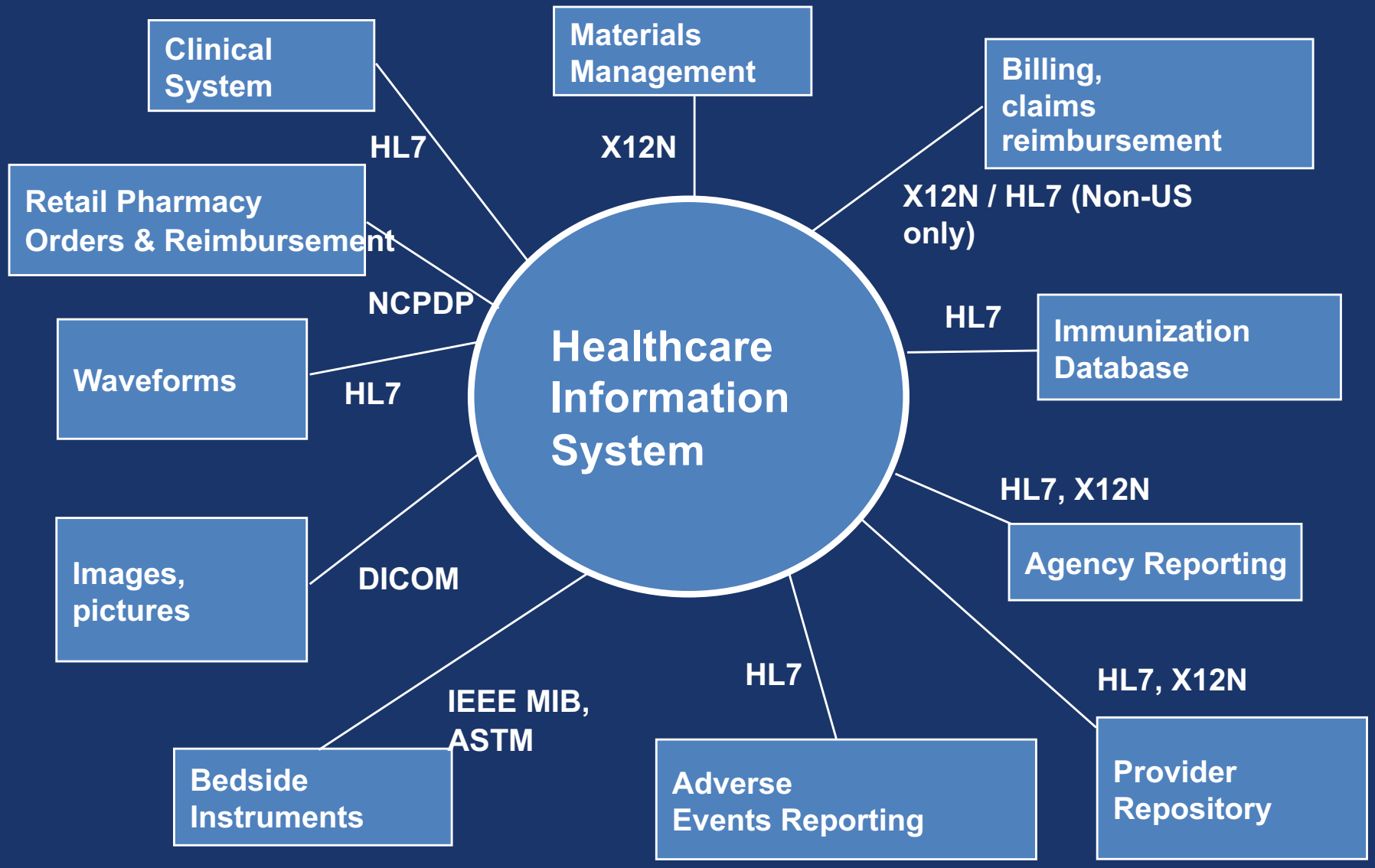
Patients/Consumers

Enrollment

Employers

http://www.slideshare.net/AShakir/amia-now-session-two

Leading Health Information Exchange Standards



http://www.slideshare.net/AShakir/amia-now-session-two

http://hit-testing.nist.gov/cda-validation/downloads.html

EXTERNAL INTEGRATION: THE HL7 CONTINUITY OF CARE DOCUMENT (CCD)

```
<ClinicalDocument xmlns="urn:hl7-org:v3" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="urn:hl7-org:v3
http://xreg2.nist.gov:8080/hitspValidation/schema/cdar2c32/infrastructure/cda/C32_CDA.xsd">
  <realmCode code="US"/>
  <typeId root="2.16.840.1.113883.1.3" extension="POCD_HD000040"/>
  <templateId root="2.16.840.1.113883.3.27.1776" assigningAuthorityName="CDA/R2"/>
  <templateId root="2.16.840.1.113883.10.20.3" assigningAuthorityName="HL7/CDT Header"/>
  <templateId root="1.3.6.1.4.1.19376.1.5.3.1.1.1" assigningAuthorityName="IHE/PCC"/>
  <templateId root="2.16.840.1.113883.3.88.11.32.1" assigningAuthorityName="HITSP/C32"/>
  <id root="2.16.840.1.113883.3.72" extension="MU_Rev2_HITSP_C32C83_4Sections_MeaningfulEntryContent_NoErrors"
  assigningAuthorityName="NIST Healthcare Project"/>
  <code code="34133-9" displayName="Summarization of episode note" codeSystem="2.16.840.1.113883.6.1" codeSystemName="LOINC"/>
  <title/>
  <effectiveTime value="20101026130945"/>
  <confidentialityCode/>
  <languageCode code="en-US"/>
  <recordTarget>
    <patientRole>
      <id root="ProviderID" extension="PatientID" assigningAuthorityName="Provider Name"/>
      <addr use="HP">
        <!--
          HITSP/C83 recommends that a patient have at least one address element with a use attribute of HP, i.e. home primary
        -->
        None of the following address elements are specifically required by HITSP C32, so the address could be be just plain text a
        this location? Use of one or more of the following labeled address lines, with meaningful content, is recommended.
        <streetAddressLine>First Address Line</streetAddressLine>
        <streetAddressLine>Next Address line - if needed, etc.</streetAddressLine>
        <city>CityName</city>
        <state>StateName</state>
        <postalCode>ZipCode(5or9)</postalCode>
        <country>USA</country>
      </addr>
      <telecom/>
      <patient>
        <name>
          <given>FirstName</given>
          <given>Middle Name or Initial - if known</given>
          <family>FamilyName</family>
        </name>
        <!--
          HITSP/C83 requires patient administrative gender, e.g. M, F, I (indeterminate)
        -->
        <administrativeGenderCode code="F" displayName="Female" codeSystem="2.16.840.1.113883.5.1" codeSystemName="HL7
        AdministrativeGender"/>
        <birthTime value="19840704"/>
        <!--
          HITSP/C83 requires patient marital status - if known, e.g. S, M, D
```

```
<entry typeCode="DRIV">
  <substanceAdministration classCode="SBADM" moodCode="EVN">
    <templateId root="2.16.840.1.113883.3.88.11.83.8" assigningAuthorityName="HITSP C83"/>
    <templateId root="2.16.840.1.113883.10.20.1.24" assigningAuthorityName="CCD"/>
    <templateId root="1.3.6.1.4.1.19376.1.5.3.1.4.7" assigningAuthorityName="IHE PCC"/>
    <templateId root="1.3.6.1.4.1.19376.1.5.3.1.4.7.1" assigningAuthorityName="IHE PCC"/>
    <!-- Medication activity template  -->
    <id root="cdbd5b05-6cde-11db-9fe1-0800200c9a66"/>
    <text>
      <reference value="#SIGTEXT_2"/>
    </text>
    <statusCode code="completed"/>
    <effectiveTime xsi:type="IVL_TS">
      <low nullFlavor="UNK"/>
      <high nullFlavor="UNK"/>
    </effectiveTime>
    <effectiveTime xsi:type="PIVL_TS" institutionSpecified="false" operator="A">
      <period value="24" unit="h"/>
    </effectiveTime>
    <!--
      The following route, dose and administrationUnit elements are HITSP/C83 Sig Components that are optional elements in a
    -->
    <routeCode>
      <originalText>oral</originalText>
    </routeCode>
    <doseQuantity value="75" unit="mg"/>
    <administrationUnitCode>
      <originalText>tablet</originalText>
    </administrationUnitCode>
    <consumable>
      <manufacturedProduct>
        <templateId root="2.16.840.1.113883.3.88.11.83.8.2" assigningAuthorityName="HITSP C83"/>
        <templateId root="2.16.840.1.113883.10.20.1.53" assigningAuthorityName="CCD"/>
        <templateId root="1.3.6.1.4.1.19376.1.5.3.1.4.7.2" assigningAuthorityName="IHE PCC"/>
        <!--  Product template  -->
        <manufacturedMaterial>
          <code code="309362" codeSystem="2.16.840.1.113883.6.88" displayName="Clopidogrel 75 MG oral tablet"
          codeSystemName="RxNorm">
            <originalText>
              Clopidogrel
              <reference/>
            </originalText>
            <translation code="174742" codeSystem="2.16.840.1.113883.6.88" displayName="Plavix" codeSystemName="RxNorm"/>
          </code>
          <name>Plavix</name>
        </manufacturedMaterial>
      </manufacturedProduct>
    </consumable>
  </substanceAdministration>
</entry>
<entry typeCode="DRIV">
```

