



EMORY
UNIVERSITY

Department of
Biomedical Informatics



Electronic Health Records, CPOE and CDS

Andrew Post, MD, PhD



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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 5/23 pt noted the onset of myalgia, severe headache, nausea, neck pain, and shaking chills. She consulted her private MD for these problems, and he diagnosed migraine & prescribed a combination med (Belladonna, alkaloids), phenobarbital, and ergotamine tartrate plus aspirin. However, her sx worsened over the next week until 6/3 when she presented to our ER. She denies photophobia, diplopia, & other neurologic symptoms. She has noted a nonproductive cough but is a non-smoker 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: - Surgery - One daughter, age 12, by NVD.

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

RDS: Genit: well until 10 days PTA

Skin: -

Head: - X per HPT.

M.D.

(Signature)

NARRATIVE PHYSICAL EXAMINATION

10-199
(Rev. 1/88)

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: |
| | PT is asymptomatic patient Tolerating hypotension well Except for nausea & passage of stool C. t.t. |
| | PT is taking medication as usual Hematuria is present |
| | Rx: Domperidone |
| | Hx test: Throat clear & cold Nose: (C) bleeding O blood |
| | HP/NP: (C) slight frontal sinus Ex - clear TBC looks well healed scars, no discharge Erythema Tx: (C) ibuprofen |
| | Hx: (C) cold Rx: - Continue hypotension - plan an appt |

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: | X |
| GEN. MEDICAL HISTORY (F.H.) | Edulite & hypertension |
| ALLERGIES: | Sulf |
| OCULAR EXAMINATION: | NW -2.00 DS +3.00 cyl |
| VISUAL ACUITY: | -1.50 DS C +3.00 add |
| REFRACTION: | |
| Present (glasses) | \checkmark 20/20 C -2.00 DS |
| Manifest | $\frac{1}{J} 2$ $\frac{1}{C} 10^{\circ}$ |
| Cycloplegic | R/H -2.75 DS \Rightarrow 20/40+1 -3.00 DS \Rightarrow 20/80+1 |

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 Bloodt Venous ORDERED BY: TNT HEP CL - A160 ACCOUNT# | | COLLECTED: 04/19/89 10:10 AM RECEIVED: 04/19/89 10:51 AM ACCESSIONED: 04/19/89 10:59 AM | | | | | |
| HEMATOLOGY | | | | | | | |
| NORMAL RANGE | | | | | | | |
| HPC | 5.5 K/uL | (4.0 - 11.0) | | | | | |
| RBC | 4.52 MIL/uL | (Female: 3.8 - 5.2) (Male: 4.4 - 5.9) | | | | | |
| HGB | 14.2 gm/dL | (Female: 11.7 - 15.7) (Male: 13.5 - 17.7) | | | | | |
| HCT | 42.8 % | (Female: 35 - 47) (Male: 40 - 52) | | | | | |
| HCV | 95. fl | (80 - 100) | | | | | |
| HCH | 31.4 pg | (27 - 34) | | | | | |
| HCHC | 33.1 g/dL | (32 - 36) | | | | | |
| RDW | 13.1 % | (less than 14.5%) | | | | | |
| DIFF | | | | | | | |
| POLY | BAND | NEUT | LYMPH | MONO | EOS | BAZO | REAC-LYN |
| 56 | | | 27 | 13 | 2 | 2 | |
| HYEL | PROL | 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

PatientPatterns: Patient 3 (00000003)
Patient 3 » 75y female DOB Aug 16, 1929 MRN 00000003
Display | Patients | Logout

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

New: Orders

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

**PLACE

HISTORY AND PHYSICAL EXAMINATION

NAME: **NAME[AAA, BBB]
MEDICAL RECORD #: **ID-NUM
SERVICE: General Medicine

**ROOM

ATTENDING PHYSICIAN: **NAME[YYY M. ZZZ], M.D.*
ADMISSION DATE: 5/23/05

HISTORY OF PRESENT ILLNESS:

Mrs. **NAME[AAA] presented by way of the paramedics because of upper abdominal discomfort, initially perceived as a fullness. She tried to belch, could not pass it. Subsequently it became substernal with chest discomfort, some shortness of breath, no diaphoresis.

PAST MEDICAL/SURGICAL HISTORY:

This patient has a past medical history of diabetes mellitus type 2. Her past medical history is also significant for hypertension, peripheral polyneuropathy, morbid obesity, peripheral vascular disease, degenerative joint disease, multiple joint venostasis with venostasis ulcers of the lower extremities, right carpal tunnel in the remote past. Surgically positive for breast lumpectomy, right eye trabeculectomy, and bilateral cataract surgery. Past history is also positive for congestive heart failure and she is having a family history which is positive for myocardial infarction, congestive heart failure, diabetes mellitus, and morbid obesity.

MEDICATIONS:

She has medications which were reviewed for adverse interaction and they include:

1. Cardizem.
2. Zocor.
3. Neurontin.
4. Axid.
5. Hydralazine.
6. Lexapro.
7. Enteric-coated aspirin.

REVIEW OF SYSTEMS:

She has a review of systems negative for jaundice, night sweats, bruising, pruritis, pyrosis, odynophagia, dysphagia, hoarseness, wheezing, stridor, heat/cold intolerance, no swollen glands, skin ulcer, diarrhea, seizure disorder, acute memory deficit, diplopia, post nasal drainage, and palpitations.



EHRs in General Duplicate the Paper Chart



Moving Toward Integrated Information Displays

JOCKEY, FRE... List Recent Name

JOCKEY, FRED A
Allergies: No Known Allergies

93y M DOB:12/15/1918 MRN:78396585 PCP -
Visit: 1/17/2011 3:53 PM | START ePrescribe | FIN:315055915 | Out... Wt 190lb (05/16/12) | Ht 67in | BMI 29.75 | Tobacco: Not recorded | Problems(4): Obese 278.00, Mild hypertension 4...

Menu Standard Print 0 minutes ago

Summary Overview Demographics Chart Search Community View

Ambulatory Summary
This page is not a complete source of visit information.

Summary

JOCKEY, FRED A 93y M DOB: 12/15/1918
Visit: 01/17/2011 START ePrescribe
Notes: 1 | Orders: 0 | Charges: 0 | Rx: 0

Education (0)
Visit Summary (Depart) (Not documented)
Reconciliation (Completed)
Chief Complaint: follow up | dm follow up | sore throat
Visit Provider: Cicero , Shane
Resp Provider: Cicero , Shane
PCP: --
Adv Dir: Yes

Alerts (0)
Reminders (0 overdue | 0 due | 0 future)
Sticky Notes (0)
Future Appointments (0)
Past 5 Visits (0)
Address and Phone
Health Plans (0)

Medications (4) +

All Visits

Hx: Keflex , po 0 refills
Hx: lisinopril 10 mg oral tablet 10 mg1 tab(s), PO, daily 90 tab(s) 0 refills
Hx: metformin 500 mg oral tablet 500 mg1 tab(s), PO, bid 180 tab(s) 0 refills
Hx: Synthroid 100 mcg (0.1 mg) oral tablet 100 mcg1 tab(s), PO, daily 00

Vitals +

Last 2 years for all visits

| | Today within | Previous within | |
|-------------------|-----------------|-----------------|-----------------|
| BP | 120/80 3 hrs | 120/80 5 wks | 120/80 3 mos |
| Temp | 98 3 hrs | 98 5 wks | 101 3 mos |
| HR | 77 3 hrs | 77 5 wks | 67 3 mos |
| Respiratory Rate | 19 3 hrs | 18 5 wks | 18 3 mos |
| Oxygen Saturation | 99 3 hrs | 99 5 wks | 99 3 mos |

Measurements (3)

Last 2 years for all visits

| | Today within | Previous within | Change |
|-----------------|----------------------------------|----------------------------------|-------------------------|
| Height | 67 in 3 hrs | 67 in 5 wks | 0 in |
| Weight | 190 lb 3 hrs | 195 lb 5 wks | -5 lb |
| Body Mass Index | 29.75 kg/m ² 3 hrs | 30.54 kg/m ² 5 wks | -0.79 kg/m ² |

Labs

Last 1 years for all visits

No results found.

Documents | Notes (7) +

Last 2 years for all visits

| | Author | Date/Time |
|------------------------------------|---|----------------|
| Assessment Form | zztestO'Brien , Patrick (Do Not Use) | 05/16/12 12:58 |
| Advance Directive Forms | zztestO'Brien , Patrick (Do Not Use) | 05/16/12 12:57 |
| Assessment Form | ZZEMR Provider Access , Provider Access | 05/16/12 10:43 |
| General Clinic Note (Physician) | ZZEMR Provider Access , Provider Access | 05/16/12 10:40 |
| Assessment Form | ZZEMR Provider Access , Provider Access | 05/16/12 10:39 |
| Assessment Form | ZZEMR Provider Access , Provider Access | 04/16/12 10:38 |
| Assessment Form | ZZEMR Provider Access , Provider Access | 03/12/12 10:37 |

Recommendations (0 Overdue | 10 Due)

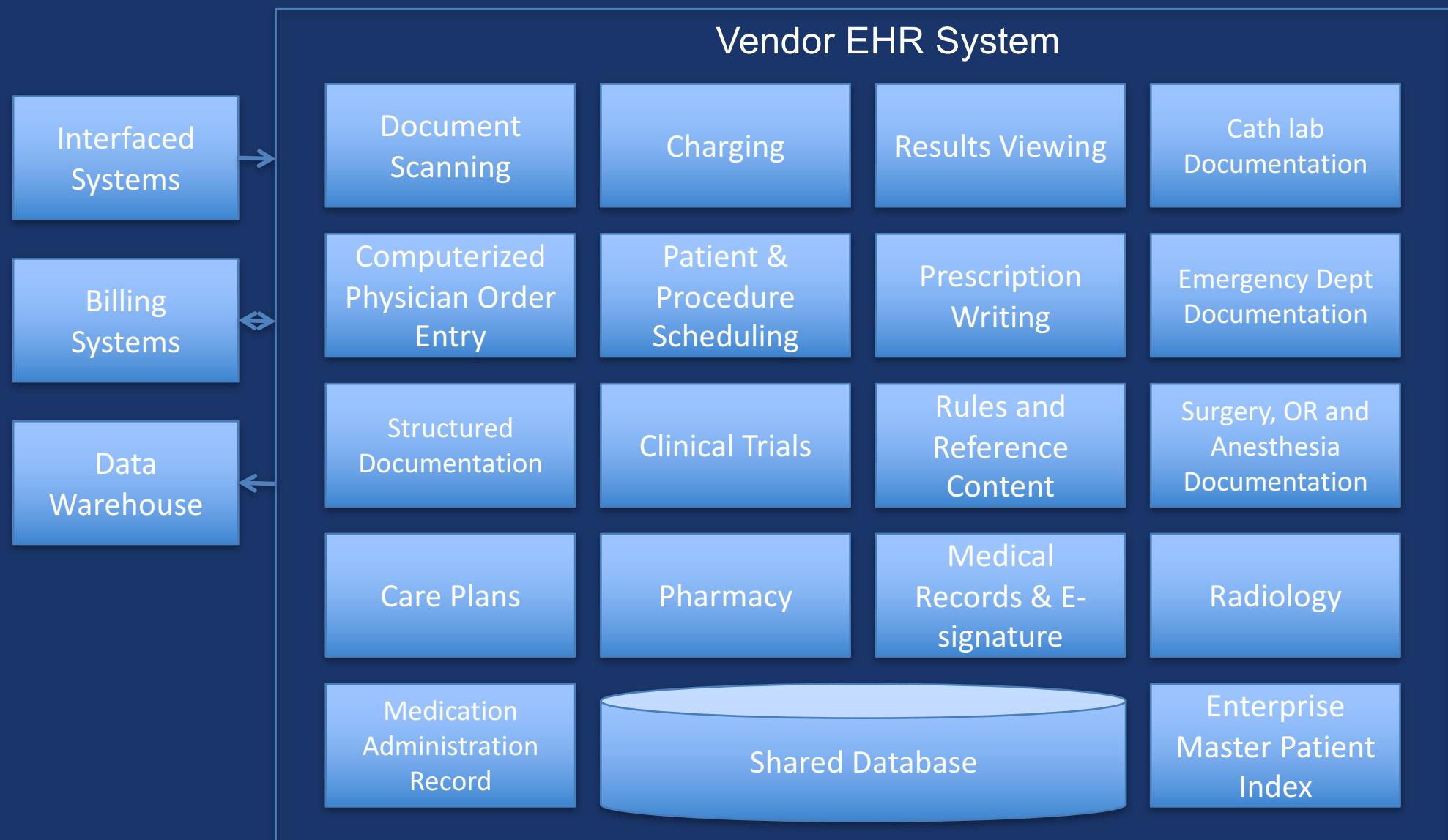
All Visits

| | Next Due |
|---------------------------------|----------|
| Expectation | 05/16/12 |
| Depression Screen | 05/16/12 |
| HIV Screen (if sexually active) | 05/16/12 |

<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).

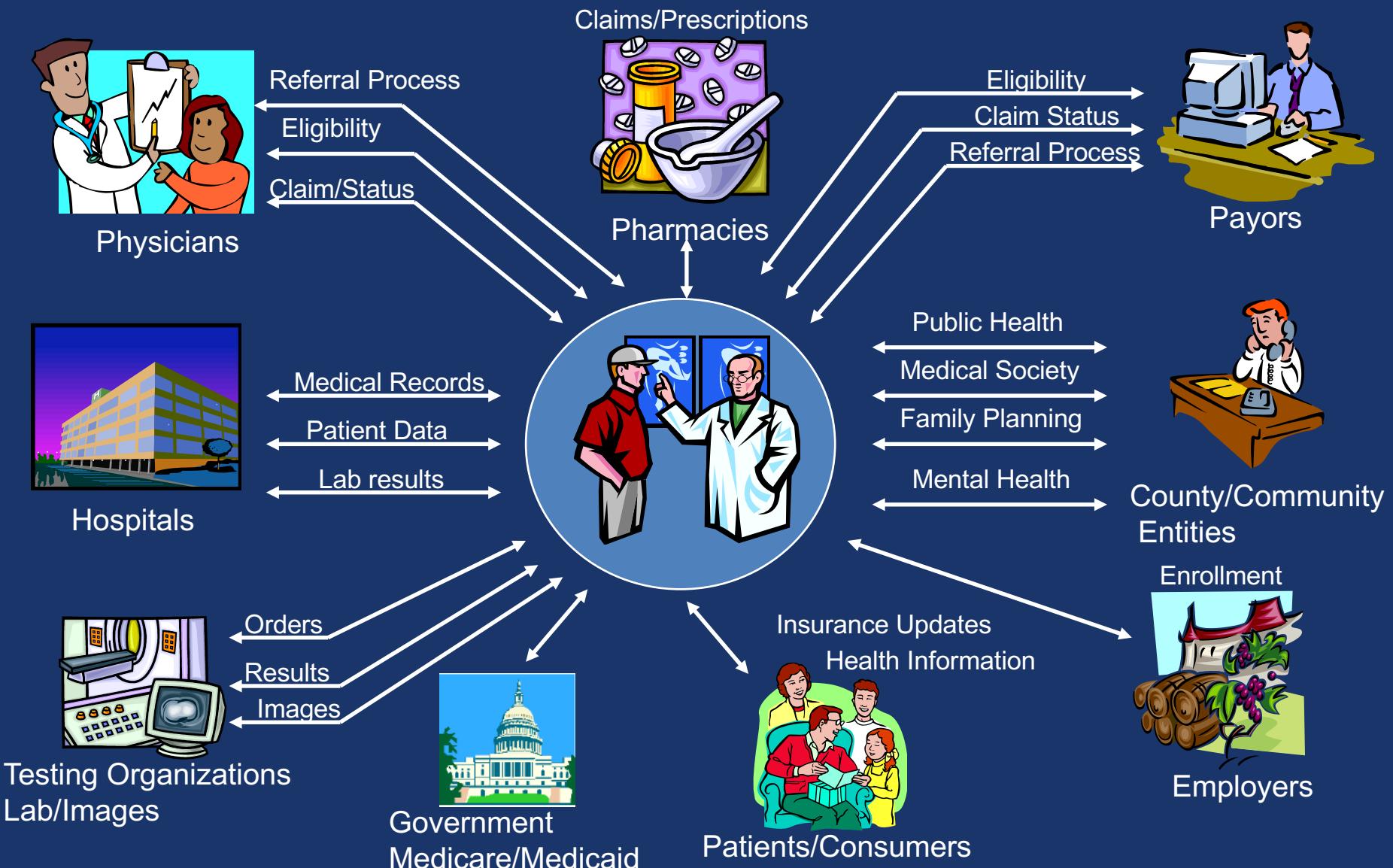
Each segment consists of fields. A *field* contains information related to the purpose of the segment, such as the name of the insurance company in the **IN1** (insurance) segment. Fields are typically (but not always) delimited by a | character.