SMART on FHIR®© – Open Platform Architecture

SOA Orchestration

mHealth

OAuth

FHIR® REST API

Clinical Element Models & FHIR Data Profiles

SMART™ Web Apps

Trusted App Registry

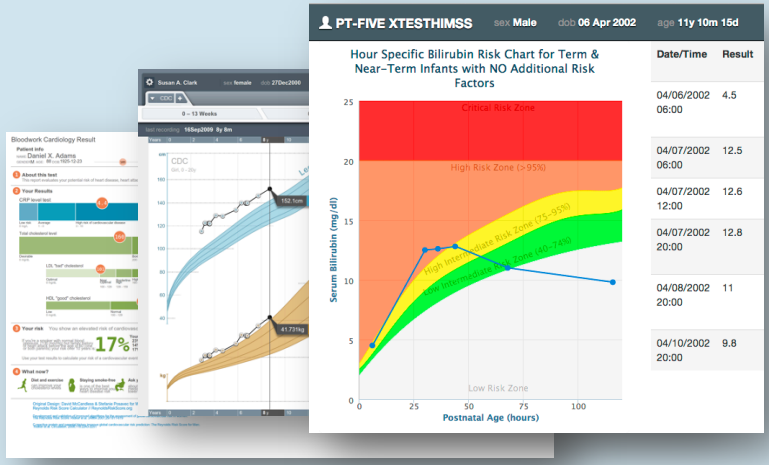
Children's Hospital Boston

Intermountain Healthcare

visualdx

"polyglot" Health Through Understanding

HARVARD MEDICAL SCHOOL



http://smartplatforms.org/smart-on-fhir/

Exhibiting Health IT Systems

- Cerner — Booth# 6965
- Intermountain Healthcare — Booth# 3903
- HARRIS — Booth# 1164
- hp — Booth# 1949

http://docs.smarthealthit.org

Healthcare App Marketplaces

SMART on FHIR

```
$ curl https://fhir-open-api-dstu2.smarthealthit.org/Patient/1551992 \
-H 'Accept: application/json'
{
  "resourceType": "Patient",
  "active": true,
  "name": [{
      "use": "official",
      "family": ["Coleman"],
      "given": ["Lisa","P."]
  }],
  "gender": "female",
  "birthDate": "1948-04-14",
  ...
}
```

Technologies:

- REST
- JSON or XML
- Healthcare data standards
- OAuth 2 (scopes and permissions)
- OpenID Connect (authentication)
- HTML5

http://docs.smarthealthit.org

Driving Forces in HIT Adoption

- The Technology Imperative
- Knowledge Explosion
- New Technologies for Dx and Rx
- Assimilating Discovery and Knowledge
- The Internet Society
- Empowerment of Patients and Consumers
- Medical Errors
- Variability in Quality, Access, and Adoption of Best Practices
- Spread of EHRs
- Aging Population
- No-Win Proposition (decreased time, increased pressure)
- Fragmentation of Care / Coordination Issues
- Defensive Medicine
- Health care costs
- P4P
- Demonstrated Benefits
- Top-down initiatives

NCHS Data Brief on Utilization of EHRs among Office-based Physician Practices

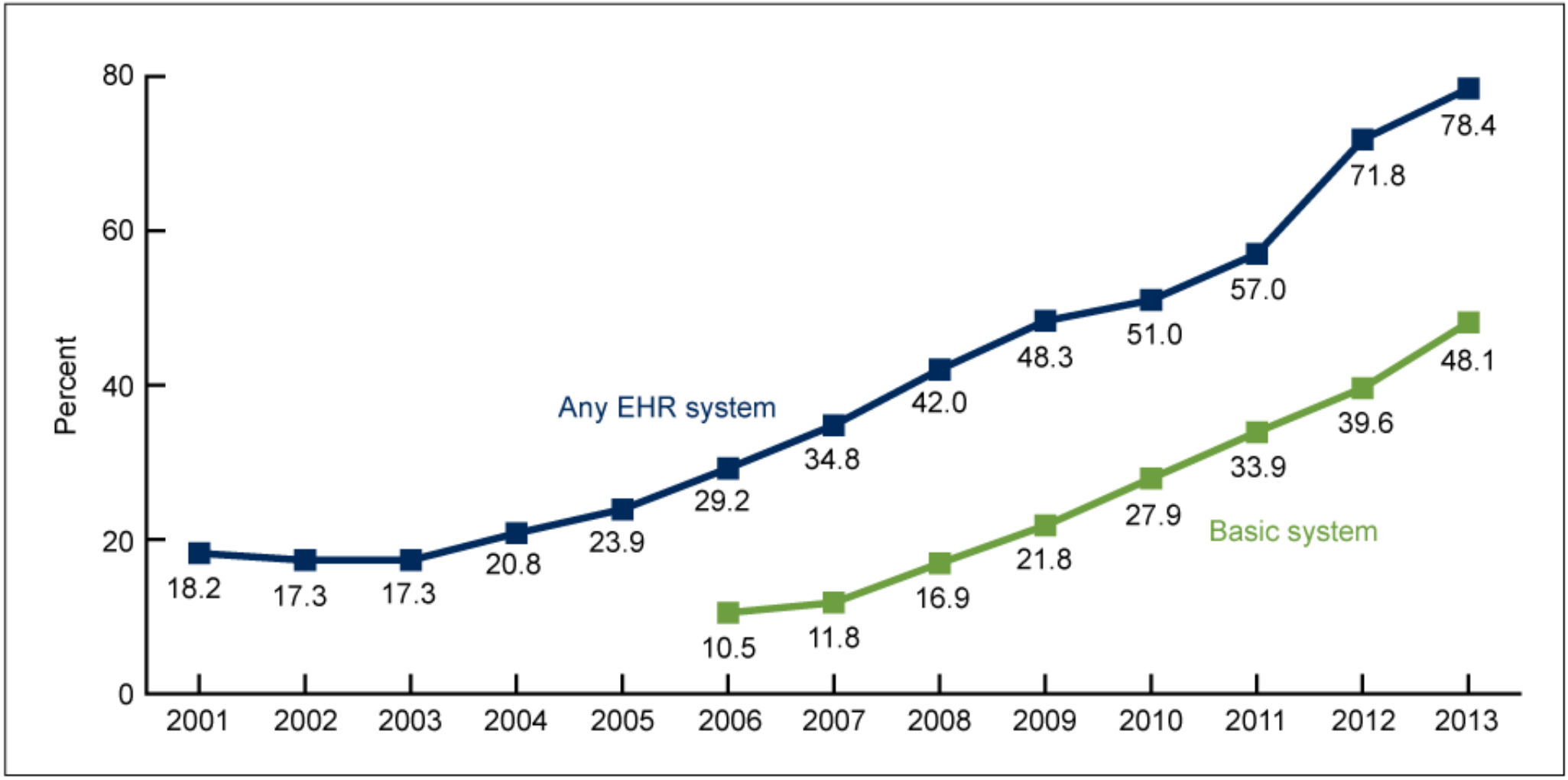
Physician office: A place where nonfederally employed physicians provide direct patient care in the 50 states and the District of Columbia; excludes radiologists, anesthesiologists, and pathologists.

Any EHR system: Obtained from "yes" responses to the question, "Does this practice use electronic medical records or electronic health records (not including billing records)?" In this report, "yes" responses are reported as having any EHR system. In recent years, the terms "electronic medical record" and EHR have been used interchangeably.

Basic EHR system: A system that has all of the following functionalities: patient history and demographics, patient problem lists, physician clinical notes, comprehensive list of patients' medications and allergies, computerized orders for prescriptions, and ability to view laboratory and imaging results electronically.

http://www.cdc.gov/nchs/products/databriefs/db143.htm

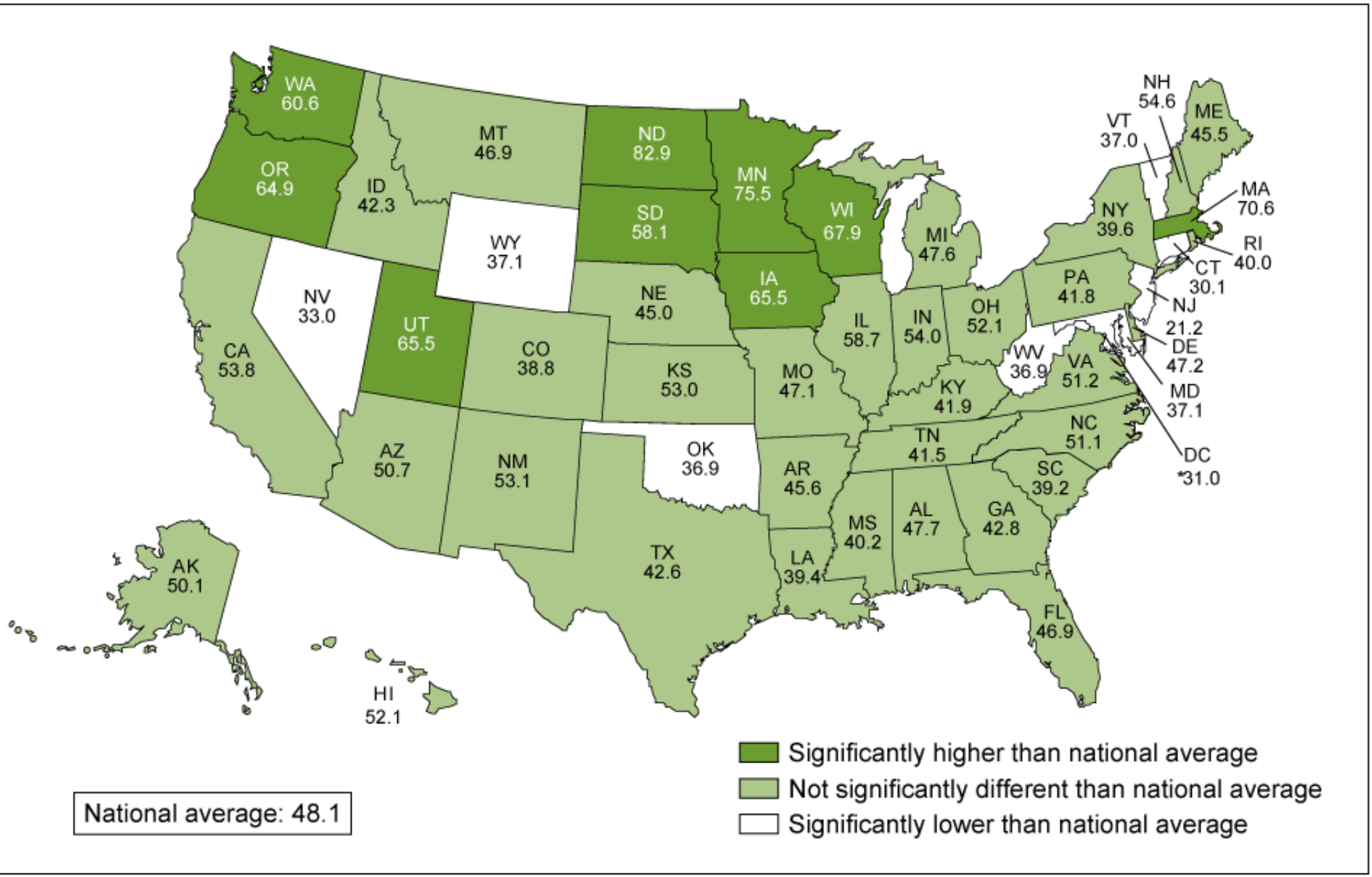
Figure 1. Percentage of office-based physicians with EHR systems: United States, 2001–2013



NOTES: EHR is electronic health record. "Any EHR system" is a medical or health record system that is either all or partially electronic (excluding systems solely for billing). Data for 2001–2007 are from in-person National Ambulatory Medical Care Survey (NAMCS) interviews. Data for 2008–2010 are from combined files (in-person NAMCS and mail survey). Estimates for 2011–2013 data are based on the mail survey only. Estimates for a basic system prior to 2006 could not be computed because some items were not collected in the survey. Data include nonfederal, office-based physicians and exclude radiologists, anesthesiologists, and pathologists.

SOURCE: CDC/NCHS, National Ambulatory Medical Care Survey and National Ambulatory Medical Care Survey, Electronic Health Records Survey.

Figure 2. Percentage of office-based physicians with a basic EHR system, by state: United States, 2013

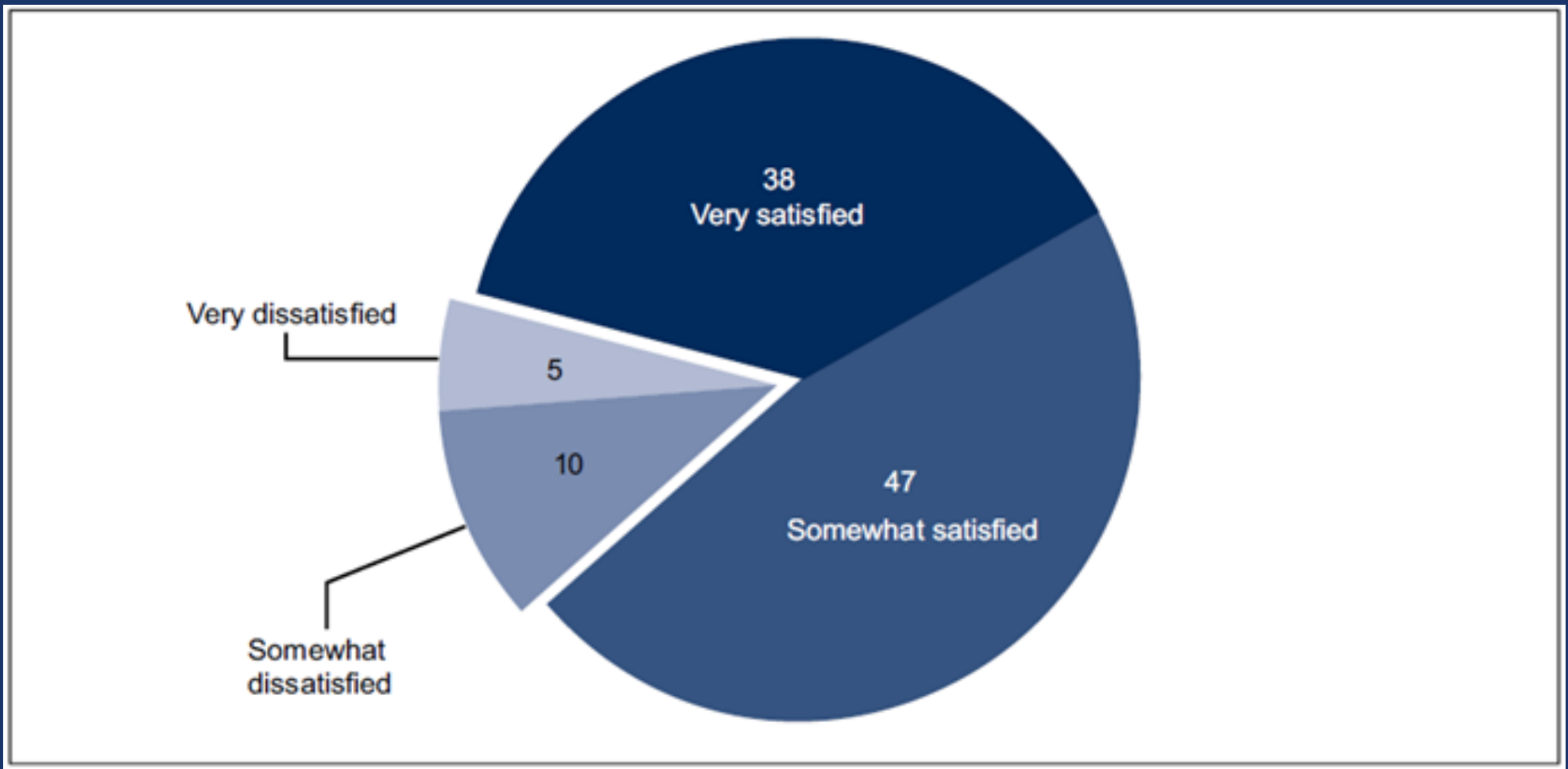


* Estimate does not meet standards of reliability or precision.

NOTES: EHR is electronic health record. Significance tested at $p < 0.05$.

SOURCE: CDC/NCHS, National Ambulatory Medical Care Survey, Electronic Health Records Survey.

EHR Physician Satisfaction



NOTES: Data represent office-based physicians who reported having adopted electronic health record systems (55% of sample). The sample includes nonfederal, office-based physicians and excludes radiologists, anesthesiologists, and pathologists. Missing values are excluded.
SOURCE: CDC/NCHS, Physician Workflow study, 2011.