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.html> Data Interchange

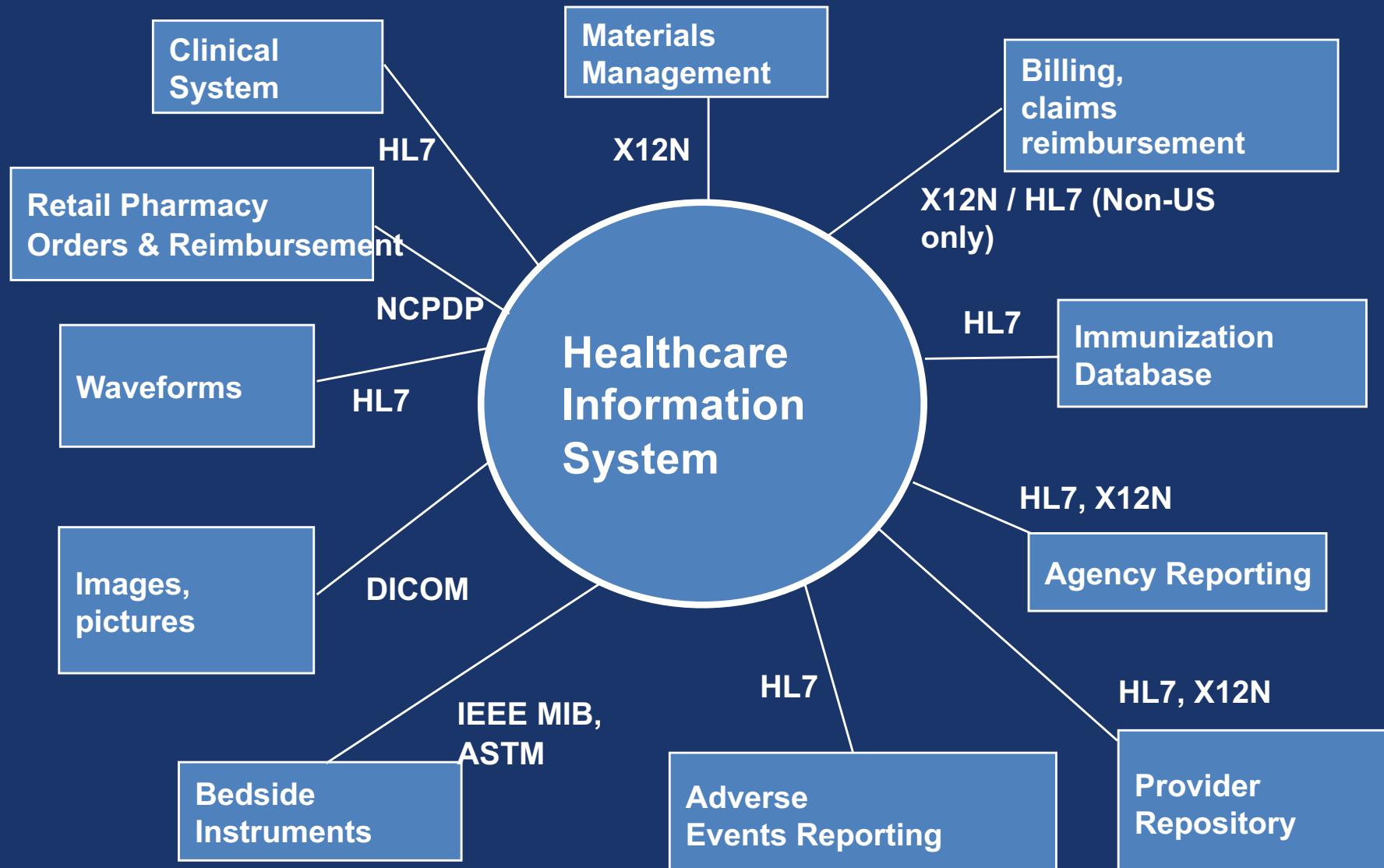


Health Information Exchange (HIE)





Leading Health Information Exchange Standards





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

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

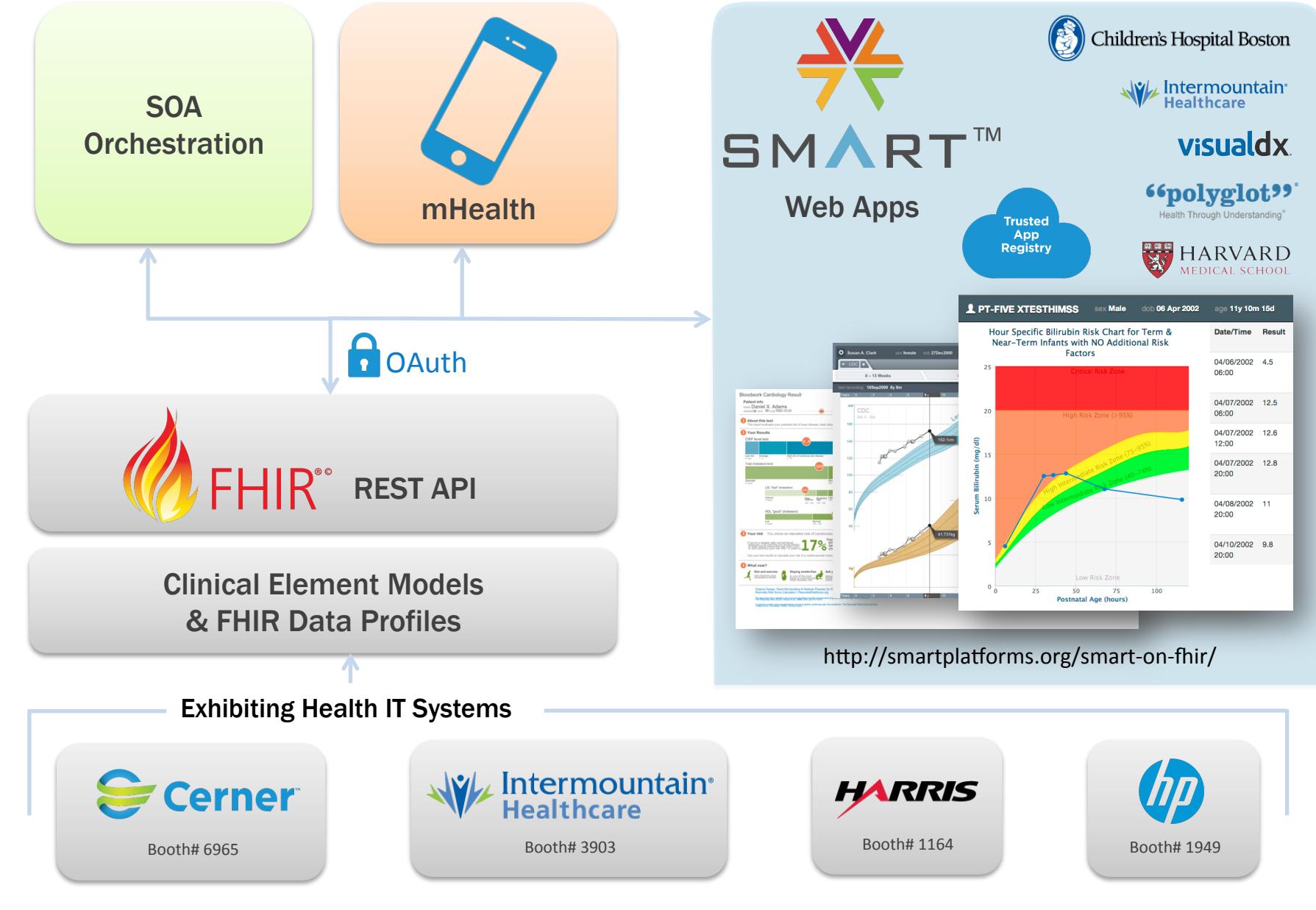


```
<ClinicalDocument xmlns="urn:hl7-org:v3" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="urn:hl7-org:v3 http://xreg2.nist.gov:8080/hitspValidation/schema/cdar2c32/infrastructure/cda/C32_CDA.xsd">
  <realmCode code="US"/>
  <typeId root="2.16.840.1.113883.1.3" extension="POCD_HD000040"/>
  <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 just plain text at 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
      -->
    </patient>
  </recordTarget>