CLINICAL DECISION SUPPORT

How Doctors Think

- 'Spinning Plates'
  - 10 y.o. boy with vertebral fracture – "we just see this sometimes"
  - 65 y.o. women with "preclinical viral pneumonia"?
    - Availability – more affected by recent cases
    - Confirmation bias – selective acceptance / ignorance of data based on how well it fits initial impression
    - Anchoring – quickly identify preferred dx and fail to consider others
  - "What's the worst thing this can be"
- 'Gatekeepers'
  - Separating acutely / significantly sick from not
  - Pressures on clinicians
  - Role of HIT

Science / Technical / Research Activities in the History of CDS

- Information retrieval
  - User-initiated
    - Taxonomy-based or Ontology-based Search
    - Free text
  - Semi-automated / Automated
- Evaluation of logical conditions
  - Decision tables
  - Venn diagrams
  - Logical expressions
    - Alerts
    - Reminders
    - Embedded conditions / constraints
  - Other logic models
- Probabilistic and Data-driven Classification or Prediction
  - Updating Probabilities
  - Decision Analysis
  - Bayesian Belief Networks
  - Technology Assessment
  - DB Prediction (Data Mining and Machine Learning)
  - EBM
- Heuristic Modeling and Expert Systems
  - Rule-based systems
  - Other
- Calculations, Algorithms, and Multistep Processes
  - Interactive dialogue
  - Computer-based consultations
  - Clinical Practice Guidelines
  - Biomedical Signal and Image Processing
- Associate Grouping of Elements

Types

- User-initiated (aka “pull”) – user has to go to a site / location and search
  - Taxonomy / ontology-based
  - Free text
- Semi-automated / Automated
  - Integrated with workflow
  - E.g. Infobuttons (good), MS Office Assistant (not?)

Information Retrieval

- How to do enable access to knowledge sources to health care providers (and others) who need the information?
- What kinds of questions?
  - How a specific disease “presents” in terms of signs and symptoms?
  - Given a disease, what tests are recommended to evaluate / confirm the diagnosis?
  - Given a disease, what are the recommended treatment alternatives, and what are their pro’s and con’s
  - How to interpret a test result (lab, radiology, pathology)
  - How common is this disease in my community?
  - And many, many more…
- Where is the information?
  - Journal articles
  - Textbooks (paper, electronic)
  - Web-based tools that gather, (assess), and allow access (UpToDate, WebMD, etc.)
  - Handheld resources
  - Drug information databases (handheld, Web, desktop)
  - Colleagues
  - Consumer health sites
  - Governmental sites
  - Clinical databases
  - And many, many more….

Taxonomies Vs. Free Text

- Taxonomy – set of finite terms in a (usually) hierarchical set of relationships to describe a given domain
- MEDLINE example – database of biomedical citations (abstracts, journal articles, etc.)
- Each MEDLINE entry is *manually* indexed by a reviewer who looks at the title, abstract, etc. and picks the terms from the MeSH (Medical Subject Headings) taxonomy to "tag" them with. Differentiate between primary (focus of the citation) vs. secondary
- http://www.nlm.nih.gov/mesh/
- http://pubmed.gov
- INDEXING -> RETRIEVAL

Free text

- On its own, susceptible to many challenges
- Matched with automated indexing, natural language processing (NLP) tools, can work very well
- Pubmed example

Aims of Computer-based Clinical Decision Support

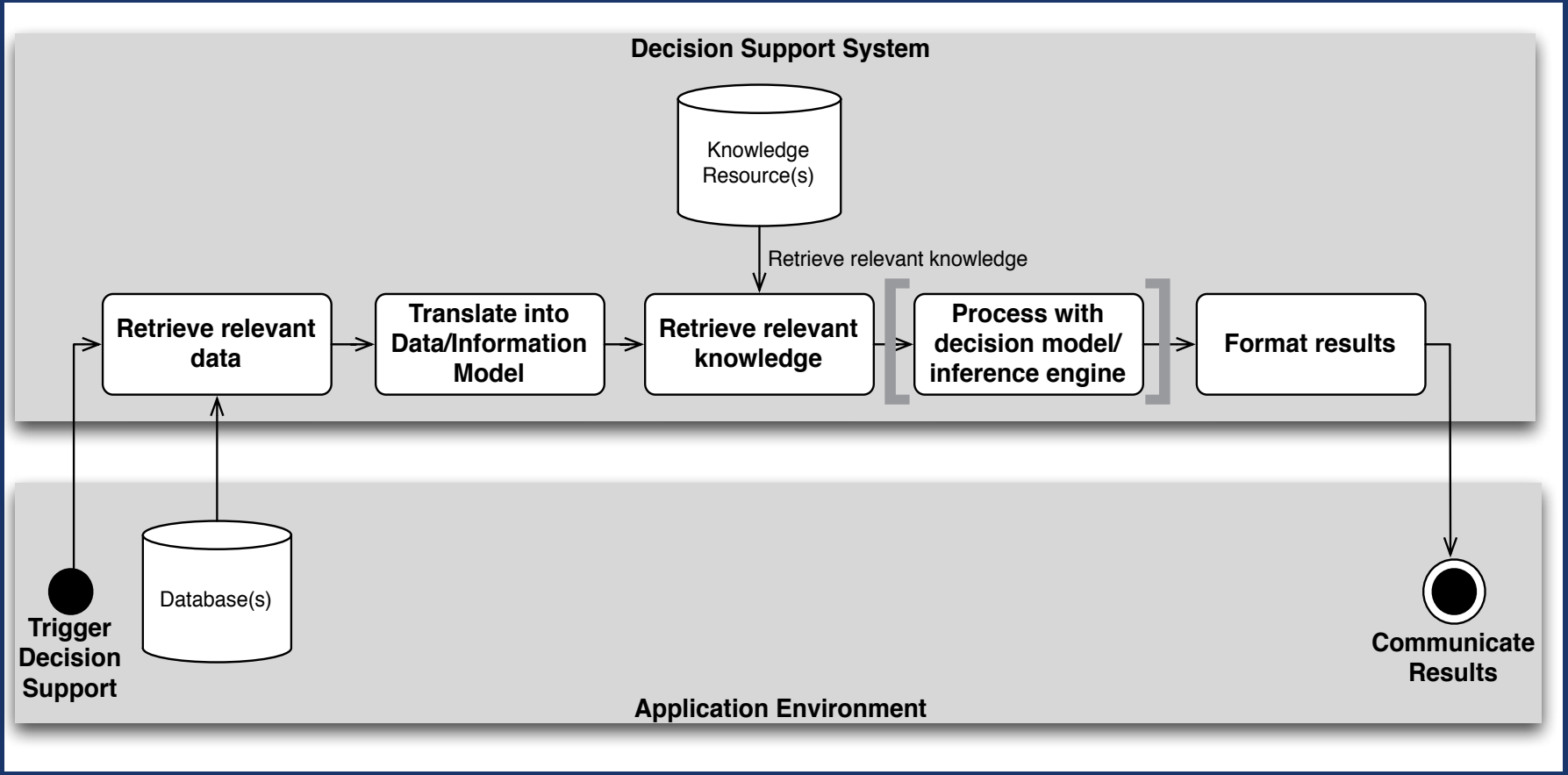
To bring relevant, high quality, evidence-based knowledge to bear on the health care and well-being of patients

More specifically, to

Increase problem-specific data access and availability

Foster optimal problem solving, decision making, and action through selection of knowledge pertinent to a specific problem in a specific patient

Elements of Decision Support Systems



Progress Thus Far

- Researched for 4 decades
- In review of 70 studies of decision support systems, [1] independent predictors of improved clinical practice were
  - Automated provision as part of clinical workflow
  - Provision of recommendations not just assessments
  - Provision of decision support at time and location of decision making
  - Computer-based decision support
- Review of 100 studies of decision support systems[2]
  - 64% of 97 studies evaluating practitioner performance showed improvement
  - Automated provision correlated with improved practitioner performance
  - 13% of 52 trials evaluating patient outcomes showed improvement
  - Many studies performed by the system developers – bias?
- Widely believed to be a good idea
- Spotty availability in commercial systems

[1]Kawamoto et al. BMJ 2005;330(7494):765.
[2]Garg et al. JAMA 2005;293:1223-38.

A Problem of Scalability

We're here

1. Initial implementation showing effectiveness in a particular application setting

A few model institutions

2. Ongoing management of decision support in the same setting

3. Wider deployment

4. Regional or national adoption

Challenges

- Implementing technical preconditions
- Knowledge maintenance, updating, dissemination and reuse
- Impact when integrated into practice settings on efficiency and workflow
- Aligning stakeholders

Diagnostic Error

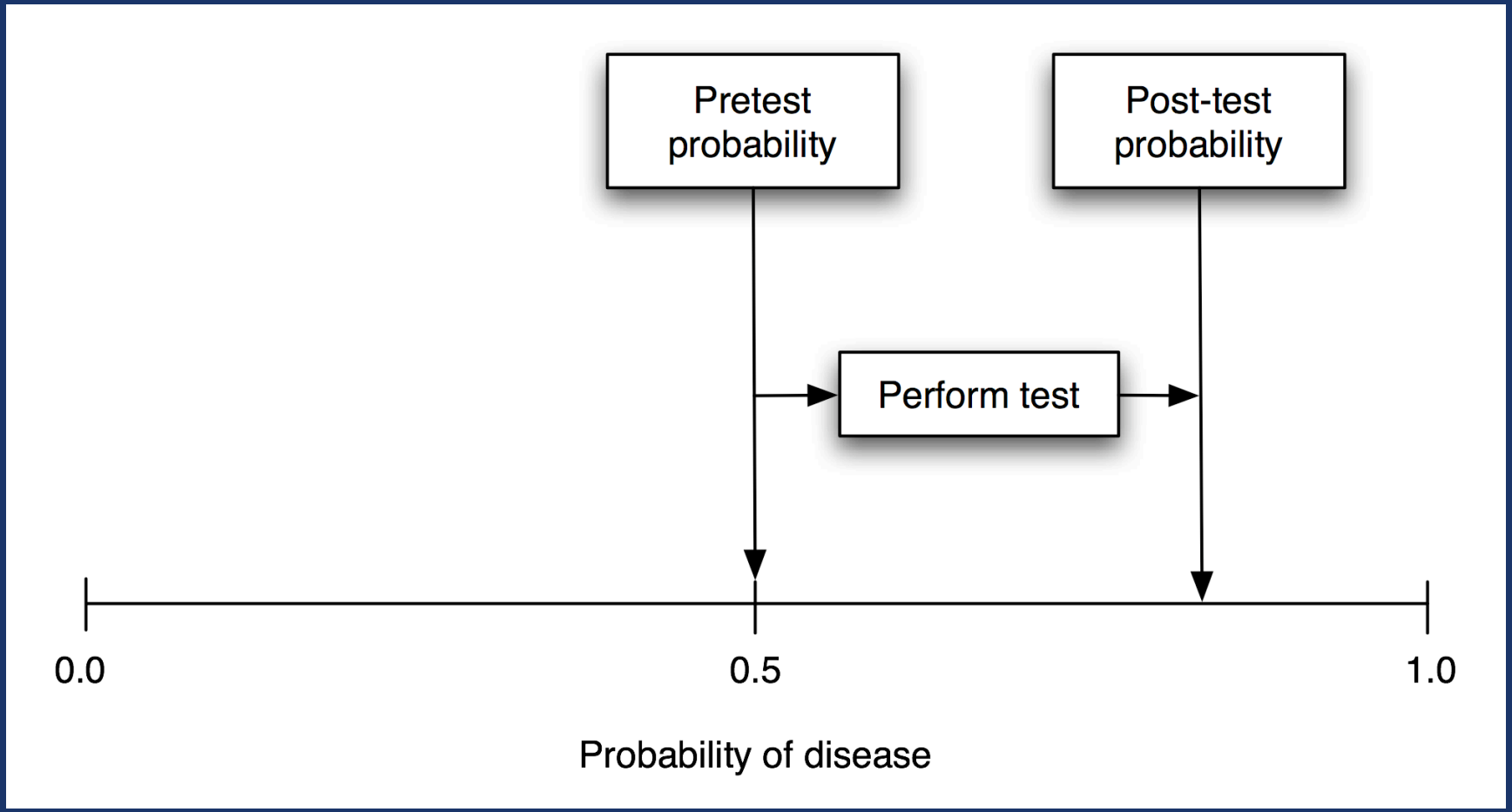
- Definition: Diagnosis that was unintentionally delayed (sufficient information was available earlier), wrong (another diagnosis was made before the correct one) or missed (no diagnosis was ever made)
- 10-15% of diagnoses may be incorrect
- Errors may be in data collection and/or interpretation

Graber ML et al. Arch Intern Med 2005;165:1493-99.

Bayes' Theorem

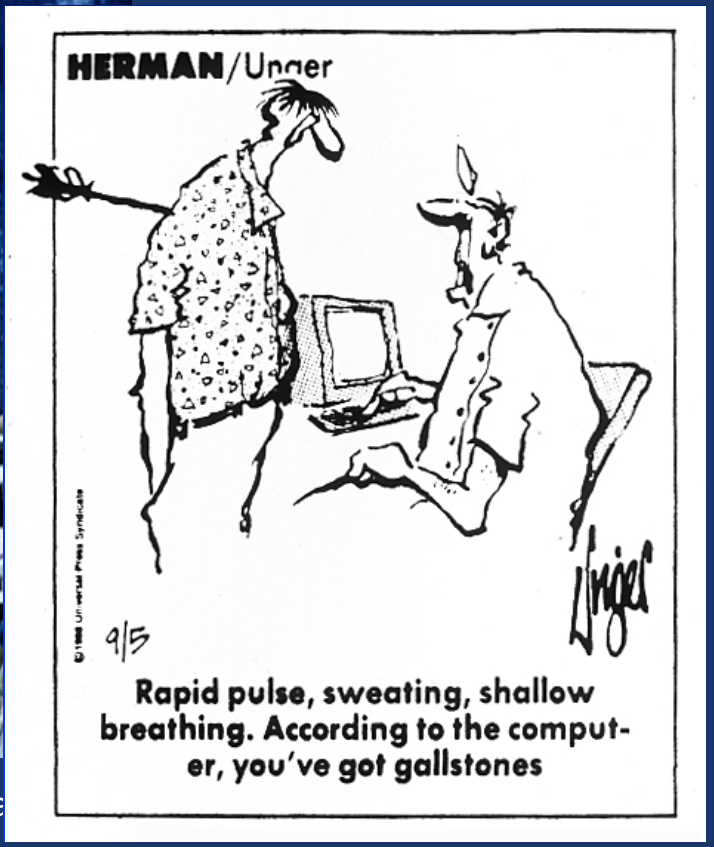
- Given
  - The sensitivity and specificity of a test for a disease
  - The prevalence of that disease
  - A result of the test for a patient
- Bayes' theorem gives the probability of disease updated by a test result