```

```
<!-->
<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



<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



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.

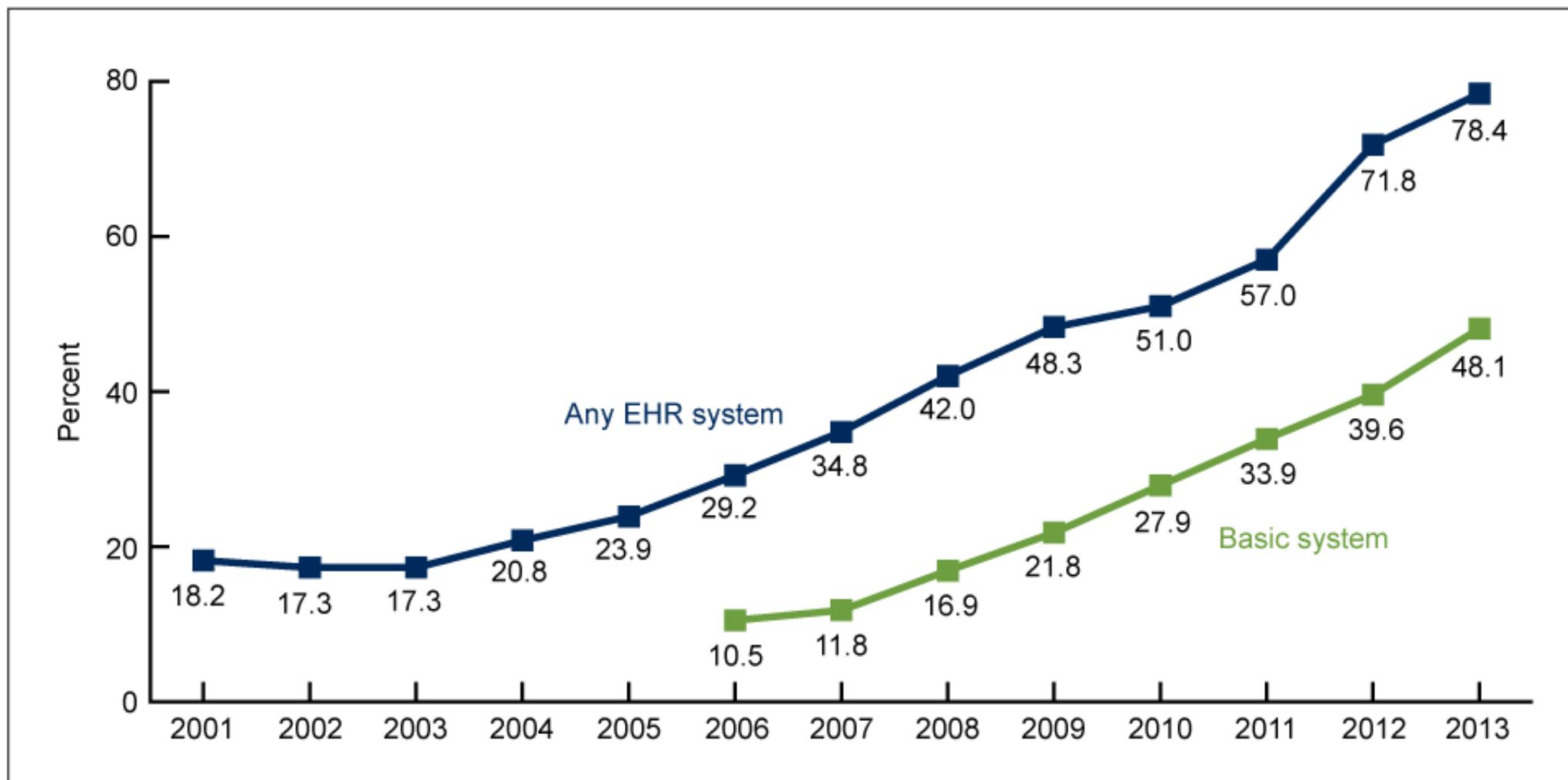
Any EHR system: Obtained from “yes” responses to the question, “Does this practice use electronic medical records or electronic health records (not including billing records)?” In this report, “yes” responses are reported as having any EHR system. In recent years, the terms “electronic medical record”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



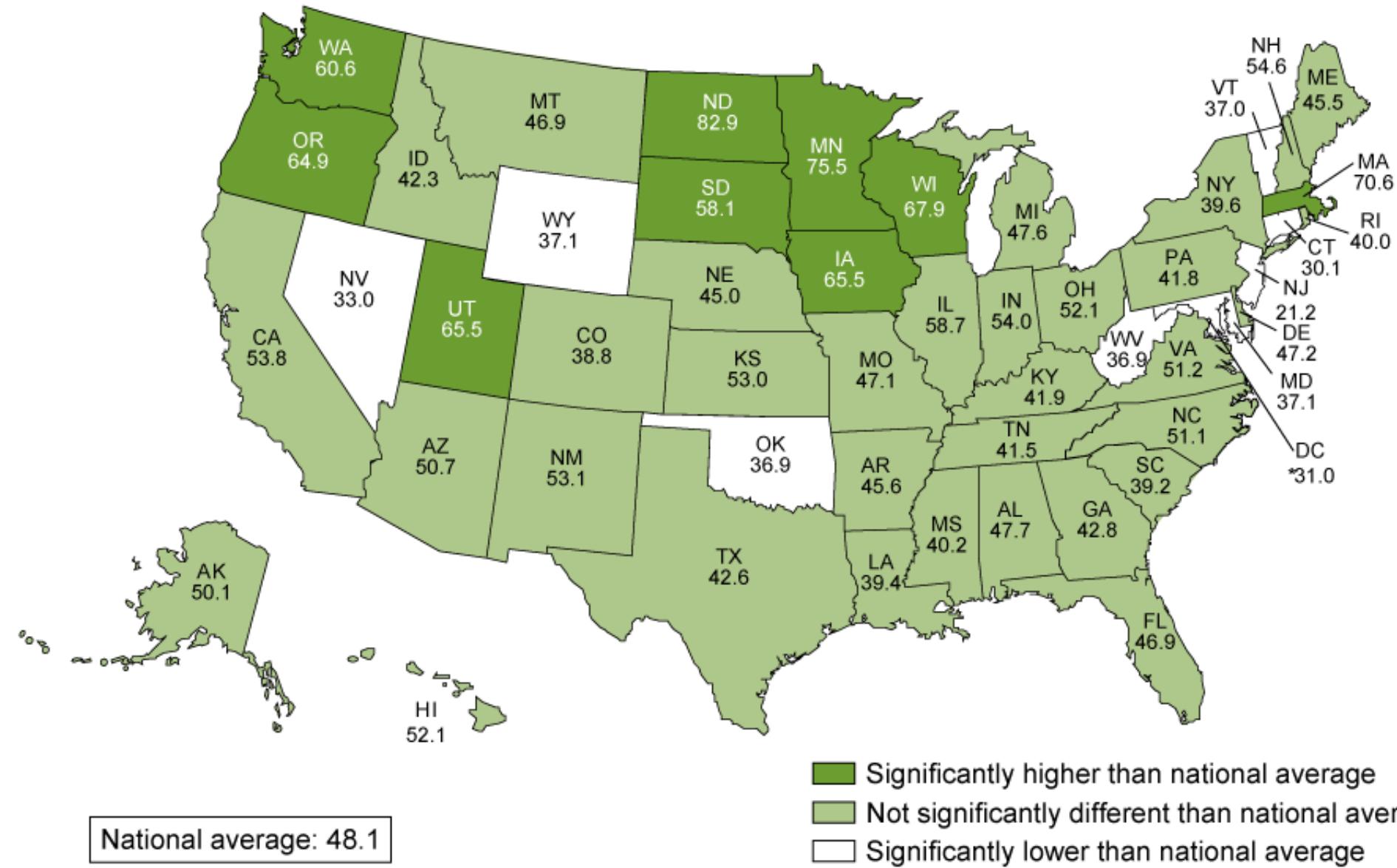
Figure 1. Percentage of office-based physicians with EHR systems: United States, 2001–2013



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



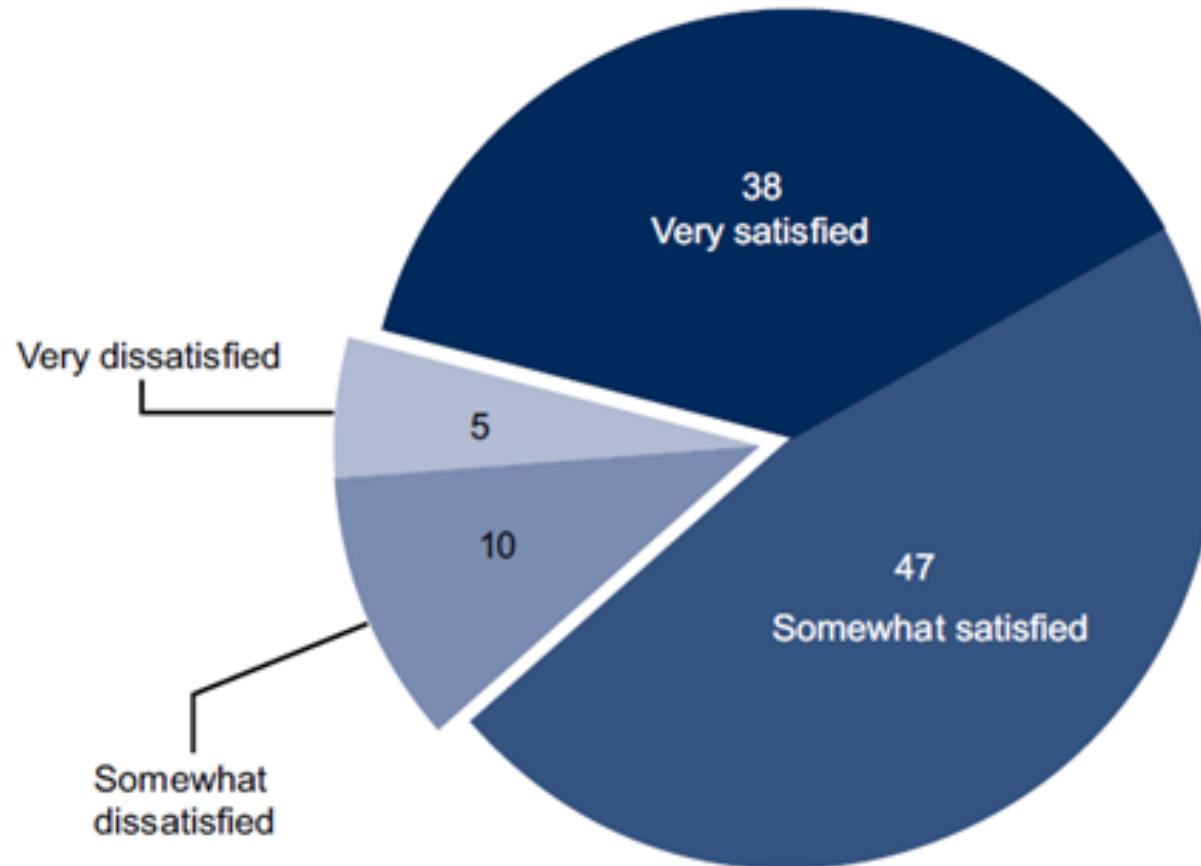
* Estimate does not meet standards of reliability or precision.

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.



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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

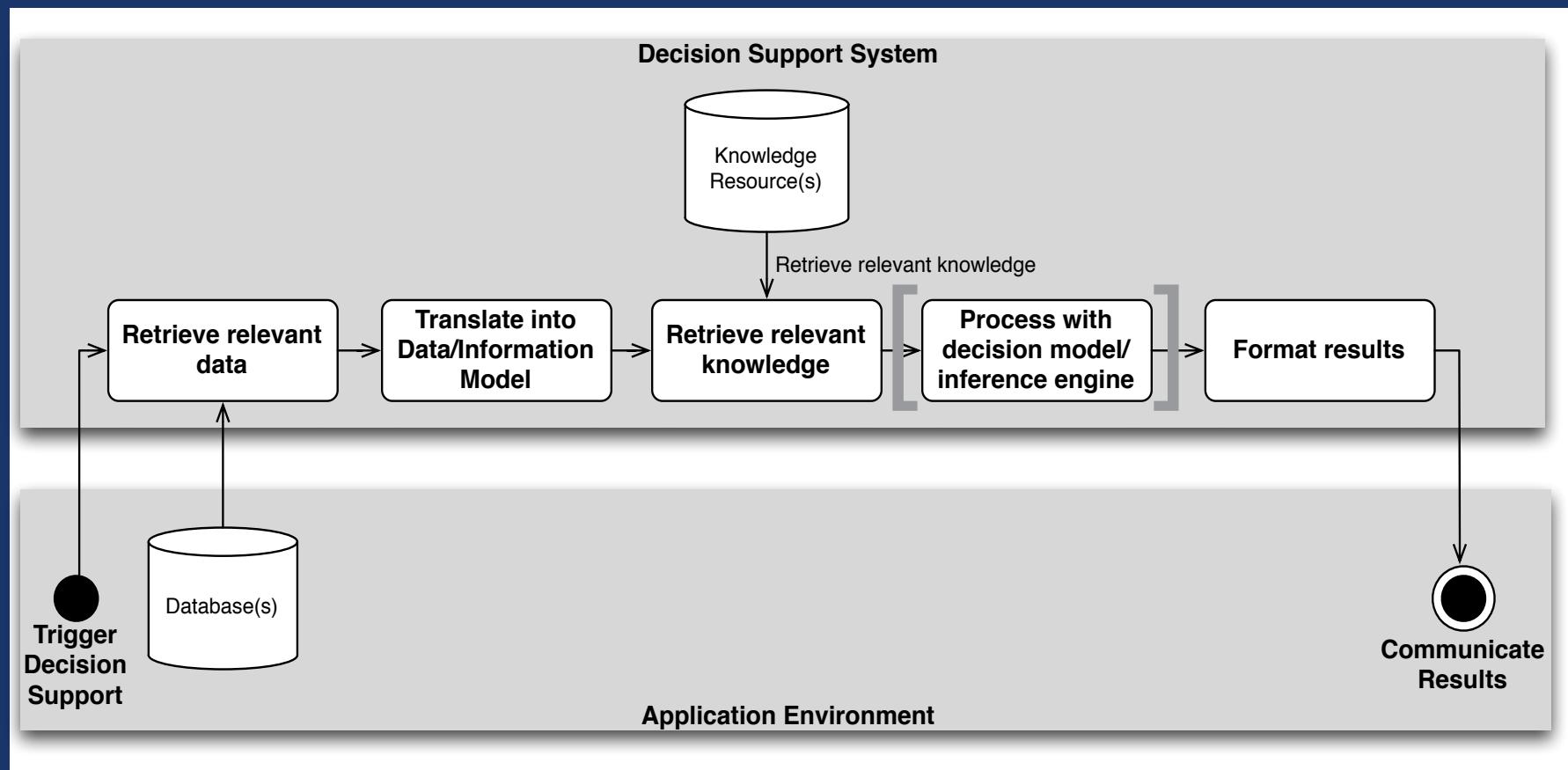
More specifically, to

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 systems²
 - 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

¹Kawamoto et al. BMJ 2005;330(7494):765.

²Garg 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

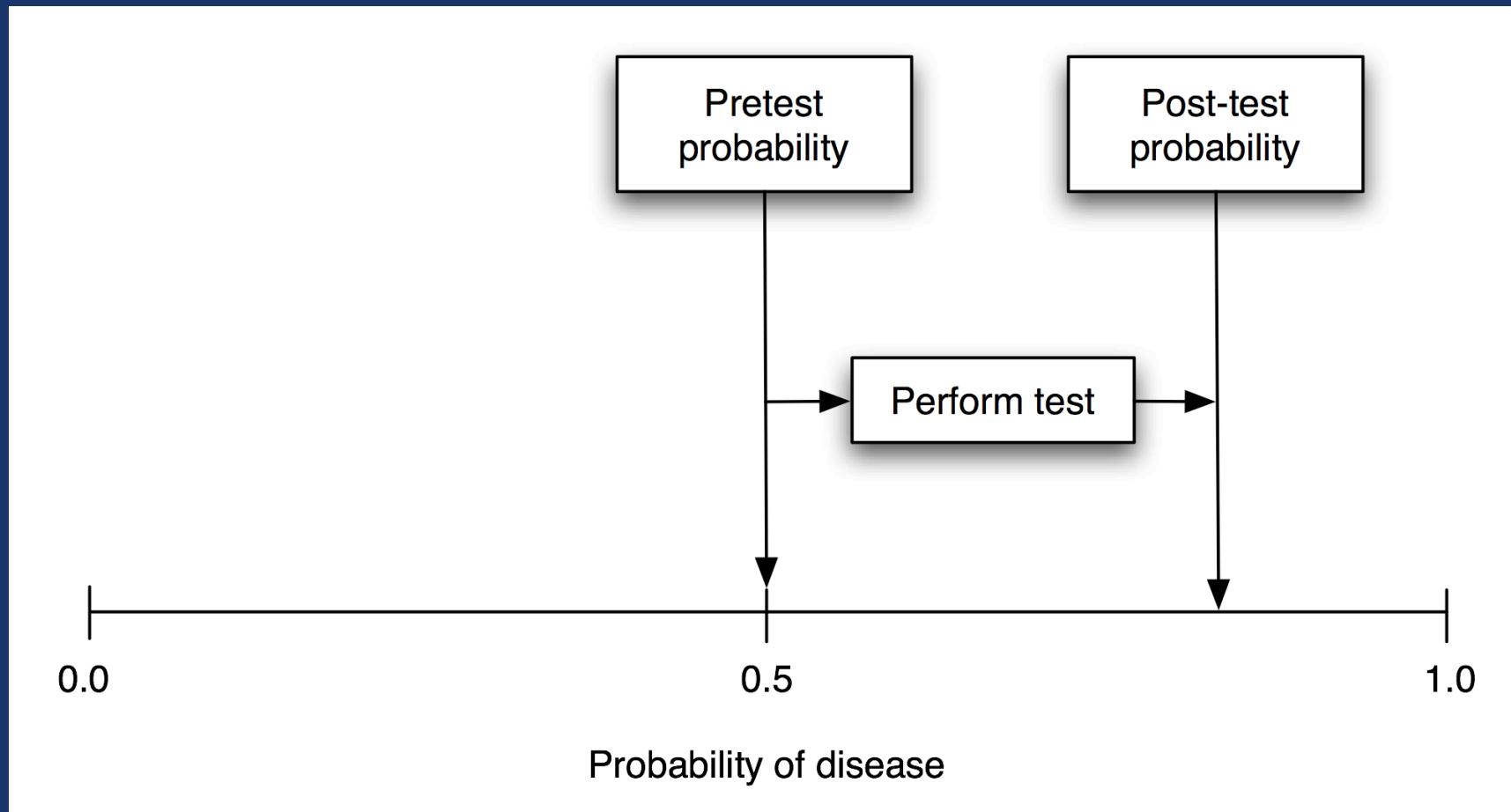


Bayes' Theorem

- 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

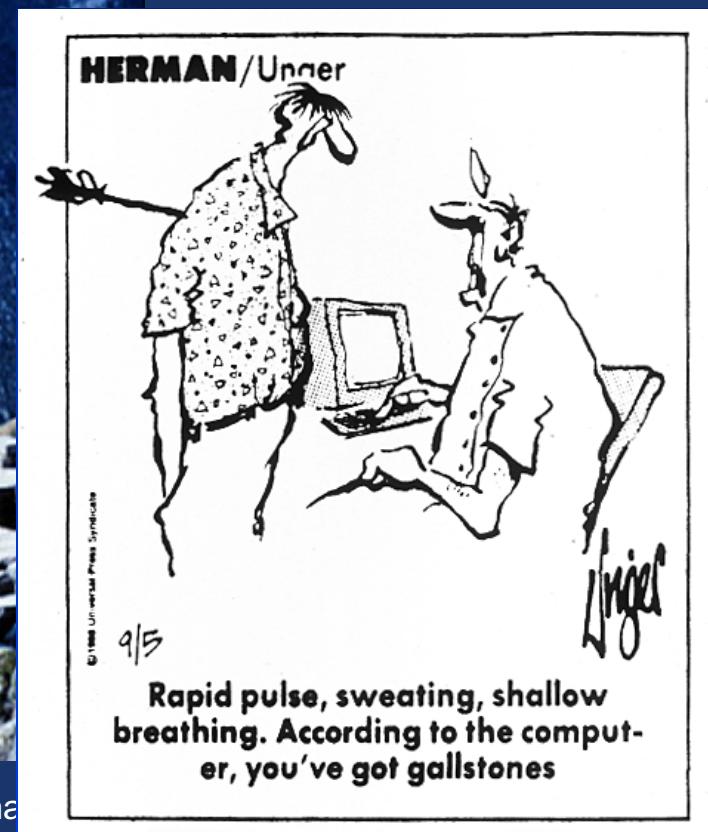




Diagnostic Decision Support