Updating Probability

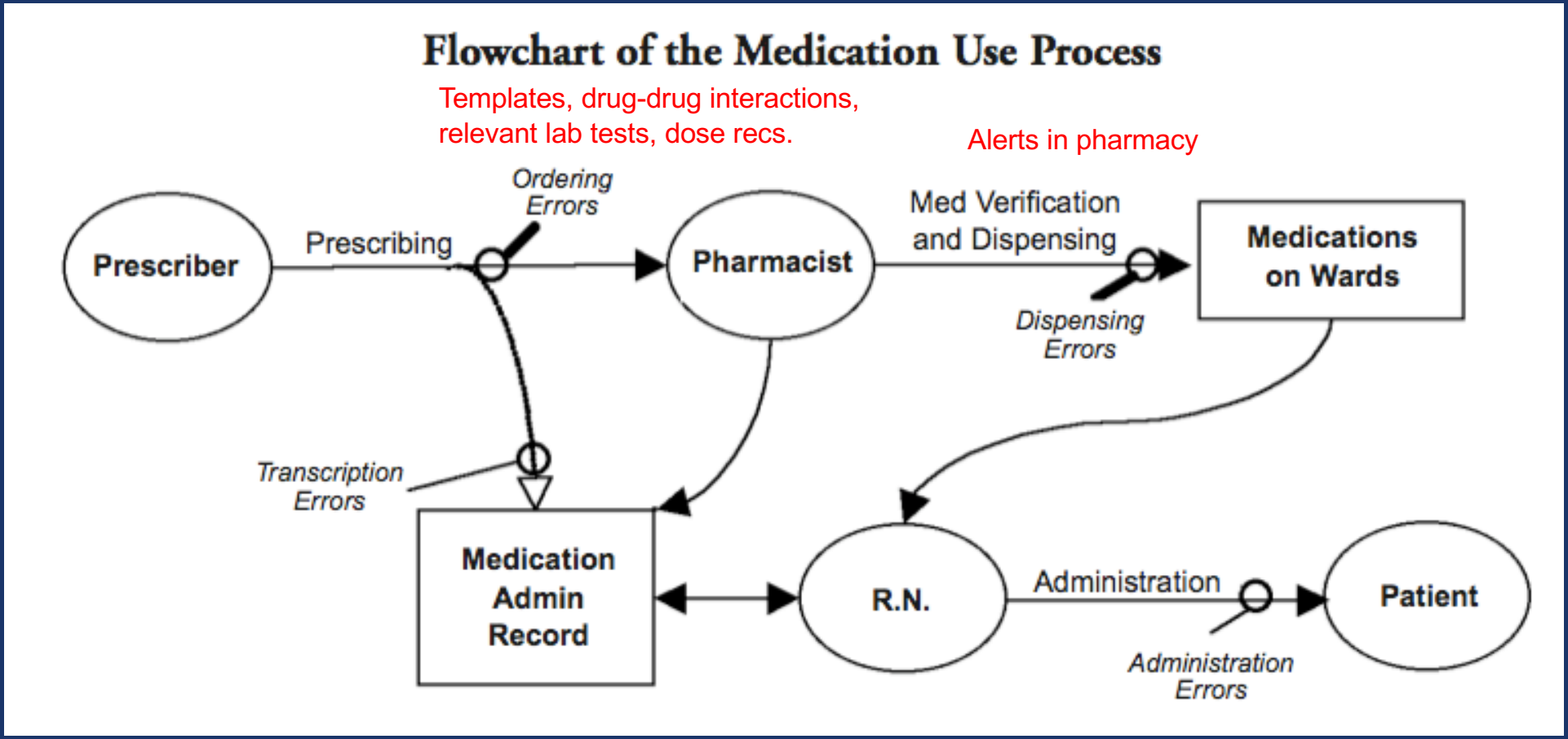


Diagnostic Decision Support

The “Greek Oracle” model (http://wings.buffalo.edu/AandL/Maecena



Errors During Order Entry



Adverse Drug Event Prevention

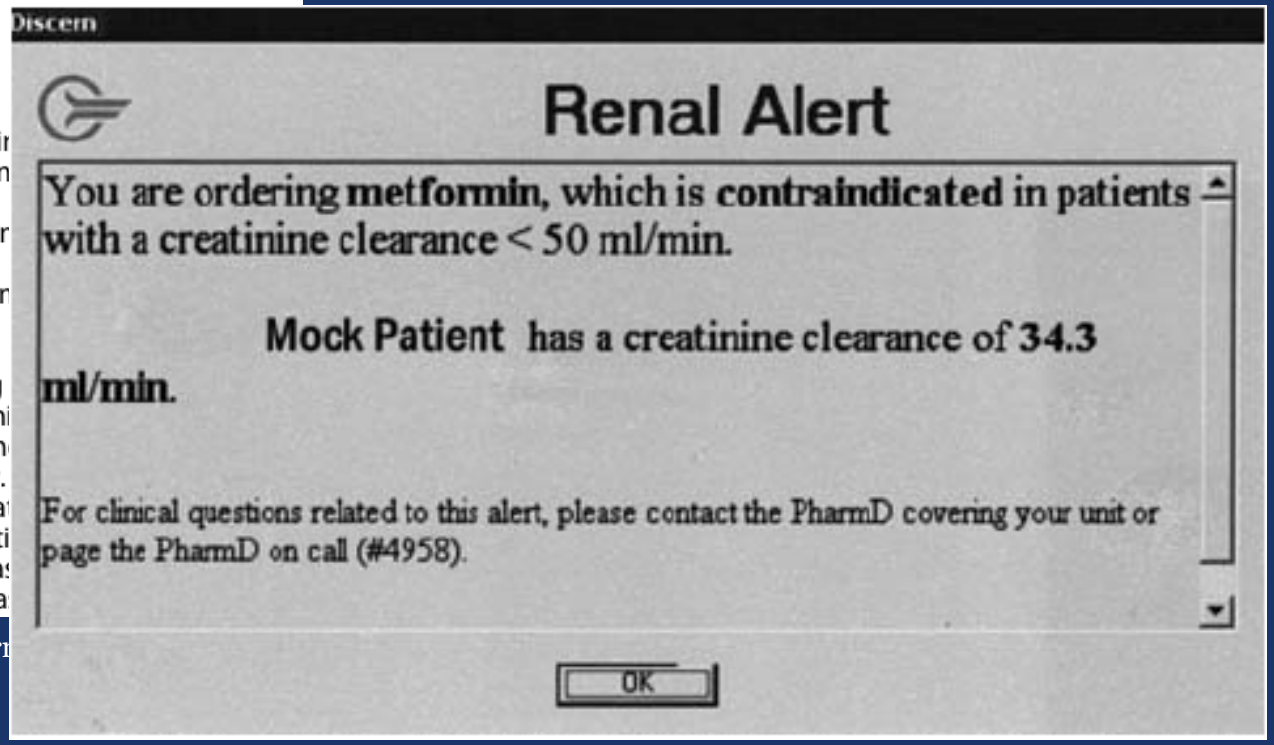
- 60% of serious medication errors occur at prescription or transcription[1]
- Many serious prescribing errors appear to be related to knowledge access[2]

[1]Bates DW et al. JAMA. 1995;274(1):29-34.
[2]Leape LL et al. JAMA 1995;274(1):35-43.

Adverse Drug Event Rules

Rule No.	Description[a]
75	Quinidine > 5
78	Theophylline > 20
71	Amikacin > 25
74	Vancomycin > 50
1055	Amikacin 10–15
73	Tobramycin > 10
1043	Metformin use and increasing creatin
1053	Potassium sliding scale and creatinin
76	Lidocaine > 5
1052	Gentamicin or tobramycin use and in
1089	Ranitidine use and creatinine > 2
1034	Antiviral use and increasing creatinin
72	Gentamicin > 10
990	Phenytoin > 18 and albumin < 3.3
1088	Fluoroquinolone use and increasing
1072	Magnesium sliding scale and creatini
1045	Digoxin use and increasing creatinin
1078	Receiving heparin by two routes (i.v.
1037	Vancomycin use and increasing creat
1044	Enoxaparin use and increasing creati
988	Hepatotoxic medications and increas
1031	Antiplatelet or NSAID use and increa

Silverman JB et al. Am J Health Syst Pharm 1;61(15):1599-603.

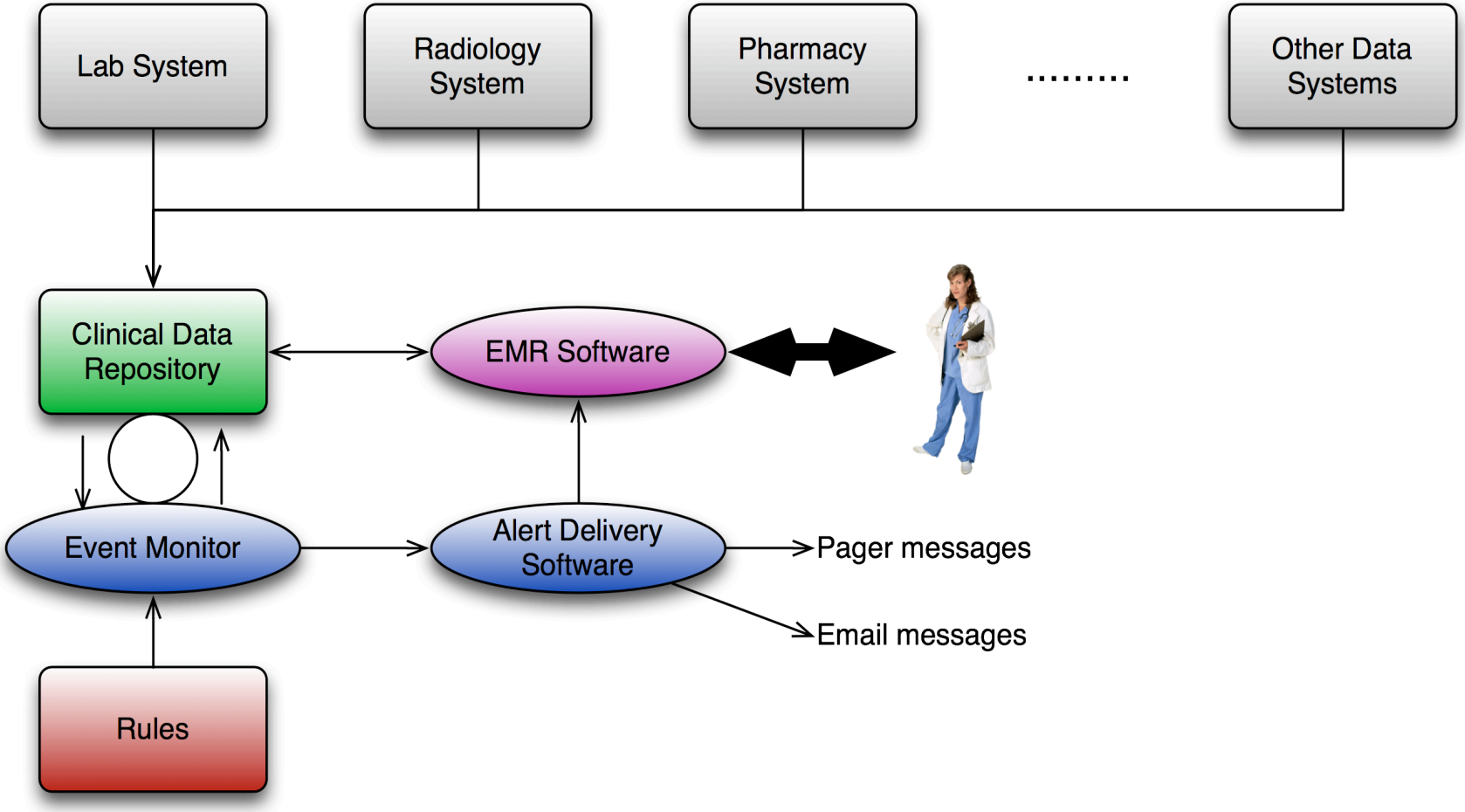


Delays in Responding to Abnormal Test Results

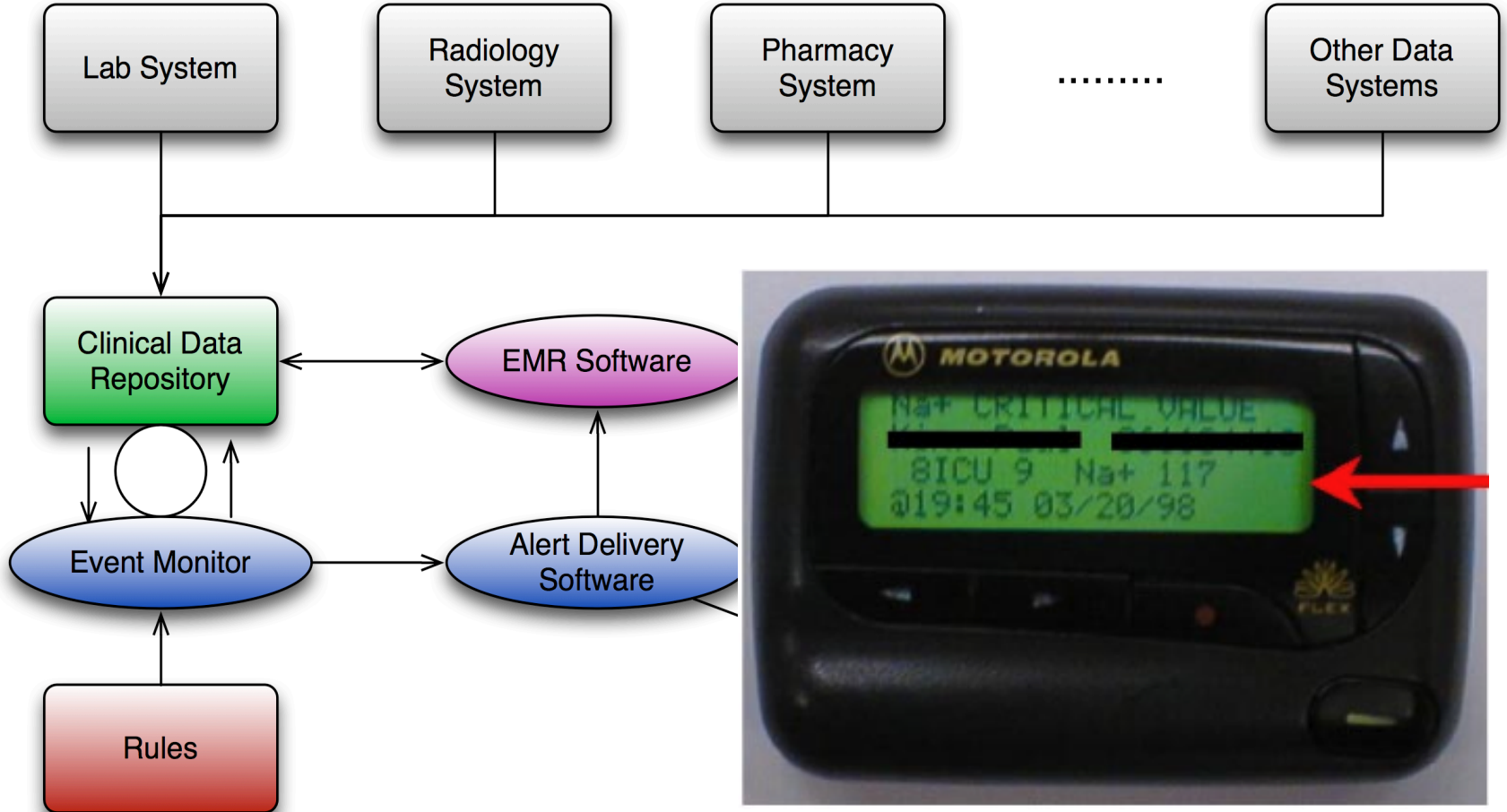
- Delays in communicating life-threatening test results to the ordering physician are a serious problem
- Median time interval of 2 ½ hours from notification of critical lab test result until appropriate treatment was ordered (over 5 hours in 25% of cases)[1]

[1]Kuperman GJ et al. JAMIA 1998;5(1):112-19.

Event Monitoring and Alerting



Event Monitoring and Alerting

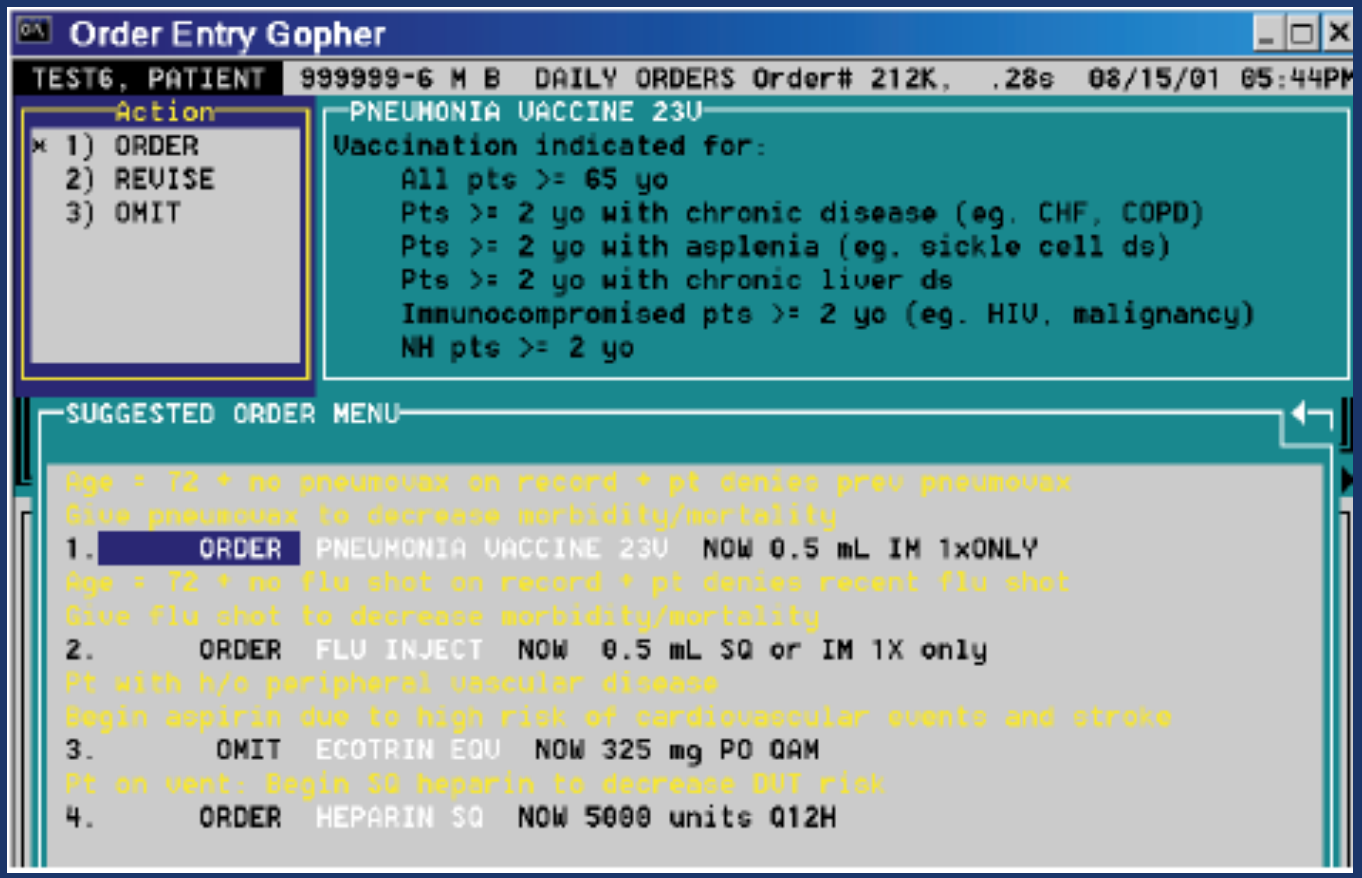


Intl Conf Sys Sci. 5000-11.