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



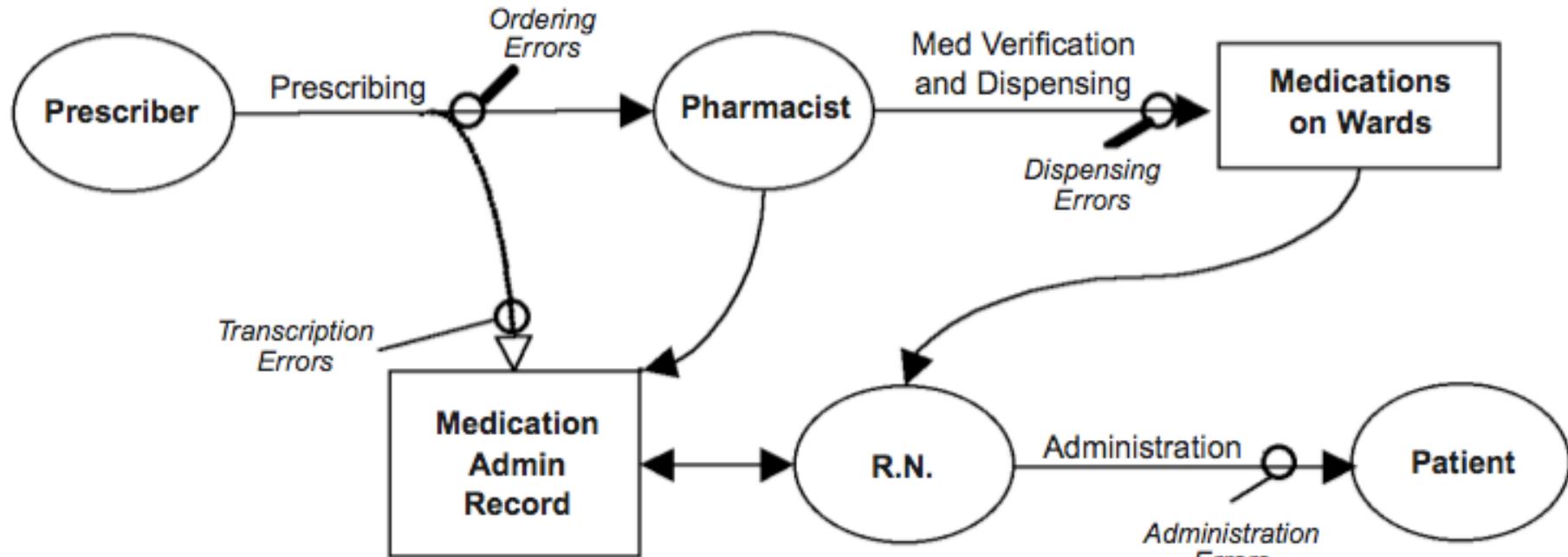


Errors During Order Entry

Flowchart of the Medication Use Process

Templates, drug-drug interactions,
relevant lab tests, dose recs.

Alerts in pharmacy





Adverse Drug Event Prevention

- 60% of serious medication errors occur at prescription or transcription¹
- Many serious prescribing errors appear to be related to knowledge access²

¹Bates DW et al. JAMA. 1995;274(1):29-34.

²Leape 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 creatinin |
| 1053 | Potassium sliding scale and creatinin |
| 76 | Lidocaine > 5 |
| 1052 | Gentamicin or tobramycin use and ir |
| 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 crea |
| 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. 2004;61(15):1599-603.

Discem

 Renal Alert

You are ordering metformin, which is contraindicated in patients with a creatinine clearance < 50 ml/min.

Mock Patient has a creatinine clearance of 34.3 ml/min.

For clinical questions related to this alert, please contact the PharmD covering your unit or page the PharmD on call (#4958).



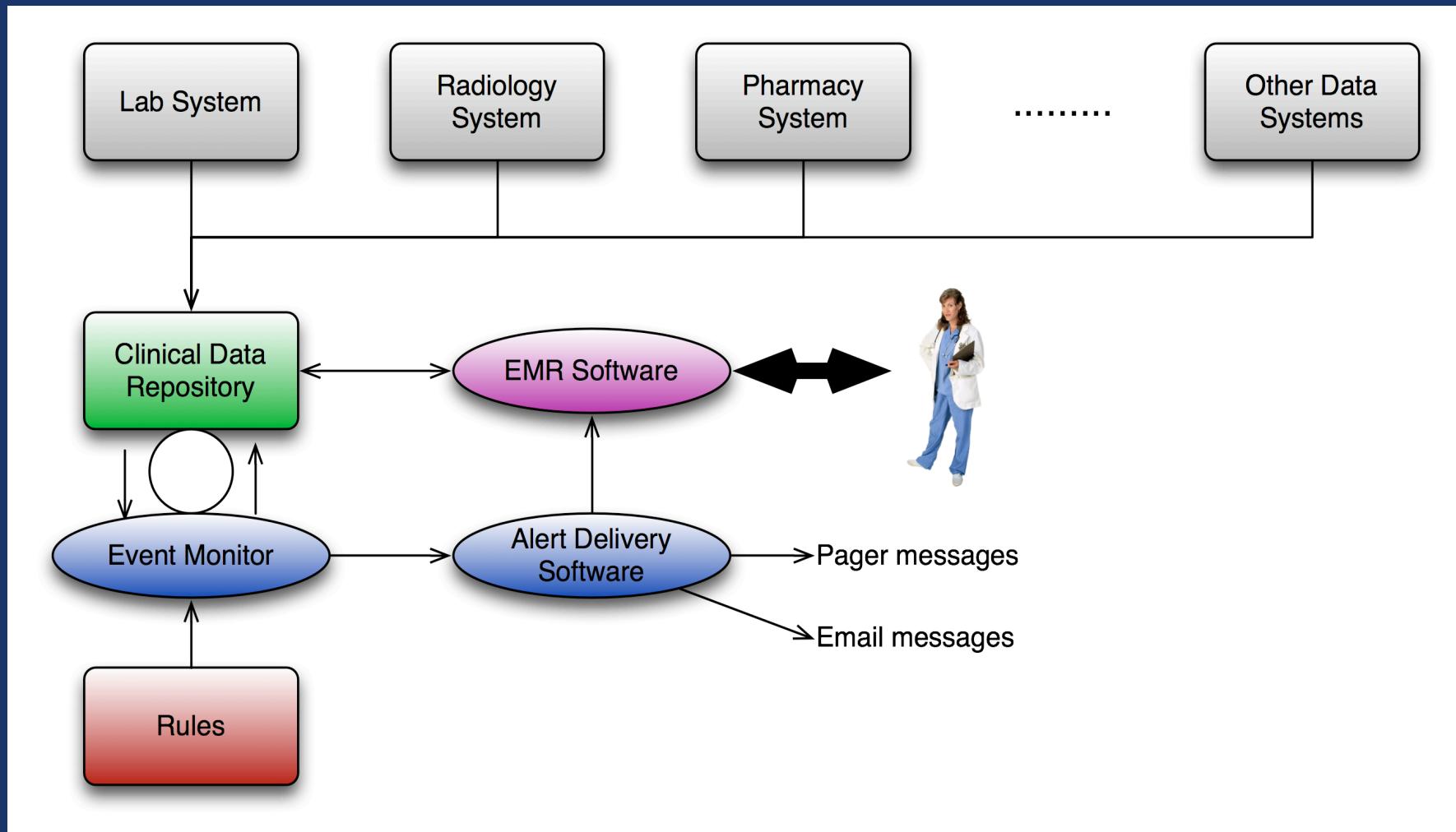
Delays in Responding to Abnormal Test Results

- 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

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

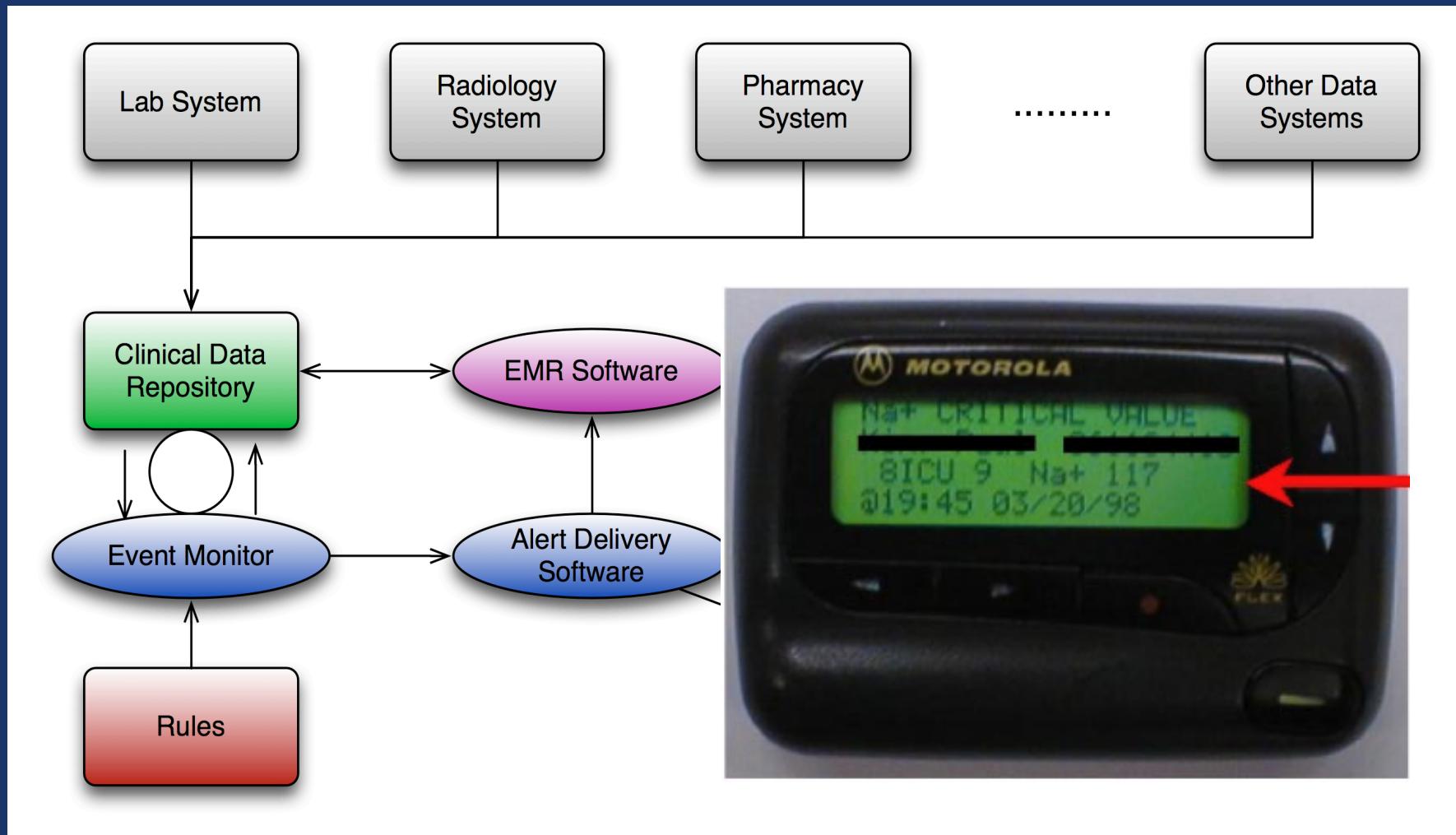


Event Monitoring and Alerting





Event Monitoring and Alerting

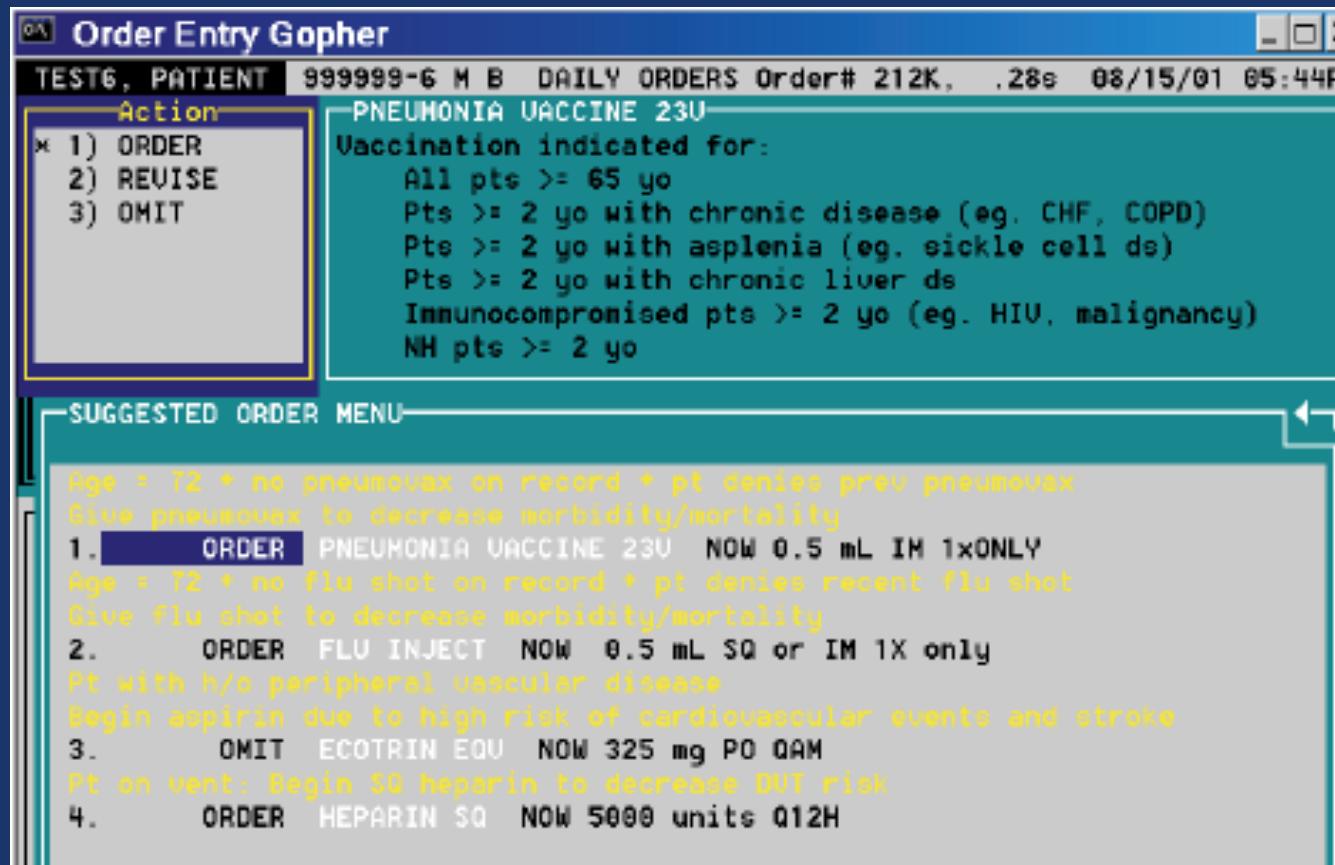




¹US Dept. of Health and Human Services. Healthy People 2000.

Underutilization of Preventative Services – Reminder Systems

- Pap smears, mammography, vaccinations and other preventative services are underutilized¹



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



Errors in Data Interpretation

- ADE Prevention Study Group, 1995¹
 - “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, 1991²
 - 9% were incorrectly used, contributing to medical errors
- 696 important prescribing errors, 1997³
 - The most common factors associated with errors were changes in renal or hepatic function requiring a dose alteration

¹Leape et al. *JAMA* 1995;274(1):35-43.

²Kraus et al. *Am J Dis Child* 1991;145(10):1171-5.

³Lesar et al. *JAMA* 1997;277(4):312-7.



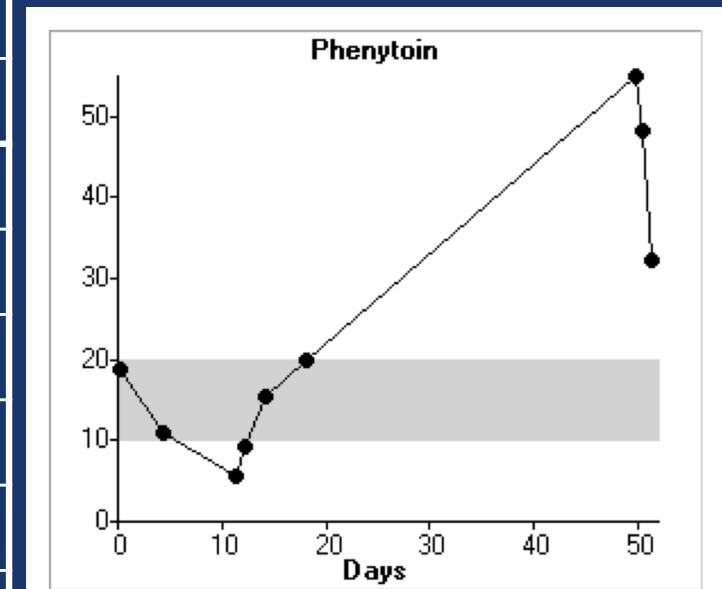
Errors in Data Interpretation

- 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 care¹
 - Are most useful at the point of care (e.g., order entry)^{2,3}

¹Grimshaw JM and Russel IT. Lancet. 1993;342:1317-22.

²Shea S et al. JAMIA. 1996;3(6):399-409.

³Overhage JM et al. JAMIA. 1997;4(5):364-75.



Future: Guideline-based Decision Support Systems

1 Any adult in the health care system

The image shows the ATHENA Hypertension Advisory software interface on the left and its corresponding hypertension management diagram on the right.

ATHENA Hypertension Advisory Interface:

- Patient SSN: [] Name: [] Patient Summary: []
- Most Recent BP in Database: 150/88 Date: []
- ENTER Today's Decision BP: 150/95 Date: [] Update Advisory: []