[1]US Dept. of Health and Human Services. Healthy People 2000.

Underutilization of Preventative Services – Reminder Systems

- Pap smears, mammography, vaccinations and other preventative services are underutilized[1]



Dexter, PR et al. 2001. N Engl J Med. 345:965-70.

Errors in Data Interpretation

- ADE Prevention Study Group, 1995[1]
  - "Monitoring problems" including laboratory data were a cause of 8% of physician ordering errors and were the third most common cause of patient injury due to medication
- 152 drug level tests, 1991[2]
  - 9% were incorrectly used, contributing to medical errors
- 696 important prescribing errors, 1997[3]
  - The most common factors associated with errors were changes in renal or hepatic function requiring a dose alteration

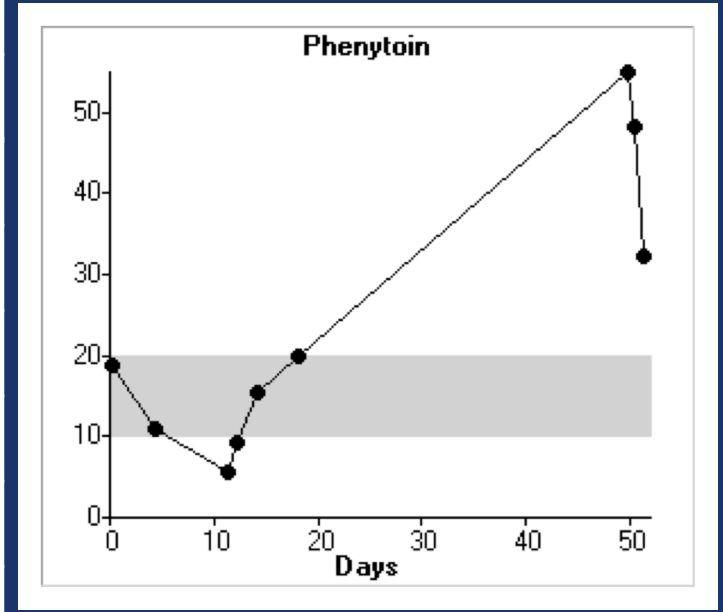
[1]Leape et al. *JAMA* 1995;274(1):35-43.
[2]Kraus et al. *Am J Dis Child* 1991;145(10):1171-5.
[3]Lesar et al. *JAMA* 1997;277(4):312-7.

Errors in Data Interpretation

- Standard chart presentation vs. problem-oriented summary
  - Elson and Connelly, Univ. Minn., 1997
    - 39% reduction in assessment time
    - 45% reduction in time to find specific results
    - 50% decrease in guideline discrepancies
  - Koopmeiners, HealthPartners, Minneapolis, 1996
    - Assessment time reduced from avg. 101 sec. To 49 sec.
- Department-oriented vs. concept-oriented data views
  - Zeng and Cimino, Columbia-Presbyterian, 1999
    - More accurate data retrieval to answer standard questions ($p<0.05$)
- Tabular vs. graphical view of laboratory data
  - Hoeke et al., Erasmus Univ., Rotterdam, The Netherlands, 2000
    - Faster retrieval and fewer classification errors with graphical views

Errors in Data Interpretation

	Day					
	0	**4**	**11**	**12**	**14**	**18**
Na	140	141	139	140	138	139
K	4.0	3.8	3.9	3.8	3.8	3.9
Cl	99	100	101	99	100	99
CO_2	25	24	25	26	24	25
Phenytoin	19.2	11.0	7.1	9.4	15.8	20.0
Digoxin	1.2	1.3	1.2	1.5	1.3	1.4



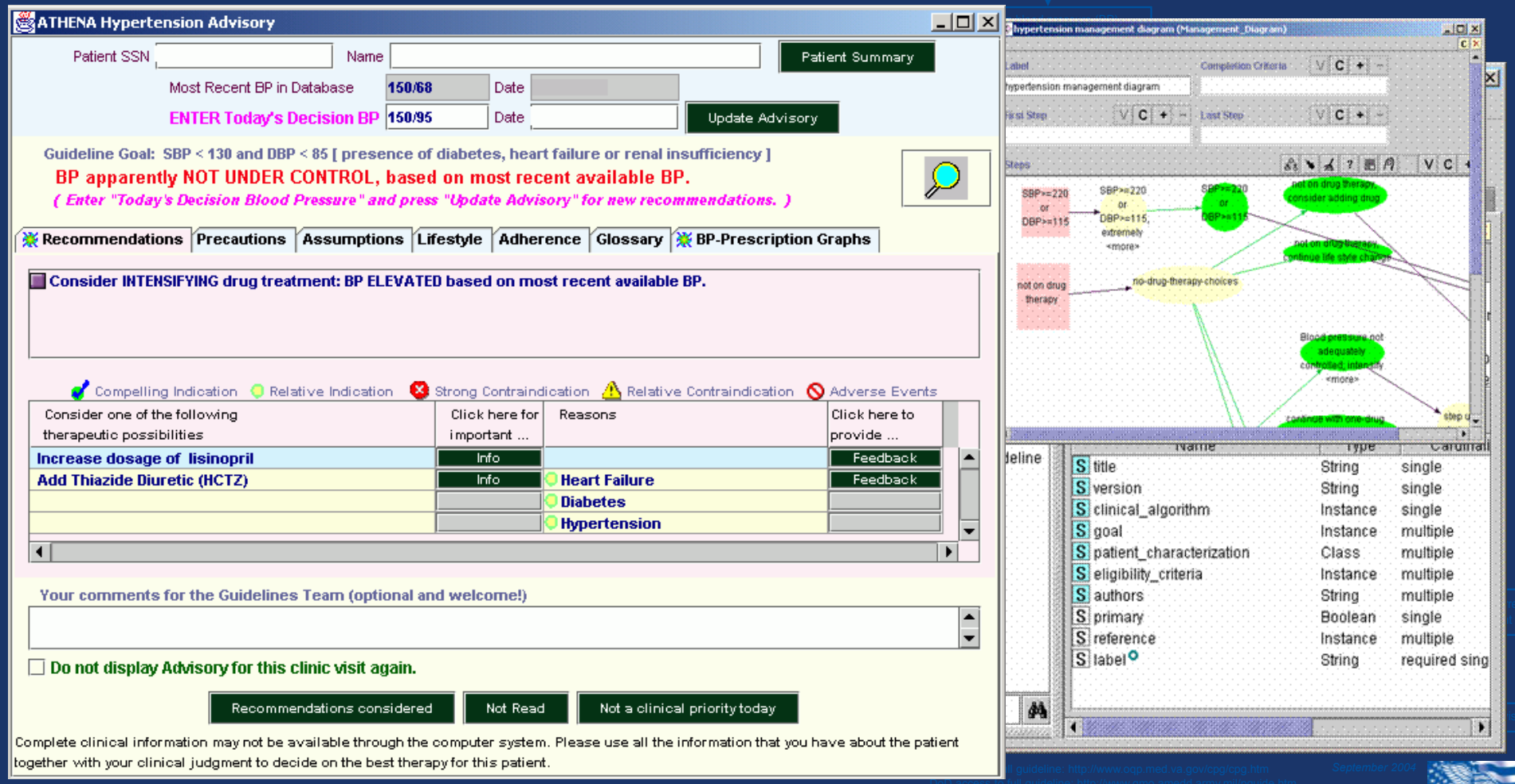
Adherence to Clinical Guidelines

- A set of schematic plans for management of patients with specific clinical conditions
- A guideline is selected for the patient
- Treatment and data collection are performed in an episodic fashion
- Plans are revised as necessary

- Can improve quality of care[1]
- Are most useful at the point of care (e.g., order entry)[2,3]

[1]Grimshaw JM and Russel IT. Lancet. 1993;342:1317-22.
[2]Shea S et al. JAMIA. 1996;3(6):399-409.
[3]Overhage JM et al. JAMIA. 1997;4(5):364-75.

Future: Guideline-based Decision Support Systems



http://www.hsrd.research.va.gov/for_researchers/cyber_seminars/archives/goldstein -091906.ppt

Unintended Consequences of Information Technology

- Highly-regarded academic medical center with relatively widely deployed CPOE system, 2005[1]
  - 75% of house staff reported observing 22 types of error risks directly attributable to the CPOE system
- Children's Hospital ICU with commercial CPOE system, 2005[2]
  - Increase in mortality following CPOE implementation
- "Homemade" drug dose calculation software system for handhelds, 2007[3]
  - Subtle bug resulted in sevenfold higher dose of noradrenaline than intended

[1]Koppel R et al. JAMA. 2005;293(10):1197-1203.
[2]Han YY et al. Pediatrics. 2005;116:1506-12.
[3]de Wildt SN et al. BMJ. 2007;334:851-2.