- Guideline Goal: SBP < 130 and DBP < 85 [presence of diabetes, heart failure or renal insufficiency]
- BP apparently NOT UNDER CONTROL, based on most recent available BP.
- (Enter "Today's Decision Blood Pressure" and press "Update Advisory" for new recommendations.)
- Recommendations | Precautions | Assumptions | Lifestyle | Adherence | Glossary | BP-Prescription Graphs
- Consider INTENSIFYING drug treatment: BP ELEVATED based on most recent available BP.
- Compelling Indication | Relative Indication | Strong Contraindication | Relative Contraindication | Adverse Events
- Consider one of the following therapeutic possibilities:
 - Increase dosage of lisinopril (Info) Reasons: Click here for important ... Feedback: []
 - Add Thiazide Diuretic (HCTZ) (Info) Reasons: Click here for important ... Feedback: []
 - [] Reasons: Click here for important ... Feedback: []
 - [] Reasons: Click here for important ... Feedback: []
 - [] Reasons: Click here for important ... Feedback: []
- Your comments for the Guidelines Team (optional and welcome!): []
- Do not display Advisory for this clinic visit again.
- Recommendations considered | Not Read | Not a clinical priority today

Hypertension management diagram (Management_Diagram):

This diagram illustrates the decision-making process for hypertension management. It starts with initial blood pressure thresholds (SBP ≥ 220 or DBP ≥ 115) leading to a central node. From there, it branches into drug therapy options (not on drug therapy, consider adding drug, or no-drug-therapy choices) and non-pharmacological interventions (lifestyle changes). A feedback loop returns to the initial threshold node if blood pressure is not adequately controlled.

| Name | Type | Cardinality |
|----------------------------|----------|-----------------|
| S.title | String | single |
| S.version | String | single |
| S.clinical_algorithm | Instance | single |
| S.goal | Instance | multiple |
| S.patient_characterization | Class | multiple |
| S.eligibility_criteria | Instance | multiple |
| S.authors | String | multiple |
| S.primary | Boolean | single |
| S.reference | Instance | multiple |
| S.label | String | required single |

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

Full guideline: <http://www.oqo.med.va.gov/cpg/cpg.htm>
Data source for full guideline: <http://www.omo.amedd.army.mil/guide.htm>
Software developed by the VA Health Informatics System in cooperation with the Offices of
the Secretary of Defense and the Department of Defense





Unintended Consequences of Information Technology

- Highly-regarded academic medical center with relatively widely deployed CPOE system, 2005¹
 - 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, 2005²
 - Increase in mortality following CPOE implementation
- “Homemade” drug dose calculation software system for handhelds, 2007³
 - Subtle bug resulted in sevenfold higher dose of noradrenaline than intended

¹Koppel R et al. JAMA. 2005;293(10):1197-1203.

²Han YY et al. Pediatrics. 2005;116:1506-12.

³de Wildt SN et al. BMJ. 2007;334:851-2.